1944 - City of Richmond Green Alley Projects

Application Details

Funding Opportunity:	1447-Virginia Community Flood Preparedness Fund - Project Grants - CY23 Round 4
Funding Opportunity Due Date:	Nov 12, 2023 11:59 PM
Program Area:	Virginia Community Flood Preparedness Fund
Status:	Under Review
Stage:	Final Application
Initial Submit Date:	Nov 12, 2023 6:42 PM
Initially Submitted By:	Jonathan Logue
Last Submit Date:	
Last Submitted By:	

Contact Information

Primary Contact Information

Active User*: Yes

Type: External User

Name*: Mr. Jonathan Kyle Logue
Salutation First Name Middle Name Last Name

Title: Consultant

Email*: klogue@greeley-hansen.com

Address*: 9020 STONY POINT PKWY

275

Richmond Virginia 23223
City State/Province Postal Code/Zip

Phone*: 804-204-2410 Ext.
Phone
###-###-####

Fax: ###-###-####

Comments:

Organization Information

Status*: Approved

Name*: Greeley and Hansen

Organization Type*:

Tax ID*: 361164980

Unique Entity Identifier (UEI)*: LKVMEJWCCVG5

Organization Website:

Address*: 100 S Wacker Drive,

Ste 1400

Chicago

Chicago	Illinois	60606-
City	State/Province	Postal Code/Zip

Phone*: 312-558-9000 Ext.

###-###-####

Fax: ###-###-####

Benefactor:

Vendor ID:

Comments:

VCFPF Applicant Information

Project Description

Name of Local Government*: City of Richmond

Your locality's CID number can be found at the following link: Community Status Book Report

NFIP/DCR Community Identification Number (CID)*: 510129

If a state or federally recognized Indian tribe,

Name of Tribe:

Authorized Individual*: William Boston

First Name Last Name

Mailing Address*: 1801 Commerce Road

Address Line 1

Address Line 2

Richmond	Virginia	23224
City	State	Zip Code

Telephone Number*: 804-646-8161

Cell Phone Number*: 804-229-8949

Email*: william.boston2@rva.gov

Is the contact person different than the authorized individual?

Contact Person*: No

Enter a description of the project for which you are applying to this funding opportunity

Project Description*:

This application presents two green alley projects, one in District 3 and one in District 6, in the City of Richmond, Virginia. Richmond had an existing green alley program and converted 13 alleys to green alleys between 2010-2021 with the intent to reduce stormwater flooding along alleys and on adjacent properties while also beautifying neighborhoods. The two alleys presented in this proposal are priority locations which experience regular flooding impacting residents and community members.

Low-income geographic area means any locality, or community within a locality, that has a median household income that is not greater than 80 percent of the local median household income, or any area in the Commonwealth designated as a qualified opportunity zone by the U.S. Secretary of the Treasury via his delegation of authority to the Internal Revenue Service. A project of any size within a low-income geographic area will be considered.

Is the proposal in this application intended to benefit a low-income geographic area as defined above?

Benefit a low-income geographic area*: Yes

Information regarding your census block(s) can be found at census.gov

Census Block(s) Where Project will Occur*: 1027, 3009

Is Project Located in an NFIP Participating Community?*: Yes

Is Project Located in a Special Flood Hazard Area?*: No

Flood Zone(s) (if applicable): N/A

Flood Insurance Rate Map Number(s) (if applicable): 5101290029D; 5101290039E; 5101290077D

Eligibility CFPF - Round 4 - Projects

Eligibility

Is the applicant a local government (including counties, cities, towns, municipal corporations, authorities, districts, commissions, or political subdivisions created by the General Assembly or pursuant to the Constitution or laws of the Commonwealth, or any combination of these)?

Local Government*: Yes

Yes - Eligible for consideration
No - Not eligible for consideration

Does the local government have an approved resilience plan and has provided a copy or link to the plan with this application?

Resilience Plan*: Yes

Yes - Eligible for consideration under all categories
No - Eligible for consideration for studies, capacity building, and planning only

If the applicant is not a town, city, or county, are letters of support from all affected local governments included in this application?

Letters of Support*: N/A

Yes - Eligible for consideration
No - Not eligible for consideration
N/A - Not applicable

Has this or any portion of this project been included in any application or program previously funded by the Department?

Previously Funded*: No

Yes - Not eligible for consideration
No - Eligible for consideration

Has the applicant provided evidence of an ability to provide the required matching funds?

Evidence of Match Funds*: Yes

Yes - Eligible for consideration
No - Not eligible for consideration
N/A - Match not required

Scoring Criteria for Flood Prevention and Protection Projects - Round 4

Scoring

Category Scoring:
Hold CTRL to select multiple options

Project Category*: All hybrid approaches whose end result is a nature-based solution

Is the project area socially vulnerable? (based on ADAPT Virginia?s Social Vulnerability Index Score)
Social Vulnerability Scoring:
Very High Social Vulnerability (More than 1.5)
High Social Vulnerability (1.0 to 1.5)
Moderate Social Vulnerability (0.0 to 1.0)
Low Social Vulnerability (-1.0 to 0.0)
Very Low Social Vulnerability (Less than -1.0)

Socially Vulnerable*: High Social Vulnerability (1.0 to 1.5)

Is the proposed project part of an effort to join or remedy the community?s probation or suspension from the NFIP?

NFIP*: Yes

Is the proposed project in a low-income geographic area as defined below?

"Low-income geographic area" means any locality, or community within a locality, that has a median household income that is not greater than 80 percent of the local median household income, or any area in the Commonwealth designated as a qualified opportunity zone by the U.S. Secretary of the Treasury via his delegation of authority to the Internal Revenue Service. A project of any size within a low-income geographic area will be considered.

Low-Income Geographic Area*: Yes

Projects eligible for funding may also reduce nutrient and sediment pollution to local waters and the Chesapeake Bay and assist the Commonwealth in achieving local and/or Chesapeake Bay TMDLs. Does the proposed project include implementation of one or more best management practices with a nitrogen, phosphorus, or sediment reduction efficiency established by the Virginia Department of Environmental Quality or the Chesapeake Bay Program Partnership in support of the Chesapeake Bay TMDL Phase III Watershed Implementation Plan?

Reduction of Nutrient and Sediment Pollution*: Yes

Does this project provide ?community scale? benefits?

Community Scale Benefits*: More than one census block

Expected Lifespan of Project

Expected Lifespan of Project*: Over 20 Years

Comments:

This project includes two alleys. Location 1 is located in a Moderate Social Vulnerability area and is not classified as low income. Location 2 is located in a High Social Vulnerability area and is classified as low income.

Scope of Work - Projects - Round 4

Scope of Work

Upload your Scope of Work

Please refer to Part IV, Section B. of the grant manual for guidance on how to create your scope of work

Scope of Work*: Green Alleys Scope of Work.pdf

Comments:

City of Richmond Green Alley Projects Scope of Work

Budget Narrative

Budget Narrative Attachment*: Green Alley Budget Narrative.pdf

Comments:

City of Richmond Green Alley Projects Budget Narrative

Scope of Work Supporting Information - Projects

Supporting Information - Projects

Provide population data for the local government in which the project is taking place

Population*: 232866.00

Provide information on the flood risk of the project area, including whether the project is in a mapped floodplain, what flood zone it is in, and when it was last mapped. If the property or area around it has been flooded before, share information on the dates of past flood events and the amount of damage sustained

Historic Flooding data and Hydrologic Studies*: Richmond Green Alley Historic flood damage data and or images.pdf

Include studies, data, reports that demonstrate the proposed project minimizes flood vulnerabilities and does not create flooding or increased flooding (adverse impact) to other properties

No Adverse Impact*: Green Alley Network Plan.pdf

Include supporting documents demonstrating the local government's ability to provide its share of the project costs. This must include an estimate of the total project cost, a description of the source of the funds being used, evidence of the local government's ability to pay for the project in full or quarterly prior to reimbursement, and a signed pledge agreement from each contributing organization

Ability to Provide Share of Cost*: FY2024 - FY2028 Proposed Capital Improvement Plan - Stormwater Improvements 002.pdf

A benefit-cost analysis must be submitted with the project application

Benefit-Cost Analysis*: Not Applicable.pdf

Provide a list of repetitive loss and/or severe repetitive loss properties. Do not provide the addresses for the properties, but include an exact number of repetitive loss and/or severe repetitive loss structures within the project area

Repetitive Loss and/or Severe Repetitive Loss Properties*: Not Applicable.pdf

Describe the residential and commercial structures impacted by this project, including how they contribute to the community such as historic, economic, or social value. Provide an exact number of residential structures and commercial structures in the project area

Residential and/or Commercial Structures*:

Location 1 is in District 3 parallel and east of Chamberlayne Ave and between W Brookland Park Blvd and Hammond Ave. Location 1 is situated in census block 1027 with 77 total housing units, 5 businesses (Richmond Coin Laundry, Car Wash, Abe's Auto Services, Eny's Hotel, and BP Gas Station), and the Richmond Fire Station 14. Location 1 has economic and social value as it has businesses which employ and service the local community. This location also has safety value as the Fire Station services the local community. This alley likely falls just outside of the Ginter Park Historic District boundary which was listed on the National Register of Historic Places in 1986.

Location 2 is in District 6 and west of Willis St between Chesterman Ave and Mimosa St. Location 2 is situated in census block 3009 with a total of 44 housing units. There are no businesses or critical facilities within the project area.

If there are critical facilities/infrastructure within the project area, describe each facility

Critical Facilities/Infrastructure*:

Location 1 has the Richmond Fire Station 14 located within the project area. This fire station services the surrounding community for emergency services such as firefighting and medical emergencies.

Location 2 has no critical infrastructure/facilities.

Explain the local government's financial and staff resources. How many relevant staff members does the local government have? To what relevant software does the local government have access? What are the local government's capabilities?

Financial and Staff Resources*:

DPU/SW leadership and project managers, in coordination with other departments and agencies, are experienced in executing capital projects from the time of inception and scoping to construction and final close-out. DPU/SW has sufficient capacity including staff, external consultants & contractors, and financial resources to adequately manage and facilitate all that is required to bring this project to completion. Any and all reporting requirements, either those of the City or those specific to DCR Community Flood Preparedness Grant Fund will be adequately addressed as may be required.
The team responsible for managing the design and implementation of this project will be the stormwater capital improvement team which is composed of the stormwater capital improvement program manager, two (2) capital improvement managers, program and operations supervisor, and a senior engineer. Relevant software includes Microsoft Suite, GIS, CADD, and PCSWMM.

Identify and describe the goals and objectives of the project. Include a description of the expected results of the completed project and explain the expected benefits of the project. This may include financial benefits, increased awareness, decreased risk, etc.

Goals and Objectives*:

Goal 1. Eliminate flooding in alleys and on adjacent properties while also reducing stormwater runoff
- Objective 1.1. Eliminate flooding in alleys and on adjacent properties and ensure that new designs effectively redirect stormwater.
- Objective 1.2. Decrease stormwater runoff to existing CSS system and separate stormwater system during peak flows.
- Objective 1.3. Increase stormwater infiltration and storage through green infrastructure elements and set goal of capturing 85% of stormwater runoff during a 2-year storm with new green alley construction.
- Objective 1.4. Increase stormwater quality through native vegetation filtration and treatment by planting native grasses and plants where appropriate.

Goal 2. Increase beautification and mobility of alley spaces
- Objective 2.1. Increase native biodiversity in alleys with vegetation areas by prioritizing the planting of native grasses and plants where appropriate. Set up maintenance program to maintain these areas.
- Objective 2.2. Implement design elements that limit visible waste containers but will not impact waste collection practices.
- Objective 2.3. Create a branded alley wayfinding system to allow for increased public access and usability during construction.

Goal 3. Engage in public outreach and awareness of green alleys and green stormwater infrastructure
- Objective 3.1. Host at least one in person community event every year about green alleys to provide education and visibility on the

implementation of crucial green infrastructure elements in residents? neighborhoods.
- Objective 3.2. Create a webpage dedicated to green alley information, contacts, tools, and reporting system by the completion of this project.

Goal 1 Expected Results - Stormwater storage capacity and infiltration increased within green alleys achieving an 85% reduction in stormwater runoff. No new flooding complaints from alley adjacent residents.
Goal 2 Expected Results - Residents and visitors regularly use green alleys as a place of walking, biking, and community.
Goal 3 Expected Results - Increased community engagement and education sessions for green alleys and green stormwater infrastructure regularly held and advertised to the public.

Outline a plan of action laying out the scope and detail of how the proposed work will be accomplished with a timeline identifying expected completion dates. Determine milestones for the project that will be used to track progress. Explain what deliverables can be expected at each milestone, and what the final project deliverables will be. Identify other project partners

Approach, Milestones, and Deliverables*: Green Alleys Project Approach Milestones and Deliverables.pdf

Where applicable, briefly describe the relationship between this project and other past, current, or future resilience projects. If the applicant has received or applied for any other grants or loans, please identify those projects, and, if applicable, describe any problems that arose with meeting the obligations of the grant and how the obligations of this project will be met

Relationship to Other Projects*:

These two (2) projects are a continuation of the 2010-2021 City of Richmond Green Alley Program which converted 14 alleys into Green Alleys. This previous Program had ample support from the impacted communities, and reduced flooding complaints in the project neighborhoods were achieved. These projects aim to match and exceed the success of past green alley projects.

The City of Richmond received two (2) grants in the Round 1 Virginia CFPF Grant Awards, one (1) grant in Round 2, and one (1) grant in Round 2 Supplemental. There have been no problems that have arose with meeting the obligations of the grants or with meeting the obligations of the projects.

For ongoing projects or projects that will require future maintenance, such as infrastructure, flood warning and response systems, signs, websites, or flood risk applications, a maintenance, management, and monitoring plan for the projects must be provided

Maintenance Plan*: Green Alley City of Richmond Maintenance Plan.pdf

Describe how the project meets each of the applicable scoring criteria contained in Appendix B. Documentation can be incorporated into the Scope of Work Narrative

Criteria*:

Applicable scoring criteria contained in Appendix D in the CFPF Manual.

Eligible Projects - Hybrid approach resulting in nature-based solutions (15 points).
Green alleys utilize green infrastructure elements such as permeable pavers/pavement and edge vegetation which result in nature-based solutions for stormwater infiltration and treatment.

Social Vulnerability - High Social Vulnerability (1.0 to 1.5 (8 points)
Location 1 is in a moderate social vulnerability area and Location 2 is in a high social vulnerability area.

Community scale of benefits - More than one census block (25 points)
Both Location 1 and 2 cover one census block each. Therefore, two census blocks are included in these two projects.

Expected lifespan of project - Over 20 years (10points)
The expected lifespan of green alleys is over 20 years. The oldest existing green alley in the City of Richmond was installed in 2010 and is now 14 years old. This existing green alley receives regular maintenance and continues to service the surrounding community.

Remedy for NFIP probation or suspension - No (0 points)
These projects are not a remedy for NFIP probation or suspension.

Proposed project part of a low-income geographic area - Yes (10 points)
Location 2 is in a low-income geographic area. Location 1 is not in a low-income geographic area.

Proposed project implements a Chesapeake Bay TMDL BMP - Yes (5 points)
The green alley projects will implement Chesapeake Bay TMDL BMPs to treat pollutants and protect natural waterways.

Budget

Budget Summary

Grant Matching Requirement*: Projects that will result in hybrid solutions - Fund 60%/Match 40%

Total Project Amount*: $1,797,692.00

REQUIRED Match Percentage Amount: $719,076.80

BUDGET TOTALS

Before submitting your application be sure that you meet the match requirements for your project type.

Match Percentage: 40.00%

Verify that your match percentage matches your required match percentage amount above.

Total Requested Fund Amount: $1,078,615.31

Total Match Amount: $719,076.87

TOTAL: $1,797,692.18

Personnel

Description	Requested Fund Amount	Match Amount	Match Source

No Data for Table

Fringe Benefits

Description	Requested Fund Amount	Match Amount	Match Source

No Data for Table

Travel

Description	Requested Fund Amount	Match Amount	Match Source

No Data for Table

Equipment

Description	Requested Fund Amount	Match Amount	Match Source

No Data for Table

Supplies

Description	Requested Fund Amount	Match Amount	Match Source

No Data for Table

Construction

Description	Requested Fund Amount	Match Amount	Match Source
Construction for green alley at Location 1.	$442,426.53	$294,951.02	City of Richmond DPU
Construction for green alley at Location 2.	$489,675.96	$326,450.64	City of Richmond DPU
	$932,102.49	**$621,401.66**	

Contracts

Description	Requested Fund Amount	Match Amount	Match Source
Design and CM for Location 1	$55,303.32	$36,868.88	City of Richmond DPU
Design and CM for Location 2	$61,209.50	$40,806.33	City of Richmond DPU
	$116,512.82	**$77,675.21**	

Maintenance Costs

Description	Requested Fund Amount	Match Amount	Match Source

No Data for Table

Pre-Award and Startup Costs

Description	Requested Fund Amount	Match Amount	Match Source

No Data for Table

Other Direct Costs

Description	Requested Fund Amount	Match Amount	Match Source
Permitting for Location 1	$15,000.00	$10,000.00	City of Richmond DPU
Permitting for Location 2	$15,000.00	$10,000.00	City of Richmond DPU
	$30,000.00	**$20,000.00**	

Long and Short Term Loan Budget - Projects - VCFPF

Budget Summary

Are you applying for a short term, long term, or no loan as part of your application?

If you are not applying for a loan, select "not applying for loan" and leave all other fields on this screen blank

Long or Short Term*: Not Applying for Loan

Total Project Amount: $0.00

Total Requested Fund Amount: $0.00

TOTAL: $0.00

Salaries

Description	Requested Fund Amount

No Data for Table

Fringe Benefits

Description	Requested Fund Amount

No Data for Table

Travel

Description	Requested Fund Amount

No Data for Table

Equipment

Description	Requested Fund Amount

No Data for Table

Supplies

Description	Requested Fund Amount

No Data for Table

Construction

Description	Requested Fund Amount

No Data for Table

Contracts

Description	Requested Fund Amount

No Data for Table

Other Direct Costs

Description	Requested Fund Amount

No Data for Table

Supporting Documentation

Supporting Documentation

Named Attachment	Required	Description	File Name	Type	Size	
Detailed map of the project area(s) (Projects/Studies)		Detailed map of proposed green alley projects. Location 1 is in District 3 parallel and east of Chamberlayne Ave and between W Brookland Park Blvd and Hammond Ave. Location 2 is in District 6 and west of Willis St between Chesterman Ave and Mimosa St.	Detailed_Map_of_Richmond_Green_Alley_Projects.pdf	pdf	3 MB	11 0
FIRMette of the project area(s) (Projects/Studies)		Firmettes of proposed green alley projects. Location 1 is in District 3 parallel and east of Chamberlayne Ave and between W Brookland Park Blvd and Hammond Ave. Location 2 is in District 6 and west of Willis St between Chesterman Ave and Mimosa St.	Richmond Green Alley Firmette.pdf	pdf	1 MB	11 0
Historic flood damage data and/or images (Projects/Studies)		Historic flooding data and damage data of proposed green alley projects. Location 1 is in District 3 parallel and east of Chamberlayne Ave and between W Brookland Park Blvd and Hammond Ave. Location 2 is in District 6 and west of Willis St between Chesterman Ave and Mimosa St.	Richmond Green Alley Historic flood damage data and or images.pdf	pdf	2 MB	11 0
A link to or a copy of the current floodplain ordinance		Website Link: https://library.municode.com/va/richmond/codes/code_of_ordinances?nodeId=PTIICICO_CH14FLMAERSECODR	CORFloodplainOrdinance.PNG	PNG	347 KB	11 0
Maintenance and management plan for project		RVA Clean Water Plan	Final_RVA_Clean_Water_Plan.pdf	pdf	10 MB	11 0
A link to or a copy of the current hazard mitigation plan		Richmond Crater Hazard Mitigation Plan	FEMA-REVIEW-2-2022-Richmond-Crater-Hazard-Mitigation-Plan-071922.pdf	pdf	22 MB	11 0
A link to or a copy of the current comprehensive plan		RVA Clean Water Plan	Final_RVA_Clean_Water_Plan.pdf	pdf	10 MB	11 0
Social vulnerability index score(s) for the project area		Virginia Vulnerability Viewer (would not print)	District 6 Alley parallel Willis St and District 3 parallel Chamberlayne Green Alley Vulnerability.pdf	pdf	4 MB	11 0
Authorization to request funding from the Fund from governing body or chief executive of the local government		City of Richmond - Commitment Letter	Grant Application - VA DCR CFPF Round 4 Approval.pdf	pdf	81 KB	11 0
Signed pledge agreement from each contributing organization						
Maintenance Plan		City of Richmond Green Alley Maintenance Information	Green Alley City of Richmond Maintenance Plan.pdf	pdf	632 KB	11 0

Benefit-cost analysis must be submitted with project applications over $2,000,000. in lieu of using the FEMA benefit-cost analysis tool, applicants may submit a narrative t describe in detail the cost benefits and value. The narrative must explicitly indicate the risk reduction benefits of a flood mitigation project and compares those benefits to i effectiveness.

Benefit Cost Analysis	
Other Relevant Attachments	

Letters of Support

Description	File Name	Type	Size	Upload Date
	No files attached.			

Resilience Plan

Resilience Plan

Description	File Name	Type	Size	Upload Date
City of Richmond Resilience Plan Submission - CFPF signed by Wendy Howard Cooper. Stated that this "approval will remain in effect for a period of three years, ending on August 20, 2024.	Richmond_Resilience_Plan_CFPF.pdf	pdf	882 KB	11/09/2023 07:12 PM

Matthew J. Strickler
Secretary of Natural and Historic Resources and Chief Resilience Officer

Clyde E. Cristman
Director

COMMONWEALTH of VIRGINIA
DEPARTMENT OF CONSERVATION AND RECREATION

Rochelle Altholz
Deputy Director of Administration and Finance

Nathan Burrell
Deputy Director of Government and Community Relations

Darryl M. Glover
Deputy Director of Dam Safety & Floodplain Management and Soil & Water Conservation

Thomas L. Smith
Deputy Director of Operations

August 19, 2021

Allen Shue, P.E.
Greeley and Hansen
9020 Stony Point Parkway, Suite 475
Richmond, VA 23235-1946

RE: City of Richmond Resilience Plan Submission - CFPF

Dear Mr. Shue:

Thank you for providing an overview of your Resilience Plan, and informing DCR of the various plans that the City of Richmond will be utilizing to fulfill the Resilience Plan submission requirements. After careful review and consideration, the Virginia Department of Conservation and Recreation has deemed the Plan complete and meets all the criteria outlined in the June 2021 Community Flood Preparedness Grant Manual. This approval will remain in effect for a period of three years, ending on August 20, 2024.

The following elements were evaluated as part of this review:

1. **Element 1: It is project-based with projects focused on flood control and resilience. DCR RESPONSE**

   Meets criteria as written.

   a. Project-based: The city of Richmond lies within the James River Watershed with 24 miles of the James River flowing through the city. This has been subdivided into 4 watershed groupings, each with uniquely defined characteristics. Several projects have been completed or are phased for completion as notated in the *Richmond-Crater Hazard Mitigation Plan*. Additionally, watershed based projects have been outlined in the *RVA Clean Water Plan* and flood control and resilience projects are also identified within the *RVA Emergency Operations Plan*.

2. **Element 2: It incorporates nature-based infrastructure to the maximum extent possible. DCR RESPONSE**

   Meets criteria as written.

a. Natural and nature-based flood management measures are identified for use in projects throughout the city in the *RVA Clean Water Plan*.

3. Element 3: It includes considerations of all parts of a locality regardless of socioeconomics or race. DCR RESPONSE

Meets criteria as written.

a. All parts of a locality: Entirety of the City of Richmond's stormwater system was evaluated as part of the watershed characterization in the *RVA Clean Water Plan;* and city-wide land use patterns described in the *2017 Richmond-Crater Hazard Mitigation Plan*.

b. Social vulnerability: FEMA TEIF 2.0 analysis used to evaluate flood risk in the *2017 Richmond-Crater Hazard Mitigation Plan*.

c. Demographic Analysis: Community profiles of the city and region-wide demographics captured in the *2017 Richmond-Crater Hazard Mitigation Plan*.

4. Element 4: It includes coordination with other local and inter-jurisdictional projects, plans, and activities and has a clearly articulated timeline or phasing for plan implementation. DCR RESPONSE

Meets criteria as written.

a. Coordination with other local and inter-jurisdictional projects, plans and activities:
The development of the *Richmond-Regional–Crater PDC Multi-Regional Hazard Mitigation Plan* included coordination with public servants and planning officials from all but three of the 24 localities included in the Crater and Plan RVA PDC's. It also draws from several regional plans and activities as outlined on section 3.3 on page 3-12.

The Technical Workgroup which contributed to the development of *the RVA Clean Water Plan* drew on experience from 30 different entities including state agencies, community associations, conservation and planning organizations, educational and scientific institutions, and other collectives as outlined in Section 2 on pages 6-7.

b. Clearly articulated timeline or phasing plan for implementation:
Section 5 of the *RVA Clean Water Program* identifies strategies for green infrastructure, stream restoration and land & water conservation in the City. Sections 4, 7 and 8 Identify a planning framework for the prioritization projects as well as a means by which success will be measured.

5. Element 5: Is based on the best available science, and incorporates climate change, sea level rise, storm surge (where appropriate), and current flood maps.

Meets criteria as written.

a. The *Richmond-Regional–Crater PDC Multi-Regional Hazard Mitigation Plan* references best-available data regarding flood risk from FEMA and the NCDC in sections 5.6.6 and 5.6.9. The RVA *Clean Water Plan* is established on data from the City's 2015 *Watershed Characterization Report* as well as the City's *2017 Clean Water Modeling Report*, found in Appendix A.

VA DCR looks forward to working with you as you work to make the City of Richmond a more resilient community. If you have questions or need additional assistance, please contact us at cfpf@dcr.virginia.gov. Again, thank you for your interest in the Community Flood Preparedness Fund.

Sincerely,

Wendy Howard Cooper, Director
Dam Safety and Floodplain Management

cc: Darryl M. Glover, DCR

CITY OF RICHMOND
Department of Public Utilities

November 1, 2023

Virginia Department of Conservation and Recreation
600 E Main St., 24th Floor
Richmond, VA 23219-2094

Subject: Green Alley and Stormwater Asset Mapping Funding Commitment Letter

Dear Grant Administrator,

As part of the Virginia Department of Conservation and Recreation Community Flood Preparedness Fund grant process, a local funding match is required. This letter serves as the City of Richmond Department of Public Utilities' commitment to meet the matching fund requirement for the Green Alley and the Southside Stormwater Asset Mapping 2023 projects. The local matching fund requirement letter is required to be submitted in the grant application.

It is understood that all the non-state share of the Green Alley and the Southside Stormwater Asset Mapping 2023 projects will be contributed by the City of Richmond Department of Public Utilities.

Your assistance is greatly appreciated.

Sincerely,

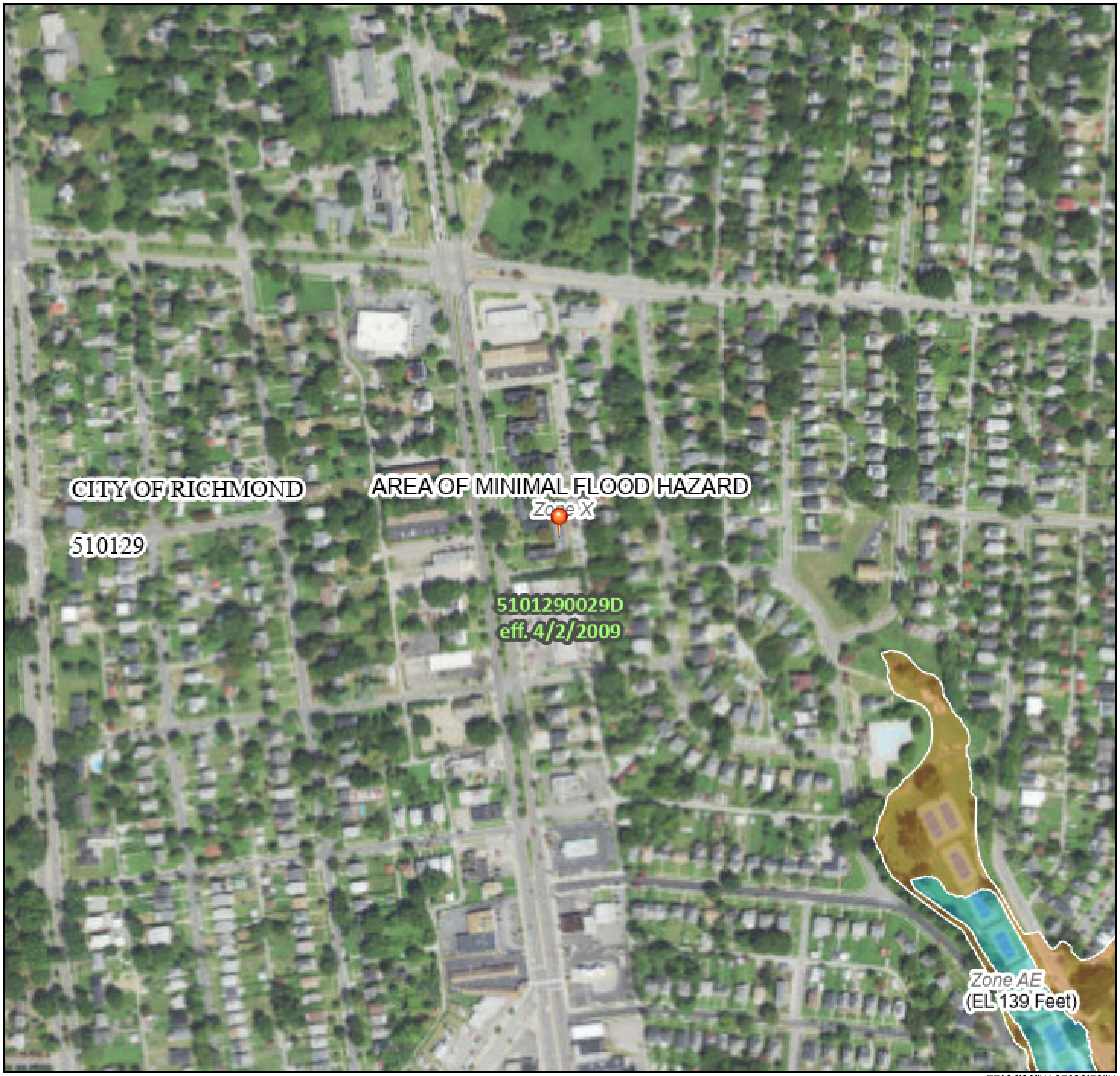
William "Bill" Boston

Stormwater Capital Improvement Program Manager, City of Richmond Department of Public Utilities

National Flood Hazard Layer FIRMette

FEMA

77°26'58"W 37°34'27"N



77°26'20"W 37°33'58"N

Feet
0 250 500 1,000 1,500 2,000

1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- B 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

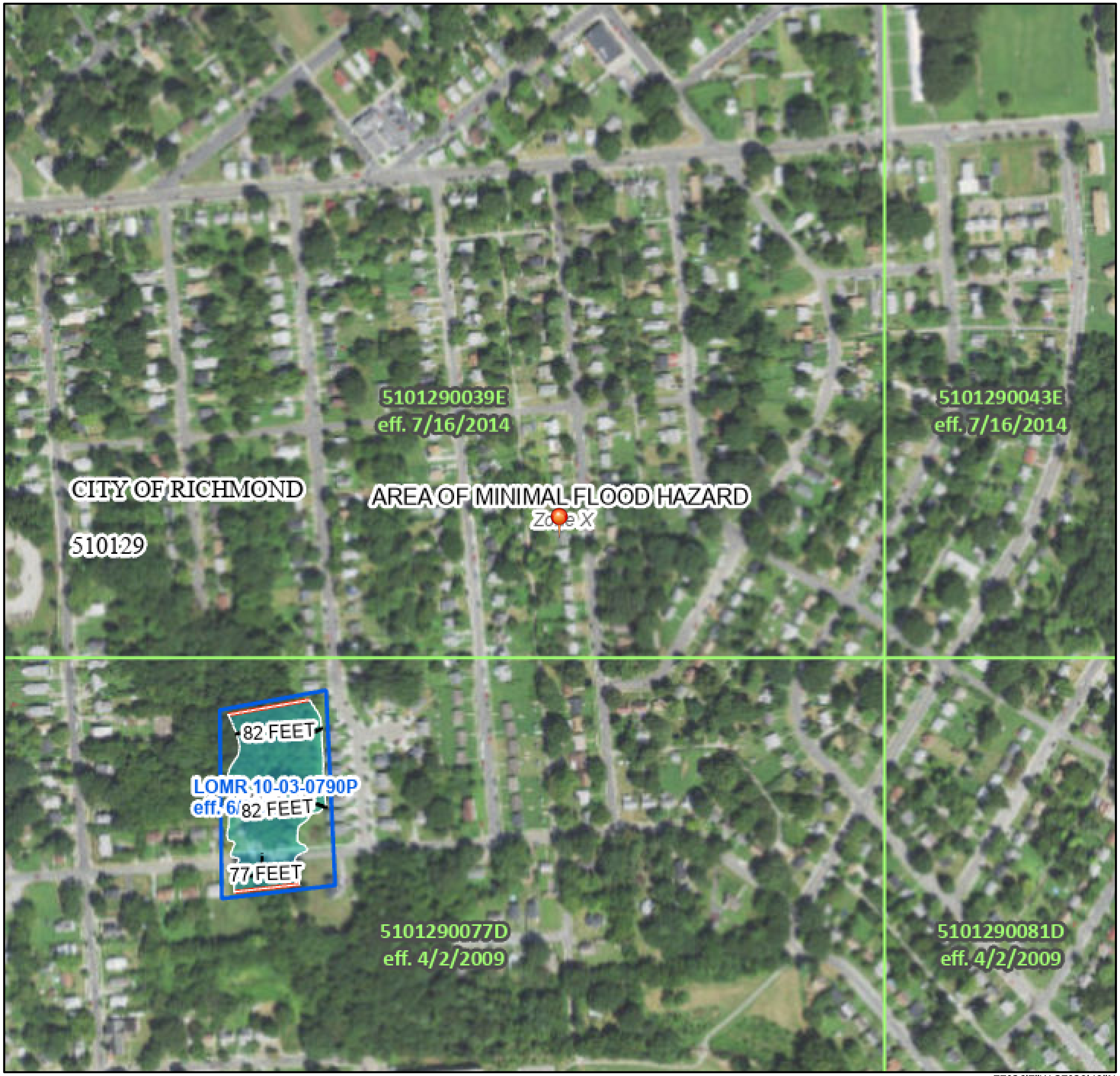
The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 11/8/2023 at 8:23 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

National Flood Hazard Layer FIRMette

FEMA

77°26'45"W 37°30'18"N



77°26'7"W 37°29'49"N

Feet

0 250 500 1,000 1,500 2,000

1:6,000

Basemap Imagery Source: USGS National Map 2023

Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

SPECIAL FLOOD HAZARD AREAS
- Without Base Flood Elevation (BFE) *Zone A, V, A99*
- With BFE or Depth *Zone AE, AO, AH, VE, AR*
- Regulatory Floodway

OTHER AREAS OF FLOOD HAZARD
- 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
- Future Conditions 1% Annual Chance Flood Hazard *Zone X*
- Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
- Area with Flood Risk due to Levee *Zone D*

OTHER AREAS
- NO SCREEN Area of Minimal Flood Hazard *Zone X*
- Effective LOMRs
- Area of Undetermined Flood Hazard *Zone D*

GENERAL STRUCTURES
- Channel, Culvert, or Storm Sewer
- Levee, Dike, or Floodwall

OTHER FEATURES
- B 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
- 8 Coastal Transect
- 513 Base Flood Elevation Line (BFE)
- Limit of Study
- Jurisdiction Boundary
- Coastal Transect Baseline
- Profile Baseline
- Hydrographic Feature

MAP PANELS
- Digital Data Available
- No Digital Data Available
- Unmapped

N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 11/12/2023 at 1:44 AM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.

Virginia Community Flood Preparedness Fund

City of Richmond Department of Public Utilities - Stormwater Division

Historic flood damage data and images

Location 1: Within District 3 parallel and east of Chamberlayne Ave and between W Brookland Park Blvd and Hammond Ave.

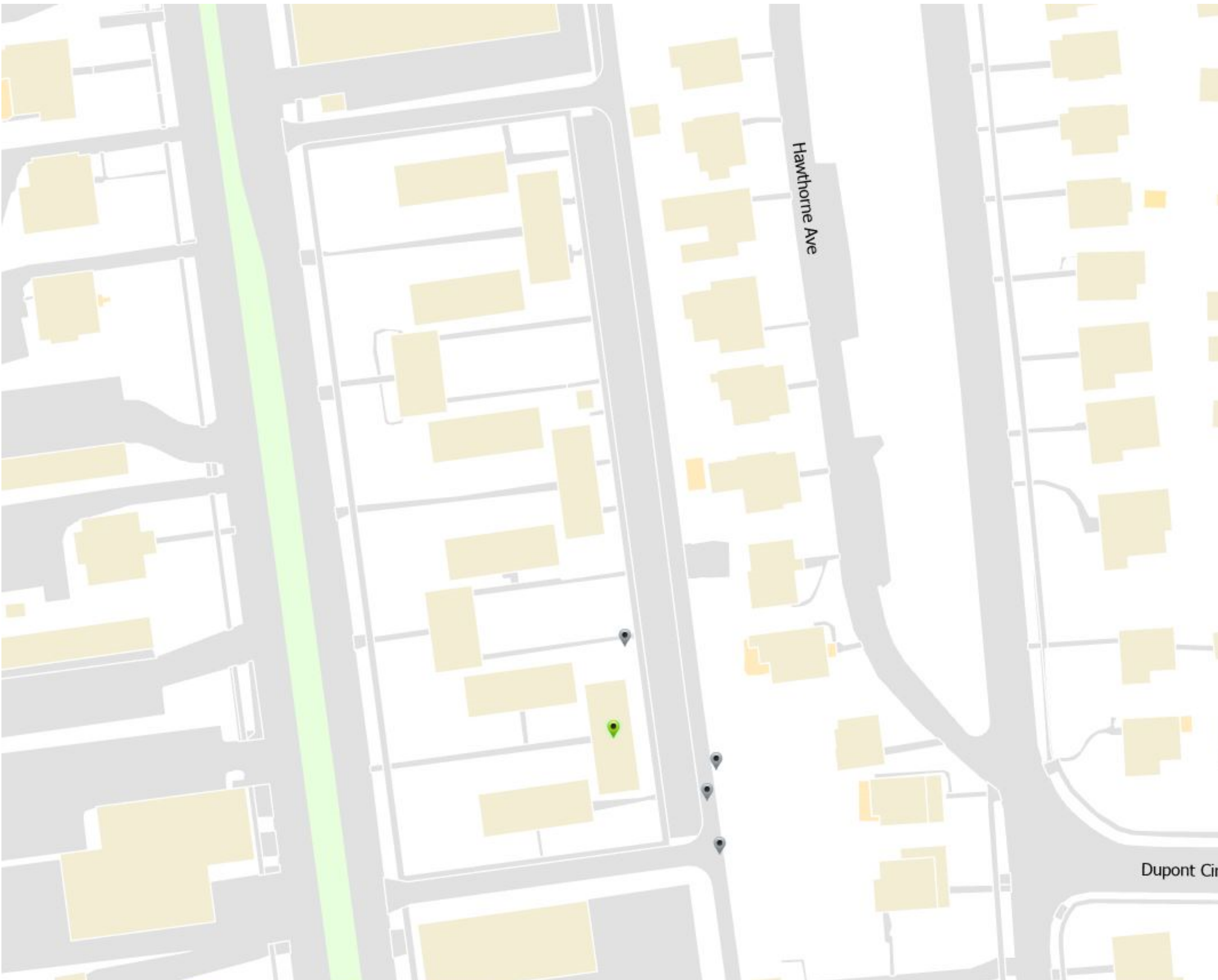


Figure 1: Flooding complaint map of location 1.

Search...

GLENN, HOWARD W

Inbox | Recent | Requests | Work Orders | Inspections | Crews | GIS Search

Calendar | Reports

Service Request

Description: 2997A0000011 Alley Gravel Repair

Request Id: 370393

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 06/21/2018 10:08 AM

Investigation: ☑

Date: 06/9/2021 10:27 AM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 06/21/2018 10:08 AM

Dispatch To: FIELDS, EVERETT

Date: 04/15/2021 2:12 PM

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: FIELDS, EVERETT

Date: 6/9/2021 10:27:48 AM

Comments: Add Comment | Sort ▲

By Interface, Cityworks: 6/21/2018 10:08:44 AM

Problem Description: Potholes in the alley need to be repaired. Along the entire alley;

By LEWIS, TRACEY N: 7/18/2018 5:59:57 PM

Forwarding the request to the supervisor for investigation and scheduling

Storm Drain Problem

By LOCKETT, LEONARDO L: 1/25/2021 9:36:08 AM

R.Brown Inpected the location and reported the it a pot hole issue at the location.

Alley Gravel Repair

By GLENN, HOWARD W: 4/15/2021 2:12:22 PM

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No:

Map Page:

District:

Location:

Details: CRMDPW000000847 - There is no media or attachements linked to this SR

Facility Id

Level Id

X: -8,621,044.156

Y: 4,518,882.307

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comment
☐	ROBERTSON	ROBIN	80	6/21/2018 2:08:35 PM	RES	CRMDPW

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Search...

GLENN, HOWARD W

Inbox | Recent | Requests | Work Orders | Inspections | Crews | GIS Search | Calendar | Reports

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 446416

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 06/11/2021 9:19 AM

Investigation: [x]

Date: 09/1/2021 11:01 AM

Emergency: [ ]

WO Needed: [ ]

Submit To: LEWIS, TRACEY N

Date: 06/11/2021 9:19 AM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? [ ]

Date:

Cancel Reason:

Canceled By:

Closed By: WILLIAMS JR, JAMES

Date: 9/1/2021 11:01:11 AM

Comments: Add Comment | Sort ▲

▶ By Interface, Cityworks: 6/11/2021 9:19:03 AM Problem Description: …

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave,

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No: 2

Map Page: 3

District:

Location:

Details: CRMDPW000080898 - https://e311production.blob.core.windows.net/rvaone/SRImages/20210611131806_1567910712_.jpg;https://e311production.blob.core.windows.net/rvaone/SRImages/20210611131820_20

Facility Id

Level Id

X: -8,621,017.324

Y: 4,518,873.789

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comment
☐	MAHMOOD	YASMEEN	57	6/11/2021 1:18:59 PM		CRMDPW(

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Search...

GLENN, HOWARD W

Inbox | Recent | Requests | Work Orders | Inspections | Crews | GIS Search

Calendar | Reports

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 453650

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 09/3/2021 12:28 PM

Investigation: ☑

Date: 12/14/2021 5:08 PM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 09/3/2021 12:28 PM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: Fleming, Darrist

Date: 12/14/2021 5:08:42 PM

Comments: Add Comment

Sort ▲

By Interface, Cityworks: 9/3/2021 12:28:36 PM

Problem Description: Alley is so worn/deep that when it rains, its enough to drown a toddler;

By Fleming, Darrist: 12/14/2021 5:08:42 PM

per W.D complete 12-14-21

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave,

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No: 2

Map Page: 3

District:

Location:

Details: CRMDPW000088517 - https://e311production.blob.core.windows.net/rvaone/SRImages/20210903162533_1430650561_.jpg

Facility Id | Level Id

X: -8,621,041.060 Y: 4,518,906.103

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comments
☐	MAHMOOD	YASMEEN	57	9/3/2021 4:28:28 PM		CRMDPW0

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Search...

GLENN, HOWARD W

Inbox | Recent | Requests | Work Orders | Inspections | Crews | GIS Search | Calendar | Reports

Service Request

Description: 2997A0000011 Alley Gravel Repair

Request Id: 488335

Category: Roadway Maintenance

Priority: Medium

Status: Open

Initiated By: Interface, Cityworks

Date: 12/4/2022 9:26 AM

Investigation: ☐

Date:

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 12/4/2022 9:26 AM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By:

Date:

Comments: Add Comment   Sort ▲

By Interface, Cityworks: 12/4/2022 9:26:45 AM

Problem Description: The alley behind the Gate Oaks Apts at 2909 Chamberlayne Ave has been in disrepair for years and must be reapired in a way that is lasting. Following a rain event, there is always 3-4" of standing water, this is not ok. The alley appears to be a a combination of gravel and asphalt, maybe ghisnisnpart of the problem. Regardless, neighbors on both sides of the alley are fed up and want this fixed.;

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave,

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No: 2

Map Page:

District:

Location:

Details: CRMDPW000127245 - https://e311production.blob.core.windows.net/rvaone/SRImages/20221204142537_967110667_.jpg;https://e311production.blob.core.windows.net/rvaone/SRImages/20221204142559_1831

Facility Id | Level Id
X: -8,621,016.297 | Y: 4,518,851.599

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comments
☐	LEASE	MICHAEL K.	80	12/4/2022 2:26:39 PM		CRMDPWC

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Location 2: Within District 6 and west of Willis St between Chesterman Ave and Mimosa St.

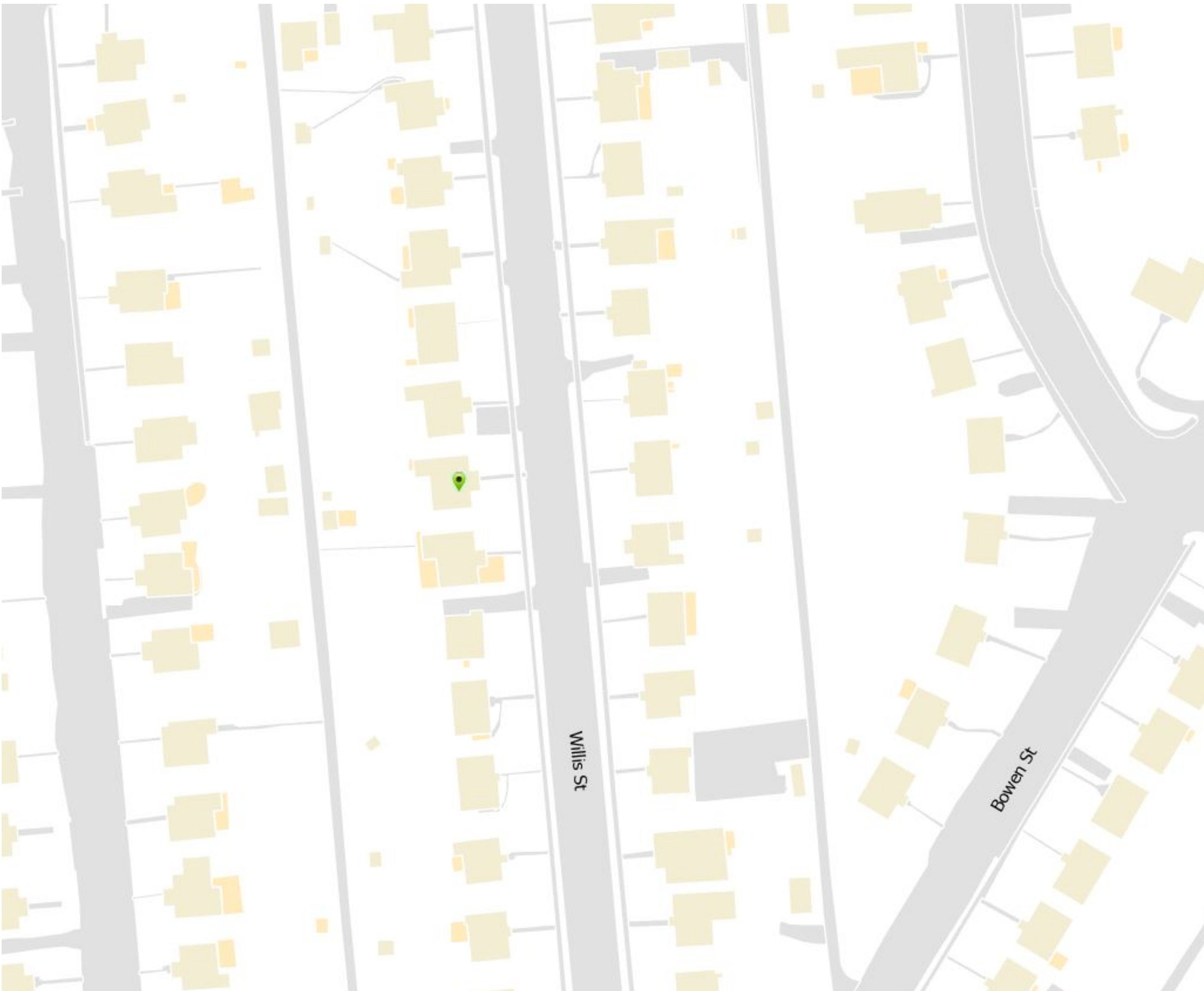


Figure 2: Flooding complaint map of location 2.

Search...

GLENN, HOWARD W

Inbox | Recent | Requests | Work Orders | Inspections | Crews | GIS Search

Calendar | Reports

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 425507

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 08/13/2020 1:01 PM

Investigation: ☑

Date: 08/18/2021 8:49 AM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 08/13/2020 1:01 PM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: WILLIAMS JR, JAMES

Date: 8/18/2021 8:49:59 AM

Comments: Add Comment | Sort ▲

By Interface, Cityworks: 8/13/2020 1:01:37 PM

Problem Description: Water after continuous raining has continuously food the entire property, crawl space and damage air conditions unit. Which has cause continuous costly repair. Due to know fault but The City of Richmond paving the alley way. Every time it rains if floods our property. I have pictures and video for proof. Some from Storm Drain came out this morning, stating you all need to put up a barrier. The water from the alley comes from both ways, flooding our entire property. I have all of my receipts.;

By Interface, Cityworks: 8/13/2020 3:22:52 PM

yard is being flooded when it rains. would like for someone to come out. she said she is having expenses and feels she should be reimbursed. Provided info to file a claim.

Streets PotholesAlley Asphalt Repair

By Interface, Cityworks: 10/20/2022 10:53:02 AM

Resolution:

Incident Information

Address: 1413 Willis St

Apt #:

City:

State:

Zip Code:

Landmark:

Shop:

Tile No: 4

Map Page: 6

District:

Location:

Details: CRMDPW000058043 - There is no media or attachements linked to this SR

Facility Id

Level Id

X: -8,620,639.224

Y: 4,509,156.828

Callers

	Last Name	First Name	M.I.	Call Time	Caller Typ
☐	COLEMAN, JR.	DEITTRA & BENJAMIN	80	8/13/2020 5:02:35 PM	RES

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 425690

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 08/15/2020 1:38 PM

Investigation: ☑

Date: 04/12/2021 9:51 AM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 08/15/2020 1:38 PM

Dispatch To: STEWART, ROSALIND

Date: 10/14/2020 9:12 AM

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: STEWART, ROSALIND

Date: 4/12/2021 9:51:05 AM

Comments: Add Comment Sort ▲

By Interface, Cityworks: 8/15/2020 1:38:47 PM

Problem Description: Everything time it rain the water from the alley runs into my yard and causing damage to my property. It is causing flooding in my yard and flooding my crawls pace and causing damage to my property.

;

By STEWART, ROSALIND: 4/12/2021 9:51:05 AM

duplicate request, cw 425507 dpw 000058043 remains open

Resolution:

Incident Information

Address: 1413 Willis St,

Apt #:

City:

State:

Zip Code: 23224

Landmark:

Shop:

Tile No: 4

Map Page:

6

District:

Location:

Details: CRMDPW000058214 - There is no media or attachements linked to this SR

Facility Id

Level Id

X: -8,620,639.224

Y: 4,509,156.828

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Commer
☐	COLEMAN JR	BENJAMIN	80	8/15/2020 5:39:45 PM		CRMDPW

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Figure 3: Photo of flooding at location 2. Ponding is visible. Alley conditions are not suitable for walking and drivers are unable to see the road.

Figure 4: Photo of flooding at location 2. Ponding is visible and seen to be flowing into the backyard of residential property 1413 Willis Street.

Figure 5: Photo of flooding of 1413 Willis Street backyard as seen from the inside of the residential house.

Figure 6: Photo of flooding of 1413 Willis Street backyard as seen from the alley.

Figure 7: Photo of flooding of 1413 Willis Street front year as seen from Willis Street side of the property.

2017
RVA CLEAN WATER PLAN

Prepared for The City of Richmond's Department of Public Utilities

CITY OF RICHMOND
DEPARTMENT OF PUBLIC UTILITIES

RVA H2O
EVERY DROP COUNTS

LimnoTech
Water Environment | Scientists Engineers

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RVA Clean Water Plan

September 2017

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3. Watershed and System Characterization 14
4. Goals & Objectives Selection 32
5. Strategy Identification 38
6. Strategy Evaluation 44
7. Implementation Program 67
8. Measuring Progress 77
9. Next Steps 81

Appendices

Appendix A – RVA Clean Water Plan Modeling Report

Appendix B – Strategy Fact Sheets

Appendix C – Goals, objectives, and metrics

Appendix D – Excel-based strategy calculator tool

Appendix E – Strategy cost estimation information

Acronyms

CBP – Chesapeake Bay Program

CFU – coliform forming units

CPMI – Coastal Plain macroinvertebrate index

CSO – combined sewer overflow

CSS – combined sewer system

CWA – Clean Water Act

DPU – Department of Public Utilities

EFDC - Environmental Fluid Dynamics Code

EPA – Environmental Protection Agency

GI – green infrastructure

GIS – geographic information system

LA – load allocation

LTCP – long term control plan

MGD – million gallons per day

MS4 – municipal separate storm sewer system

NPDES – national pollution discharge elimination system

PRCF - Parks, Recreation, and Community Facilities

SSO – sanitary sewer overflow

STV – statistical threshold value

SWMM – stormwater management model

TN – total Nitrogen

TP – total Phosphorus

TSS – total suspended solids

TMDL – total maximum daily load

UAA – use attainability analysis

USGS – United States Geological Service

VDCR – Virginia Department of Conservation and Recreation

VDEQ – Virginia Department of Environmental Quality

VSCI – Virginia Stream Condition Index

VPDES – Virginia Pollutant Discharge Elimination System

WWTP – wastewater treatment plant

Executive Summary

The City of Richmond's Department of Public Utilities (DPU) manages five utilities, three of which address water and potentially influence local water resources: wastewater, stormwater, and drinking water. The wastewater utility operates the wastewater treatment plant (WWTP), which discharges treated effluent to the James River, a sanitary sewer and combined sewer collection system, pumping stations, the Hampton-McCloy Tunnel, and the Shockoe Retention Basin. The stormwater utility manages the stormwater that runs off impervious surfaces through underground storm sewer systems and open channels into the James River and its tributaries. Approximately two-thirds of the City of Richmond is served by a municipal separate storm sewer system (MS4). The drinking water utility manages the treatment plant and distribution system of water mains, pumping stations, and storage facilities that provide water to more than 500,000 customers in the city and surrounding area using water from the James River.

Historically, the three utilities were managed independently of one another, primarily driven by the fact the regulatory agencies implemented the regulations and permit requirements independently. This approach forced the City to make decisions related to compliance for each utility without being able to consider the interrelated impacts, especially on local waterways. Integration of all of the separate programs into a coordinated approach would eliminate redundant activities, be more efficient and effective addressing wet weather impacts, and improve water resources overall. USEPA has put a significant amount of effort in recent years into describing and publicizing holistic or integrated processes to protect water quality. Richmond has applied EPA's concepts to form a framework, documented in this Richmond, Virginia (RVA) Clean Water Plan, that allows the City to efficiently evaluate, manage, and implement water quality programs, work toward their goals and objectives, and culminate in a single, integrated VPDES permit that encompasses the City's wastewater, CSO, and stormwater discharges.

The James River and its tributaries drain a watershed of over 10,000 square miles. Within the City of Richmond, the James River flows for 24 miles, providing a substantial amount of waterfront. Major features in the river include Bosher's Dam, which is located just upstream of the City along the James River, and smaller dams, levees, and pipe crossings within the City. Just downstream of the City is the Presquile Wildlife Refuge, home to several species of birds and anadromous fish, including the endangered Atlantic sturgeon.

The focus of the RVA Clean Water Plan is on the portion of the James River watershed within the City's municipal boundary and on restoring and protecting the waterways in this watershed. This watershed-wide, water quality-based strategy allows the City to develop an effective and affordable management plan while also meeting regulatory requirements, and demonstrating to the public that the plan protects and improves the watershed and waterways. Richmond's Clean Water Plan includes six elements[1], which summarized here and discussed in more detail in this document.

[1] (1)Stakeholder Involvement; (2) Watershed Characterization; (3) Strategy Identification, Evaluation and Selection; (4) Program Implementation; (5) Progress Measurement; and (6) Adaptive Management

Stakeholder Involvement

Stakeholders can represent many different groups with an interest in the watershed, including, for example, advocates for wildlife and habitat protection; boaters; residential, commercial and business interests; and environmental justice groups. The City has incorporated stakeholder involvement throughout the entire planning process to help ensure stakeholders understood the process from the outset and were part of decision-making efforts throughout the development of the plan. The City's Watershed Characterization Report includes additional discussion of the various stakeholders that have been invited to participate and/or are participating within this planning process.

The City created and initiated RVAH2O (RVAH2O.org), the name representing a citywide effort to arrive at "Cleaner Water Faster", to disseminate outreach information and facilitate communication with stakeholders. Beginning with an initial meeting in November 2014, the City has held technical meetings every 2-3 months. The City also initiated a public outreach effort, including several open houses, to lay a foundation of understanding before laddering up to the more technical conversation around watershed integration. The City's Public Outreach Plan, which includes online and offline communication strategies, has a goal of reaching 20% of the City's population in the MS4 area by 2018. Progress towards this and other goals are being measured by tracking RVAH2O Facebook and Twitter traffic, email campaign, and flier distributions.

Watershed Characterization

Understanding existing water quality, along with the sources of pollutants or stressors that impact the City's waterbodies, are key elements for developing priority actions to address existing or potential problems and developing an effective integrated plan. Collection of data and characterization of the City's watersheds were the City's first steps towards development of the Clean Water Plan. Another key step towards was the development of a water quantity and quality modeling framework, that incorporates models for the CSO areas, the non-CSO areas (including Richmond's MS4 area), and for the James River itself. The purpose of the modeling framework was to quantify present day bacteria (*E. coli*) concentrations in the James River and to predict future bacteria concentrations under the Clean Water Plan strategies.

Watershed Data and Features

The western and very northern portions of the City have experienced the least amount of hydrologic modification and possess the lowest intensely developed land use and most forested land cover. These more western areas also correspond with areas with higher soil infiltrative capacity. Alternatively, the eastern portion of the City corresponds with a higher intensity of developed land and industrial land use corridor as well as the City's urban core. Consequently, this area also corresponds to soils that are considered urban and tend to have less infiltration capacity and possesses a topography that includes some considerably steep slopes.

The James River and several of its tributaries [(Almond Creek, Falling Creek, Goode Creek, Powhite Creek, Reedy Creek, Bernards Creek, and Gillies Creek and Upham Brook (which is a tributary to the Chickahominy River and ultimately the James River)] have all been listed as impaired due to *E. coli* levels. The sources of bacteria in these streams within the City limits include CSOs, the MS4, the WWTP, direct discharge of urban runoff, and wildlife. Upstream sources also impact water quality in the City. Upstream sources include livestock, land application of manure, malfunctioning septic systems, illicit discharge of residential waste, other permitted waste treatment facilities. Reducing bacteria levels in these streams is consistent with the City's goal to provide safe recreational opportunities in the river.

The number of available water quality samples are biased heavily towards the James River, with little-to-no data available in tributary streams. Additionally, there is a lack of hydraulic data within the City, with the only local USGS gauges located outside the City limits. Biological samples and habitat assessments are also limited.

Water Quality Modeling

Water quantity and quality modeling was conducted to allow for longer and continuous periods to be evaluated relative to the water quality monitoring program. The purpose of the modeling framework is to quantify present day bacteria (E. coli) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the Clean Water Plan strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events.

Three models were used to achieve the modeling objectives and include:

- A watershed model, created using EPA's Stormwater Management Model (SWMM), to simulate flow and bacteria loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system.
- A collection system model, created using EPA's SWMM framework, to simulate flow and bacteria loads from the combined sewer system (CSS).
- A receiving water quality model, created using EPA's Environmental Fluid Dynamics Code (EFDC) model, which computes bacteria concentrations in the James River resulting from the various sources of bacteria to the river. The outputs of the watershed and CSS models are used as inputs to the receiving water quality model.

After the water quality modeling tools were developed and calibrated, they were jointly applied to assess water quality benefits associated with the selected strategies (described further below). Under current conditions, the model results illustrate that the James River is in violation of both the geometric mean and the statistical threshold value water quality standard criteria for some months out of the three year model simulation period, and the primary cause of a water quality criteria violation can sometimes be linked to Richmond's combined sewer overflows, while at other times it is due to upstream sources coming in from outside of the City. Background (mainly wildlife) and stormwater sources play a smaller overall role in the bacteria water quality violations. The WWTP does not contribute significantly to bacteria water quality violations.

Strategy Identification, Evaluation & Selection

Goals and Objectives Selection

The City implemented a multi-step process with stakeholders to form consolidated lists of overarching goals, refined goals, and objectives. Although a number of opinions and viewpoints were represented through the stakeholder process, ultimately, stakeholders achieved consensus on the overarching goal, refined goals, and objectives.

Weighting was incorporated into this process to reflect the priorities of the City and its stakeholders. This weighting process not only allowed for an understanding of how one goal or objective ranked in relation to another, it also provided information on the extent of the importance of these priorities to one other. The result of this process was a prioritization of refined goals as well as a prioritization of objectives associated with each of these goals.

The goals, objectives, and respective weights are summarized in Table ES.1.

Table ES.1 Clean Water Plan goals and objectives with associated weights

Goals (with weights)	Objectives	Weights
19%: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.	Develop one stormwater management plan to cover the City's four watershed groupings based on the City's watershed characterization report.	19%
	Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).	18%
	Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).	18%
	Reduce toxics (e.g., mercury, PAHs, PCBs), trash and other pollutants and address TMDLs for these pollutants.	17%
	Develop green infrastructure, including riparian buffers, and removal of impervious surfaces on development, existing development, and redevelopment.	27%
15%: Protect and restore aquatic and terrestrial habitats to support balanced indigenous[2] communities	Restore streams to improve, restore, and enhance native ecological communities.	25%
	Identify, protect, and restore critical habitats.	36%
	Enhance aquatic and terrestrial habitat connectivity.	23%
	Investigate, and where feasible, promote actions that might surpass regulatory requirements.	16%
14%: Engage and educate the public to share responsibility and take action on achieving healthy watersheds.	Engage and efficiently educate the public about standards, processes, and actions associated with watershed health and public health.	25%
	Assist in the education of citizens about overall water quality issues, benefits of improved water quality.	30%
	Support and encourage local action to improve water quality.	24%
	Provide quicker public notifications of spills or pollution from regulators or other "river watchers"	21%
12%: Implement land	Protect, restore, and increase riparian buffers	21%

[2] The language included here was crafted based on Technical Stakeholder discussion and a resulting consensus process. For clarification, however, this refers to balanced indigenous ecological communities.

conservation and restoration and incorporate these into planning practices to improve water quality.	Reduce impervious surfaces	19%
	Increase natural land cover with a focus on preserving, maintaining, and increasing tree canopy.	24%
	Incorporate green infrastructure in new development and redevelopment	18%
	Conserve lands where possible and consistent with Richmond's Comprehensive Plan	18%
11%: Create partnerships across the watersheds internal and external to the City of Richmond to maximize benefits and minimize impacts to all stakeholders	Develop and implement a source water prevention plan/strategy	33%
	Establish public-private partnerships to secure funding, implement strategies and projects, and to achieve plan goals.	40%
	Maintain and expand the RVAH20 group.	27%
10%: Maximize water availability through efficient management of potable, storm, and wastewater.	Reduce use of potable water for industry and irrigation.	39%
	Achieve water conservation by improving the existing water conveyance system.	30%
	Achieve water conservation by incentivizing upgrades to end-user water fixtures where appropriate.	31%
9%: Provide safe, accessible, and ecologically sustainable water-related recreational opportunities for all.	Improve water quality to promote safe recreation consistent with the City's Riverfront Plan.	36%
	Promote ecologically sustainable management of riverfront and riparian areas.	40%
	Improve river and waterfront access for recreation.	24%
9%: Work collaboratively to gather consistent high-quality data to characterize the status and trends of water resources and to gauge the effectiveness of restoration efforts.	Conduct water quality and biological monitoring	28%
	Provide timely water quality information.	19%
	Collaborate with citizens and local/state agencies for coordinated monitoring.	23%
	Utilize results to target restoration efforts and convey progress.	30%

Strategy Identification

The next step in this process was the identification of strategies that can be expected to achieve the previously identified goals and objectives. Strategies were defined as activities, actions, or items that will help meet goals and objectives.

The first step in brainstorming potential strategies included a workshop for DPU staff involved in stormwater, wastewater, and CSO-related projects. Because the Clean Water Plan would be implemented during the next VPDES permit cycle (2018 - 2023), staff compiled a list of projects that had been identified or proposed to meet various programmatic needs and could be implemented over that period. Because many of these projects impact small-scale areas, these City projects were "rolled up" to a strategy scale where necessary.

In addition to these DPU projects, stakeholders were also asked to submit suggestions for strategies that they felt would achieve the agreed upon goals and objectives. The Clean Water Plan development team created a synthesized set of draft strategies that consolidated ideas put forth by both stakeholders and DPU staff.

Once the draft set of strategies was identified, it was important to determine if these strategies were feasible. Because DPU is ultimately responsible for implementation of this program, the feasibility of strategies was defined as efforts that DPU has the authority to implement.

Final draft strategies and supporting actions were presented to stakeholders who were given the opportunity to edit them further. Supporting actions include efforts that may broaden the main strategy, add specificity on how a strategy could be implemented, or identify additional resources and data needs to fully implement the main strategy. Each of the strategies referenced in the remainder of the Clean Water Plan are considered to be "feasible" and agreed upon by the Technical Stakeholder group (Table ES.2).

Table ES.2. Strategies and associated details

Strategy	Strategy Details
Riparian Areas	Replace or restore 10 acres of riparian buffers according to state guidance. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Green Infrastructure in MS4	Install or retrofit GI draining 104 acres of impervious surfaces, including efforts such as: • 30 acres on DPU property • 18 acres on City-owned vacant properties • 20 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 100 trees in tree boxes (e.g., Filtera-type practices); 30 acres total drained to this practice • Retrofit 4 DPU stormwater BMPs (e.g., dry ponds to more efficient BMPs), draining at least 6 acres of impervious surface
Green Infrastructure in CSS	Install or retrofit GI draining 18 acres of impervious surfaces, including efforts such as: • 6 acres on DPU property • 2 acres on City-owned vacant properties • 2 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 24 trees in tree boxes (e.g., Filtera-type practices); 8 acres total drained to this practice
Stream Restoration	Restore 2,500 linear feet of stream: • Through removal of concrete channels, repair of incised banks, etc. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Natives/Invasives	Use 80% native plants in new landscaping at public facilities by 2023.
Trees	• Increase tree canopy on City property by 5% (80 acres added) • Protect existing tree canopy by following maintenance addressed in the Tree Planting Master Plan
Land Conservation	Place an additional 10 acres under conservation easement, prioritizing conservation of land that creates connected green corridors. • Evaluate opportunities for inclusion of access points to waterbody for recreational

	activities
Water Conservation	Reduce water consumption by 10% through implementation of new water conservation technologies and promotion of water conservation efforts, including: • Installing water-efficient fixtures as a policy by 2023 in all new public facility construction • Implementing incentive programs • Encouraging water conservation on City properties
Pollution Identification and Reduction	Reduce contribution of pollutants to the MS4 through: • Conducting at least one special study per year in hot spot areas to identify illicit discharges/connections. (Studies will meet the criteria necessary to achieve Bay TMDL pollutant reduction requirements. Assume that, over five years, three of these studies will result in pollutant reductions that meet Bay TMDL requirements.) • Collecting data associated with non-structural BMPs to facilitate quantification of pollutant reduction (e.g., storm drain clean-outs, pet waste stations, street sweeping)
CSS Infrastructure	LTCP projects, including: • Installing wet weather interceptor to convey more flow to the WWTP • Increasing WWT to 300 MGD at the treatment plant • Expanding secondary treatment at the WWTP to 85 MGD • Expanding Shockoe retention basin by 15 MG to capture more overflow • Disinfecting overflow at Shockoe retention basin (wet weather disinfection facility) *Note that that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost.*

Strategy Evaluation

Once strategies were drafted, an analysis was needed to determine which ones would be best for implementation. There are multiple factors at play that influence the selection of strategies. A strategy may do well with one factor, such as permit-related pollutant reductions, but not so well with others, like cost. As a result, the analysis of the various factors did not result in a clear and decisive outcome of one strategy that performed the best across all factors. What the strategy evaluation did determine was that all of the “pieces of the puzzle” needed to be evaluated collectively to achieve a complete picture of how well strategies achieve specific goals (Figure ES.1).

Figure ES.1. Puzzle piece conceptual model demonstrating how various factors fit together to inform the decision making process

An Excel-based strategy scoring calculator was developed to compare the various strategies proposed through this stakeholder process. This tool helped in the decision-making process by allowing the City and stakeholders to evaluate various alternatives by assigning scores to the alternative strategies.

The methodology used for this scoring calculator is a multi-objective decision analysis (MODA). A set of metrics was developed that includes a method of measurement. At least one metric was identified for each objective.

Multiple "puzzle pieces", or factors, were taken into consideration in the analysis of strategies (Figure ES.1). The **Permit** puzzle piece represents the VPDES permit-related requirements that establish pollutant reduction targets by which the strategies were compared.

The **Strategy Score** "puzzle piece" involved using the calculator tool to evaluate strategy scores in several different ways. These analyses included evaluating:

- Permit-related metrics – metrics that related to total Nitrogen (TN), total Phosphorus (TP), total suspended solids (TSS) and bacteria were isolated in the calculator and scores associated with just these metrics were used to evaluate the effectiveness of strategies in reducing these pollutants of concern
- "Standardization" of strategies addressing permit-related metrics – strategies, which varied in size, were all standardized to 10 acres to compare these permit-related metrics in an "apples to apples" manner
- All metrics – including the full set of metrics associated with all of the objectives in addition to the pollutant-related metrics
- "Standardization" of all metrics – comparing how the same sized strategies (all 10 acres) address all metrics

The calculator tool was also tied to the **Strategy Cost** information. Metrics specific to pollutant reductions (e.g., pounds of pollutant removed by a strategy) were used to calculate **Cost Effectiveness**. Overall, strategy costs were then evaluated in association with **Affordability**.

Another puzzle piece, **Modeling Results,** provided the bacteria reductions associated with several strategies that were used as raw score inputs into the calculator. Modeling results also provided information pertaining to the relative nature of bacteria sources to the James River and tributaries.

After taking the evaluation process through the "Standardization of all metrics", the following top-ranked strategies resulted:

1. Riparian Area Restoration
2. Stream Restoration
3. Green Infrastructure in the CSS area
4. Green Infrastructure in the MS4

The various "pieces of the puzzle" were used to understand how to best prioritize activities for implementation. What these analyses have shown is that no one strategy consistently scores the highest or performed the best across the analyses, however, several strategies consistently performed well (a summary of the analyses are included in Table ES.3; green highlighted information depicts those that consistently score highest).

Table ES.3. Summary of Strategy Analysis and Strategy Prioritization

Rank	Pollutants of Concern Metrics	Pollutants of Concern Metrics: Standardized*	All Metrics	All Metrics: Standardized*	Cost Effectiveness (TN)	Cost Effectiveness (TP)	Cost Effectiveness (TSS)	Cost Effectiveness (bacteria)
1	**CSO Infrastructure**	**Stream restoration**	**GI in MS4**	**Riparian**	**Stream restoration**	**Stream restoration**	**Stream restoration**	**CSO Infrastructure**
2	**Stream restoration**	**GI in CSS**	**Riparian**	**Stream restoration**	Water conservation	Pollution ID and reduction	**Pollution ID & reduction**	**GI in CSS**
3	**Pollution ID & reduction**	**GI in MS4**	**Stream restoration**	**GI in the CSS**	**GI in MS4**	**GI in MS4**	**GI in MS4**	**GI in MS4**
4	**GI in MS4**	**Riparian**	**CSO Infrastructure**	**GI in MS4**	**GI in CSS**	**GI in CSS**	**GI in CSS**	**Riparian**
5	**GI in CSS**	Water conservation	Water Conservation	Water Conservation	Pollution Identification	Water conservation	Water conservation	
6	**Riparian**	Trees	Trees	Land Conservation	**CSO Infrastructure**	**Riparian areas**	**Riparian areas**	
7	Trees	Pollution ID & reduction	Natives/ invasives	Natives/ invasives	**Riparian**	**CSO Infrastructure**	**CSO Infrastructure**	
8	Water Conservation	Natives / invasives	Land Conservation	Trees	Trees	Trees	Trees	
9	Natives/ invasives	Land Conservation	**GI in the CSS**	Pollution Identification				
10	Land Conservation		Pollution ID and reduction					

*WWTP/CSO strategy cannot be evaluated on a 10-acre basis so it is not included herein

To allow for the consideration of multiple factors in determining priorities, it was determined that rather than ranking 10 strategies individually, that strategies would be grouped into one of three tiers based on effectiveness (Figure ES.2). Tier 1 includes those strategies that best address metrics associated with the pollutants of concern (total Nitrogen, TN; total Phosphorus, TP; total suspended solids, TSS; bacteria) as well as the non-pollutant related metrics. These strategies were also the most cost effective. Tier 2 also addressed pollutant and non-pollutant related metrics, but not as efficiently or cost effectively as those in the Tier 1 grouping. Tier 3 are those strategies that do not address the pollutants of concern.

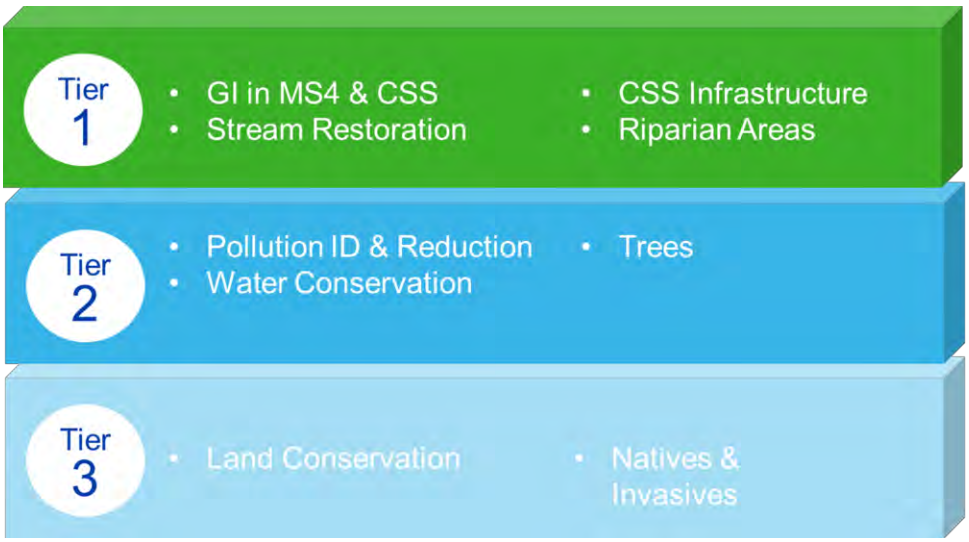


Figure ES.2. Organization of strategies into tiers for prioritization

It is important to note that while select strategies may be *prioritized,* it does not mean that the remaining strategies will be disregarded. Implementation of these strategies will be assessed based on additional resources available to DPU or priorities and resources available from other City departments or other partners.

It is also important to note that this analysis was done at a high level. As DPU moves toward implementation and conducts a more refined evaluation of strategies, there may be modifications to this prioritization.

Program Implementation

An important part of this RVA Clean Water Plan is developing an approach that can help the City implement these strategies in the most efficient and cost effective manner possible. DPU will use a “Framework Planning” approach. The Framework Planning approach provides a methodology that ties together different strategies (and, subsequently, site-specific projects) and, where possible, aligns these strategies with other City or stakeholder-driven initiatives. The goal of the Framework Planning Approach is to identify and sequence a blend of activities that yield the greatest environmental benefit (as measured by identified metrics) in the most cost-effective (and affordable) manner. The Framework Planning approach includes the following elements:

1) Data and information gathering
2) Identification of potential opportunities

3) Prioritization
4) Plan development
5) Implementation

There are several important concepts that will be taken into account through implementation. For instance, it is envisioned that implementation will occur incrementally over the course of the permit cycle (e.g., 10 acres of riparian buffers will not necessarily be restored all at once or within only one project, but may be addressed through the implementation of several projects/project clusters). Flexibility is incorporated into implementation through adaptive management. If it is found that one strategy cannot be implemented in whole or in part, DPU will work to identify an alternative approach to achieving the same or similar pollutant reductions and other identified goals and objectives.

Implementation of projects, particularly those that involve stakeholders or other City departments, will require significant coordination. In addition to regular Technical Stakeholder meetings to provide updates on progress, DPU will convene a workgroup of those organizations involved in these implementation efforts. As projects are implemented, associated benefits (pollutant reductions, area treated, other metrics addressed) will be tracked as well.

Progress Measurement

As the City's implementation moves forward, measuring progress will include determining if goals have been met, if progress has been deemed sufficient, or if changes should be made within the program to try to improve the level of progress made. Measuring progress; however, can be complex. Targets may be established at various scales (i.e., site scale, sub-watershed, watershed, city scale). Implementation actions can also include a wide range of options including structural and non-structural practices as well as practices that address various source sectors (i.e., stormwater, wastewater, non-point sources). As a result, the approach used for measuring progress under the City's program must be flexible enough to account for these variations in scale and options that will be employed to mitigate pollutants and meet the City's goals.

Measuring progress will be done in a holistic manner based on data from the City's monitoring programs, modeling efforts, and other programmatic information (e.g., implementation targets, such as miles of stream buffers restored per year or number of residents reached by outreach efforts). Each element of this process to evaluate Clean Water Plan progress will occur on a regular/annual basis over the course of the permit. Each of these elements is outlined in Table ES.4.

Table ES.4. Monitoring activities and associated outcomes implemented under the Clean Water Plan

	Activities	Outcomes
Water Quality Monitoring	Instream water quality, biological (e.g., macroinvertebrates), CSO and WWTP discharge monitoring	Progress made toward pollutant reduction targets in permit
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
		Identify sources, stressors, or pollutants of concern
		Identify trends over time
	BMP monitoring	Effectiveness of specific BMPs or source reduction efforts
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
Programmatic Monitoring	Tracking strategy implementation	Progress made toward strategy implementation goals (e.g., acres of green infrastructure implemented)
		Progress made in pollutant reduction through strategy implementation (e.g., pounds of TN reduced through green infrastructure implemented)
		Progress made toward pollutant reduction targets identified in permit
Modeling	Receiving water, CSS, and watershed modeling and analysis	Progress made in bacteria WQS compliance
		Progress made in bacteria load reduction
		Progress made in reduction of CSO events or volume discharged

Next Steps

The RVA Clean Water Plan has resulted in a comprehensive understanding of the City's watersheds and associated water resources. The next step is to use the Clean Water Plan to develop a watershed-based VPDES permit. Watershed-based permitting has been long supported by EPA and allows multiple pollutant sources to be managed under one permit. For Richmond, these pollutant sources are CSO, wastewater, and stormwater via the MS4 and direct drainage. The Clean Water Plan provides the planning framework and strategies to manage these sources and prioritize control projects based on their improvements to local waterways. Therefore, the Clean Water Plan will be included in the VPDES permit as a source of data and provide information to be included in the "Special Condition" section related to best management practices (BMPs) to be implemented and additional monitoring to be done to track progress. The Clean Water Plan will also be included in the Permit Fact Sheet as an information source.

Once the watershed-based VPDES permit is issued to the City, next steps include implementing the projects and programs in the Clean Water Plan and conducting monitoring and modeling to measure progress towards the goals of the plan. The City will also continue to engage stakeholders to inform them of activities and associated progress towards the goals of the Plan, and solicit their input on Plan updates.

The Modeling Framework will continue to be used as needed to evaluate the water quality improvements related to the implementation of projects and strategies. Additionally, it is anticipated that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the Long Term Control Plan (LTCP) projects, but at a reduced cost.

1. Background and Introduction

The City of Richmond's Department of Public Utilities (DPU) manages five utilities, three of which address water: wastewater, stormwater, and drinking water. As all three of these utilities can influence local water resources, such as the James River, each operates under regulations and permit requirements established to ensure protection of the environment and public health.

The Wastewater Utility was implemented to operate and maintain the wastewater treatment plant (WWTP), which discharges treated effluent to the James River (45 MGD dry weather flow and 75 MGD wet weather flow). The Utility also operates and maintains a sanitary sewer and combined sewer collection system, pumping stations, and the Hampton-McCloy Tunnel, storage capacity of 7.2 million gallons, and the Shockoe Retention Basin, a 50-million gallon reservoir used during heavy rains.

The Stormwater Utility is relatively new compared to the other utilities. It was implemented in July 2009 to manage the stormwater that runs off impervious surfaces. The Stormwater Utility also enhances public safety and health and protects property by improving the quality and decreasing the quantity of polluted stormwater runoff. Approximately two-thirds of the City of Richmond is served by a municipal separate storm sewer system (MS4). This mixture of underground storm sewer systems and open channels are separate from the sanitary sewer system.

The City of Richmond is one of the largest water producers in Virginia, with a modern plant that can treat up to 132 million gallons of water a day from the James River at the western edge of the City. The Drinking Water Utility manages the treatment plant and distribution system of water mains, pumping stations, and storage facilities that provide water to more than 200,000 customers in the city. The facility also provides water to the surrounding area through wholesale contracts with Henrico, Chesterfield, and Hanover counties. All total, this results in a facility that provides water for approximately 500,000 people.

Historically, the three utilities were managed independently of one another, primarily driven by the fact the regulations and permit requirements established by the regulatory agencies were also implemented independently. This approach forced the City to make decisions related to compliance for each utility without being able to consider the interrelated impacts. There is often overlap in these requirements and sometimes an action occurring under one regulatory program has a direct impact on another. For instance, separating a combined section of sewer leads to impacts on the separate sanitary sewer system and the storm sewer system. Integration of all of the separate programs into a coordinated approach is necessary to eliminate redundant activities and be more efficient and effective addressing wet weather impacts and improving water resources overall.

USEPA Integrated Planning Frameworks

USEPA has put a significant amount of effort in recent years into describing and publicizing its vision of management of these separate programs through the concepts of Integrated Planning (EPA 2011, EPA 2012a), Integrated Watershed Management (EPA 1996, EPA 2008), and Watershed-based Permitting

(EPA 2007, EPA 2003). An emphasis within each of these concepts involves providing an opportunity to examine different possible ways to look at protecting water quality given very limited resources at both the City and the state level. Often these limited resources must be used to manage and implement multiple and costly regulatory requirements, such as:

- Replacing/repairing aging infrastructure;
- Developing and implementing long-term control plans (LTCPs) for combined sewer overflows (CSOs);
- Developing and implementing capacity, management, operation and maintenance programs for sanitary sewer overflows (SSOs);
- Improving peak flow management at WWTPs;
- Addressing requirements to control nutrients and emerging contaminants at the WWTP;
- Managing stormwater to mitigate flooding;
- Developing and implementing MS4 pollution prevention plans;
- Investing in treatment technologies to comply with effluent limits based on total maximum daily loads (TMDLs); and,
- Complying with Safe Drinking Water Act and/or National Pollutant Elimination Discharge System (NPDES) requirements.

All of these issues are currently of importance to the City of Richmond, or will be over time. All of these activities or requirements are rarely coordinated or considered in a holistic manner. Without coordination among these competing demands, the City's constrained resources aren't likely to achieve the maximum benefit to the utility, the public, and the environment. Too often, the need for investment (especially for wet weather controls) greatly exceeds the City's financial capacity, even over a 20-year period. As a result, there is uncertainty in prioritizing investments, and with how to create a plan that progressively moves toward meeting clean water goals.

To address these issues, Richmond is using EPA's Integrated Watershed Management and Integrated Planning frameworks for planning purposes. Because both of these have a number of consistencies between them, these approaches have been combined and organized to form a framework that allows the City to efficiently evaluate, manage, and implement water quality programs and work toward their goals and objectives (see Figure 1.1). The endpoint of this overall effort is a single, integrated VPDES permit that encompasses DPU's wastewater, CSO, and stormwater discharges.

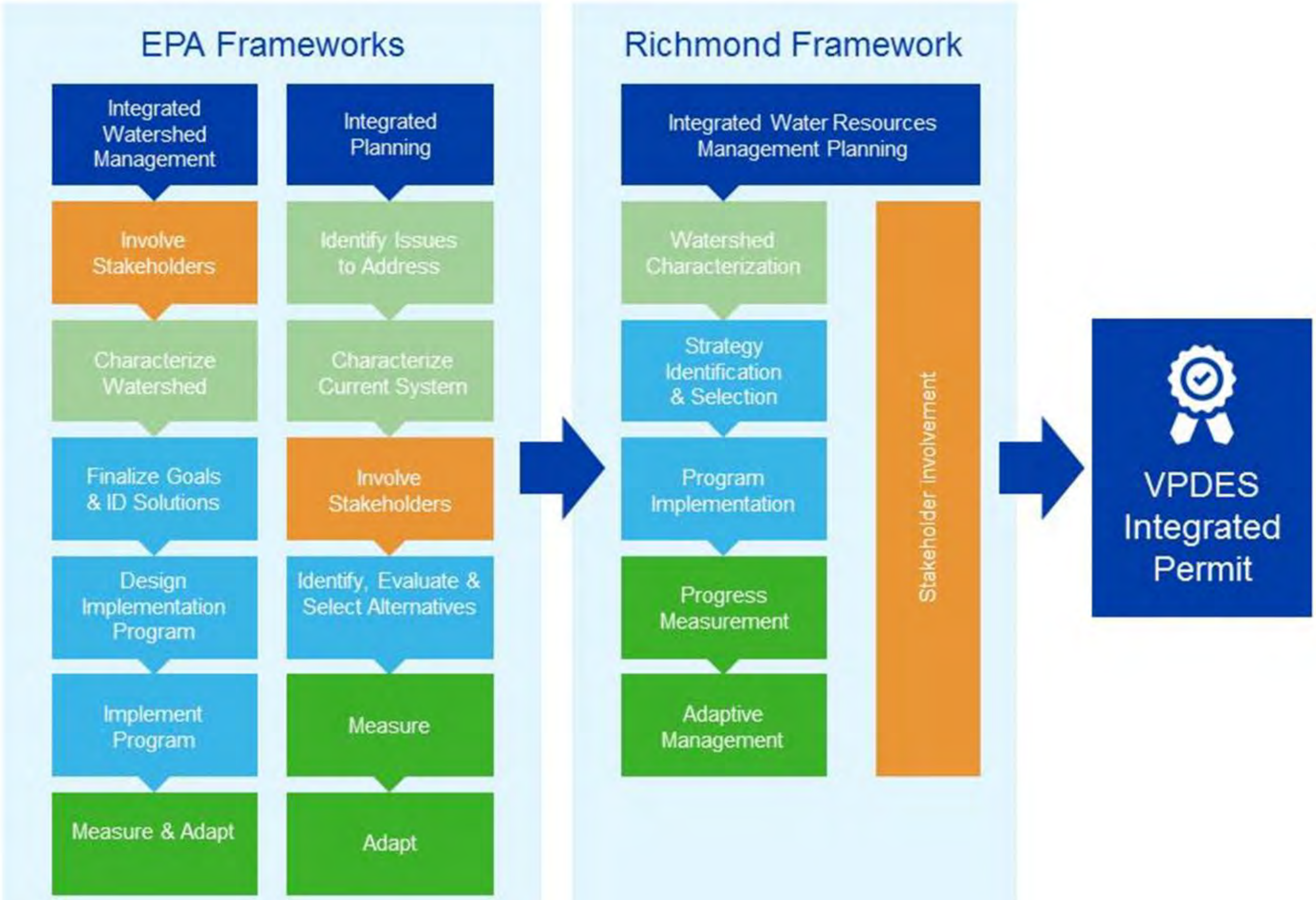


Figure 1.1 – Demonstration of the overlap in elements between EPA's Integrated Watershed Management and Integrated Planning Approaches and how these elements have been merged to develop the framework for the Integrated Water Resources Management Plan where stakeholder involvement is a part of each step of the process.

Richmond's Clean Water Plan Framework

Efforts to prioritize a community's investments have traditionally tended to focus on meeting infrastructure-related goals, such as reduction in the number of CSOs. The focus of the RVA Clean Water Plan, however, is on the watershed and restoring and protecting the waterways in these watersheds. Given this focus, the Clean Water Plan is framed by water quality standards (WQS) and watershed goals rather than solely by municipal infrastructure project considerations. This watershed-wide, water quality-based strategy allows the City to develop an effective and affordable management plan while also meeting regulatory requirements and demonstrating to the public that the plan protects and improves the watershed and waterways. The integration includes the WWTP, CSO, and stormwater programs, and maintaining minimum in-stream flows. Richmond is also taking drinking water and source water protection into consideration to ensure a more comprehensive focus on overall watershed health.

The City's Department of Public Utilities began the Clean Water Planning process in March of 2014 (see Figure 1.2), with the establishment of a Technical Stakeholder Group and related outreach plan. The effort continued in January, 2015 with a watershed characterization effort that culminated in the development of a Watershed Characterization Report (Richmond DPU 2015). Work on the Clean Water Plan began in 2016, which will ultimately be used to inform the development of an integrated Virginia Pollutant Discharge Elimination System (VPDES) permit that collectively addresses DPU's discharge permit requirements. The permit application is due to VDEQ in January, 2018, with the Integrated VPDES permit expected to be reissued in June of 2018.

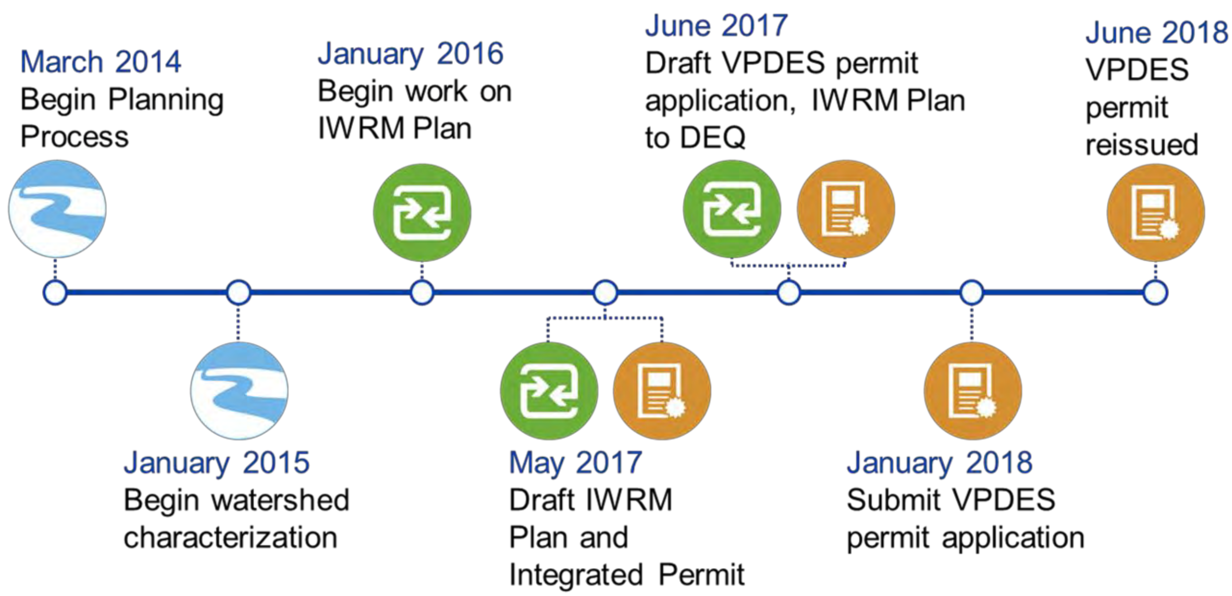


Figure 1 .2– Richmond's schedule for the development of a Watershed Management Plan (WMP), Integrated Plan and Watershed-based Permit (WBP)

Richmond's Clean Water Plan includes six elements, which are summarized below and discussed in more detail in the subsequent sections of this document.

Stakeholder Involvement

DPU determined early on that community input and support would be key to the success of its Clean Water Plan as this support would facilitate development of an integrated VPDES permit as well as future implementation efforts. It was felt that this input and support could be gained by implementing a thoughtful, well-informed approach that demonstrates the Utility's commitment to improving the environment while continuing their good stewardship of their infrastructure assets and local water resources. Community support was especially important in considering priorities and options for improving and protecting the City's waters.

Watershed Characterization

The watershed characterization process within the Clean Water Plan provides the data needed to support this process. This includes data such as monitoring related to meeting receiving water standards and goals, and characterizing receiving water conditions and sources of pollutants throughout the watershed. Existing data are compiled and, if necessary, new data are collected to provide the data needed to complete the watershed characterization. Evaluating data from a watershed perspective helps to facilitate a watershed-based approach to planning and, subsequently, implementation. Ongoing data collection will ensure the Clean Water Plan is up-to-date and accurate, and will facilitate future updates using an adaptive management approach. A beneficial outcome will be that data collected through watershed characterization efforts will serve multiple purposes. For instance the activities associated with the TMDL development and implementation will help determine appropriate targets for the Clean Water Plan.

Strategy Identification, Evaluation, and Selection

The data collected through the watershed characterization effort serves as the basis for helping to identify and quantify problems or issues of concern within the watersheds. This helped guide the selection of goals and objectives the City and its stakeholders identified for this process. As high-level strategies to meet these goals were identified, they were incorporated into an Excel-based strategy scoring calculator that included the weighting of these goals, associated objectives, and metrics by which these strategies were measured. Other factors, such as strategy costs, cost effectiveness, and watershed and water quality modeling results, were also used to prioritize strategies.

Program Implementation

After selection and prioritization of high-level strategies is completed, these high-level strategies (e.g., Green Infrastructure implementation in the MS4 area) will be translated into localized projects (e.g., two acres of bioretention and one acre of pervious pavement in a particular subwatershed). A “Framework Planning” approach is being used to strategically direct implementation in a way that aligns activities that yield the greatest environmental benefit in the most cost-effective manner.

Progress Measurement

Once projects and programs have been implemented, measuring progress will be accomplished through a three-pronged approach. This will include programmatic tracking, which will involve evaluating the progress made toward strategy implementation (e.g., acres or feet of implementation, etc.) as well as the pollutant reduction calculated through this implementation. The City will also conduct water quality monitoring to evaluate progress made toward pollutant reduction targets in the permit, progress made toward achieving WQS, and trends over time. Modeling will also be used to evaluate progress made toward bacteria-related WQS, bacteria load reductions, and reduction of CSO events or volume discharged. Progress will be reported annually through VPDES permit-related reporting.

Adaptive Management

Because the City, its waterbodies, regulatory drivers, and community needs are not static, City and stakeholder priorities may also change over time. The Clean Water Planning process incorporates flexibility to address these changing needs. This flexibility, or adaptive management, is an iterative, ongoing, learning process used to continually improve understanding of the City’s programs and practices by learning from their outcomes over time.

Adaptive management will be critical for the success of Richmond’s Clean Water Plan as new data collected through the course of this effort will be used to refine and modify the Plan so it is up-to-date and accurate.

2. Stakeholder Involvement

From the very beginning, the City knew stakeholder involvement would be a key component of developing and implementing an effective and successful integrated approach to the City's water resources management. While building partnerships is identified as one "Step" in both EPA's Integrated Watershed Management and Integrated Planning processes, the City has actually incorporated stakeholder involvement throughout the entire planning process to help ensure stakeholders understood the process from the very beginning and were part of decision-making efforts along the way. It also helped ensure that stakeholders had a voice to convey any concerns they may have or encourage sharing of data and information that could be helpful with planning, and subsequently, implementation efforts.

To aid in this communication effort as well as in the dissemination of outreach information, DPU created and initiated RVAH2O (RVAH2O.org). The name was formed from "RVA," which is popular shorthand for Richmond, Virginia, and "H2O," which is the chemical formula for water. Together, the name represents a citywide effort to arrive at "Cleaner Water Faster."

The RVAH2O.org website educates the community about ways to keep the City's waterways pollution-free and the importance of integrating drinking water, wastewater, and stormwater under one watershed management program. It is all water. The website is also used to share information conveyed during Technical Stakeholder and public meetings discussing the Clean Water Planning process. RVAH2O has also been expanded into a Facebook page and Twitter feed to reach a larger public audience. The logo and its clean water messages appear on billboards, bumper stickers, community meeting handouts, school bulletin boards, and on DPU booths and water stations at community events and water-related festivals.

A detailed discussion of each of the elements of the stakeholder involvement process is included below, as well as further detail surrounding public outreach.

Stakeholder Identification

Stakeholders can represent many different groups with an interest in the watershed, including, for example, advocates for wildlife and habitat protection; boaters; residential, commercial and business interests; and environmental justice groups. As discussed in the City's Watershed Characterization Report, an initial step in this process was the identification of groups or individuals that would be interested in being more involved in the City's water future and/or would potentially bring data, information, and insight to the table that could assist the City with reviewing the problems and looking at the relative contribution of all sources and stressors on the watershed.

The City reached out to a variety of stakeholders in and surrounding the City, including environmental advocates, recreational users of the James River, property owners, businesses, and state and local governmental agencies and representatives.

The initial stages of the stakeholder involvement process resulted in categorizing these participants into several groups based on expected technical knowledge and perceived level of interest and involvement. As a result, a Technical Workgroup was formed to provide technical insight and feedback on the Clean Water Planning process. This group included representatives of groups such as:

- Chesapeake Bay Foundation
- James River Association & Riverkeepers
- The Nature Conservancy
- Middle James Round Table
- Alliance for the Chesapeake Bay
- Virginia Department of Environmental Quality (VDEQ)
- Virginia Department of Health (VDH)
- City Department of Public Works (DPW)
- The Reedy Creek Coalition
- Fall of the James Scenic River Group
- James River Park System
- Virginia Commonwealth University (VCU)
- Richmond Regional Planning District Commission
- James River Outdoor Coalition
- Capital Region Land Conservancy
- Marine Resources Commission
- University of Richmond
- American Water
- Tree Stewards of Richmond
- The Counties of Hanover, Chesterfield & Henrico (reached through the Planning District Commission)

Additionally, a special interest and public stakeholder group was identified with participants anticipated to have a high level of involvement. This group included representatives of organizations such as:

- Friends of James River Park
- Sierra Club – Falls of the James Group
- Home Builders Association of Virginia
- Hispanic Chamber of Commerce
- Richmond City Council Districts
- Richmond Paddle Sports and other sports organizations

Participants in this special interest and public stakeholder group with an anticipated lower level of involvement included representatives from organizations such as:

- Richmond Audubon Society
- James River Advisory Committee
- Retail Merchants Associations
- Tenant, Civic and Neighborhood Associations

The City's Watershed Characterization Report includes additional discussion of the various stakeholders that have been invited to participate and/or are participating within this planning process.

Once stakeholders were identified, kick-off meetings were held in November 2014 to speak with the technical stakeholders and the special interest/non-technical stakeholder group. A meeting schedule was developed early on to ensure consistent communication with the technical stakeholders on a quarterly basis and with the special interest/public stakeholder group approximately every six months.

Technical Stakeholder Meetings

Since the initial meetings in November 2014, technical stakeholder meetings have been held regularly every two to three months and have accomplished several specific objectives including: identifying issues of concern, setting goals, developing indicators to track progress, and conducting public outreach. Information on the Technical Stakeholder meetings (including when and what information was discussed at each meeting) can be found on the RVAH2O.org website under meetings.

The activities of the Technical Stakeholder workgroup have included:

- Determining the overarching goal for the City of Richmond's watershed plan
- Identifying and weighting goals and multiple objectives and strategies
- Meeting bi-monthly to shape the plan's contents and discuss outstanding issues
- Forming partnership agreements that will aid in achieving cleaner water faster

The majority of technical stakeholders have found the meetings to be important opportunities to learn about and discuss watershed issues, and have expressed interest in continuing to meet regularly once the Plan and Permit are in place.

Public Meetings

At the outset of this initiative, a survey of the Richmond public was conducted to establish a baseline of knowledge about Richmond's water systems. It was determined that Richmond residents had limited knowledge about water sources, water quality and their role in helping to keep waterways clean and litter-free. Using RVAH2O as a platform, 2015 was the start of a public outreach effort to lay a foundation of understanding before laddering up to the more technical conversation around watershed integration.

First, a flier was created to illustrate how a household contributes to stormwater pollution. This was widely distributed at libraries, schools, neighborhood meetings, and public events.

Then, a series of posters were created to be put up around the City, each with a theme related to its location: 1) Pet waste poster mounted at dog parks and veterinary offices; 2) Automotive oil poster mounted at service stations and oil-changing stations; 3) Cigarette butt poster mounted at workplaces where people take smoking breaks, etc. In all, six themed posters were created.

An initial public meeting was held in October of 2014. This provided an opportunity for a high-level introduction to the City's regulatory requirements, what has been done to date to address water quality in the City, and the City's goals moving forward. On June 9, 2015, an open house was held at the Science Museum of Virginia to provide opportunity for the general public to be introduced to the City's Integrated Planning process (Figure 2.1). Five different stations were set up, each at which a different topic area was discussed. There were over 50 attendees recorded from the general public. Each station was staffed with members of the RVAH2O team or other DPU staff. This provided a one on one opportunity for the public to ask questions about each station including:

- The watersheds

- The stormwater, sanitary, and wastewater collection systems
- Stormwater issues
- The James River and associated creeks and streams
- Outreach and educational information

A station was also set up at which the public could sit down and anonymously submit questions and comments for the RVAH2O team.

In general, it was observed that attendees expressed knowing little about the river's needs coming in, but by the end, their post-it note comments and comment cards seemed to demonstrate that they had obtained a real grasp of the needs and concerns for water quality in Richmond.

This public open house was deemed a success and in the following year, August 2016 and September 2016, two more open houses were held in local parks (Figure 2.2). Attendance at the first 2016 event was 52; at the second, due to a storm, attendance was less than 10. However, this format for sharing information as the watershed program evolves will continue.

Figure 2.1. Flier advertising the June 9, 2015 community open house

Conducting Public Outreach

While technical stakeholders have been involved during each step of the Clean Water Planning process, the City also recognized the need to conduct a wider public outreach effort related to the City's water resources. The RVAH2O initiative also aims to further educate and identify ways in which the community can be involved in clean water management. The benefits of the effort are two-fold: to help ensure a wider dissemination of information associated with the RVAH2O initiative (integrated water resources planning) as well as to conduct outreach and education related to the City's various water related programs.

Outreach and involvement in association with the Clean Water Planning process are also closely coordinated and consistent with other DPU and City communication programs. For instance, a plan for public outreach and communication will be incorporated as part of the monitoring plan, to achieve the objective of making the monitoring data (historical and current) available to the public. This plan includes a web-based component as well as other print media.

Both online and offline communication strategies make up a Public Outreach Plan that builds awareness and encourages support for the goals of RVAH2O. This effort has also been designed to meet the requirement of the City's VPDES MS4 permit, which is to reach 20% of the City's population in the MS4 area by 2018.

DPU, using RVAH2O as the communications platform, has invited the public to numerous events and shared its water quality message widely through email, social media, the RVAH2O website, billboards, fliers, school education and community meetings. For example:

- Thousands of Richmonders and others were able to fuel themselves with public water at the September 2015 Union Cycliste Internationale (UCI) bike competitions, where eight drinking stations were hooked up to fire hydrants and draped with RVAH2O logo and information.
- At the 2016 Earth Day and Riverrock festivals, DPU employees at an RVAH2O booth greeted nearly 1,100 people personally, passed out literature, and held drawings for rain barrels.
- The first annual Storm Drain Art Contest attracted several dozen entries and drove hundreds of visitors to RVAH2O social media pages; over 450 people voted for their favorite Storm Drain. Each drain selected flows directly into the James River; one of the requirements was that each drain feature a stormwater/pollution message.
    - This contest's art submissions were showcased at Richmond City Hall for one month.
    - The contest received numerous online and print articles, with front page news in the Richmond Times Dispatch on two occasions when the City's mayor toured the drains in July 2016.
    - The project won a national award by the National Association of Clean Water Agencies and Richmond local ad club award, furthering the news coverage.

Figure 2.2. Flier for Watershed Open House public meeting held at a local park

  - A "How-To" flier was created to assist other U.S. municipalities in setting up their own storm drain projects. So far, approximately two dozen communities have requested guidance.
  - The 2017 RVAH2O Storm Drain Art Project has already launched, and storm drains for this annual promotional effort are earmarked through 2020.
- RVAH2O took its message to neighborhood associations and universities, engaging students at VCU and the University of Richmond, some of whom have joined outreach causes.
- RVAH2O representatives have met with the James River Association to help them further their outreach efforts with a storm drain stencil art project. It's anticipated that more collaboration with special interest groups will take place in the future.
- A billboard campaign took place throughout the summer of 2016 in both English and Spanish and will be repeated in 2017 and include bus wraps on routes passing through under-served neighborhoods.
- 100 sets of "James River Pollution and Water Conservation" messages have been printed for bulletin boards in elementary school classes, libraries and community centers.

The Future of Public Outreach

The goals associated with stakeholder involvement and transparency to the public are critical and have been incorporated into this process to ameliorate concerns regarding:

- If progress is being made;
- If limited resources are being expended wisely;
- If benefits are being realized; and,
- If adjustments are being made based on what has been learned.

With a foundation of knowledge about the importance of keeping Richmond's waterways litter-free, Richmond's water sources and systems, and the public's role and responsibility in assuring a cleaner water future, DPU will turn its attention to bringing Richmonders up to speed on the Clean Water Planning process. In late 2017, it will focus more attention on business and civic leaders as well as on partnerships with the technical stakeholders to deliver a unified message to the public.

Tracking process of outreach efforts included (depicted in Figure 2.3):

- Email campaign to "public" attendees
- Flier distributed at Riverrock 2015
- Social media campaign drove up on-line engagement

On Facebook:

- RVAH2O Facebook page likes increased by 8%
- RVAH2O received at least 25 direct event responses and reached 4,967 people through Facebook Ads –on less than a $70 budget

- 45 people joined the event through Facebook (organic and paid)

On Twitter:

- Tweet mentions were up 28.6%.
- RVAH2O followers increased by 14.85%.

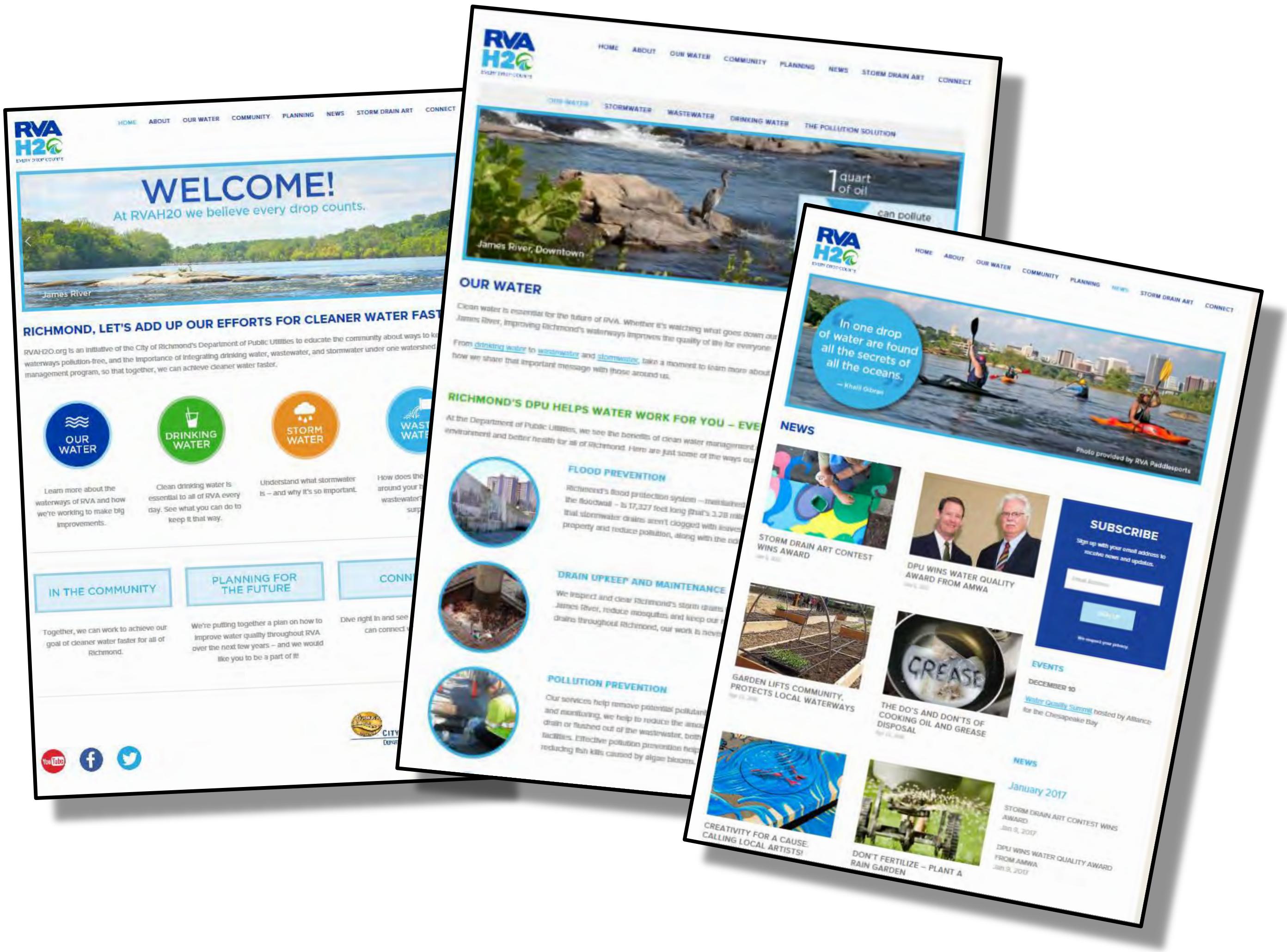


Figure 2.3. Examples of RVAH2O website and Facebook pages.

Stakeholder Partnerships

As discussed further in Chapter 5 (Strategy Identification), DPU is limited in terms of the land and other resources available for strategy implementation. Opportunities to expand strategies will require tapping into the resources from other entities, including other City departments and stakeholder organizations within the City. One way to address this challenge was to create partnerships among the RVAH2O technical stakeholders who have an interest in helping the City implement the goals and objectives that form the basis for the RVA Clean Water Plan.

DPU presented on partnerships at several Technical Stakeholder meetings and discussed ways organizations may wish to partner by making commitments at varying levels of involvement. Examples include participating in the ongoing RVAH2O technical advisory committee, providing volunteer assistance for different types of work (e.g., water quality monitoring, habitat monitoring, tree planting and maintenance), or partnering on larger projects involving land conservation, green infrastructure or stream restoration.


Partnership Opportunities for Implementation
A "Declaration of Cooperation" Approach

RVAH2O Partnership Survey

1. DPU welcomes the opportunity to create partnerships among the RVAH2O technical stakeholders who have an interest in helping the City implement the Goals, Objectives and Strategies that will form the basis for an **Integrated Resources Management Plan**. Organizations may wish to partner by making commitments at varying levels of involvement – such as participating in the ongoing RVAH2O technical advisory committee, providing volunteer assistance for different types of work (e.g., water quality monitoring, habitat monitoring, tree planting and maintenance), or partnering on larger projects involving land conservation, green infrastructure or stream restoration.

For the March 21 RVAH2O Technical Stakeholder Meeting, we would like to discuss different ways that your organizations might envision partnering in the years ahead. Whatever level of detail you're able to provide would be most helpful.

First, please indicate whether you give permission to RVAH2O to share your answers with other stakeholders at the March 21 meeting.

Yes, I give permission on behalf of my organization to share this information with other RVAH2O stakeholders.

No, I do not give permission.

Figure 2.4 Partnership survey circulated to technical stakeholders

A partnership survey was circulated to stakeholders (Figure 2.4) and additional detail on partnership efforts will be documented as these conversations continue over 2017.

3. Watershed and System Characterization

Effective integrated planning and watershed management rely upon identification of the conditions and issues that characterize the watershed. Understanding existing water quality, along with the sources of pollutants or stressors that impact the City's waterbodies, are key elements for developing priority actions to address any existing or potential problems. Characterization of existing collection systems and drainage areas within the City also helps assist in meeting regulatory requirements and implementing other watershed improvements.

Collection of data and characterization of the City's watersheds were the City's first steps towards development of the Clean Water Plan. The City's Watershed Characterization Report (Richmond DPU 2015) includes a detailed discussion of this information. This chapter summarizes this information and highlights how the information and data collected through the effort served as the foundation for subsequent steps of the watershed planning process.

Another key step towards the development of the Plan was the development of a water quantity and quality modeling framework, that incorporates models for the CSO areas, the non-CSO areas (including Richmond's MS4 area), and for the James River itself. The purpose of the modeling framework was to quantify present day bacteria (*E. coli*) concentrations in the James River and to predict future bacteria concentrations under the Clean Water Plan strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. The City's Clean Water Plan Modeling Report (Appendix A) includes a detailed discussion of the model development, calibration, and application.

Regulatory Drivers

To understand how the characterization of the collection systems and the City's watersheds can help assist in meeting regulatory requirements, it is important to first understand the regulatory drivers associated with the design and management of these systems and associated programs. Each of these drivers is discussed further below.

Water Quality Standards (WQS)

The Clean Water Act (CWA) establishes the requirement for states to develop and set WQS (see CWA § 303(c)). Once approved by EPA, the WQS are then to be used for CWA purposes, such as in establishing VPDES permit requirements.

The WQS have three distinct parts:

- A designated use;
- Criteria to protect the designated use (generally referred to as ambient water quality criteria and often expressed as chemical-specific concentration values); and

- An antidegradation policy and implementation method.

The designated uses are established based upon data available and are expected to be consistent with the goals established in § 101 of the CWA.

Virginia's regulations set at a minimum that all waters have these designated uses:

- recreational uses (e.g., swimming and boating);
- propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them;
- wildlife; and
- production of edible and marketable natural resources (e.g., fish and shellfish).

The regulations provide authority to establish more specific subcategories of designated uses, such as for the Chesapeake Bay – "Subcategories of the propagation and growth of a balanced indigenous population of aquatic life, including game fish designated use for waters in the Chesapeake Bay and its tidal tributaries are listed in this subsection."

As noted, water quality criteria are required as part of the WQS and must be established at a level to protect the designated use. Criteria protecting recreational uses rely primarily on fecal indicator bacteria levels to prevent an unacceptable level of illnesses when recreating on or in the water. Criteria for aquatic life uses, such as cold water fishery or areas designated as habitat for specific sensitive species can include temperature, dissolved oxygen, and toxic pollutant limitations designed to ensure healthy populations of organisms that are expected to be present in those areas. Criteria for aquatic life uses may also be based on biological indices. States may designate water bodies for agricultural water supply to ensure that water quality is appropriate for irrigation of crops.

The applicable WQS can be found at:

9VAC25-260
http://leg1.state.va.us/000/lst/h2568263.HTM

The third part of the WQS is the antidegradation policy and its purpose is to protect existing uses and the level of water quality necessary to support these uses, to protect high quality waters, and to provide a transparent analytic process for states and tribes to use to determine whether limited degradation of high quality waters is appropriate and necessary. It is important to note that antidegradation focuses on "existing uses" not "designated uses."

Assessing Water Quality Standard Attainment and Total Maximum Daily Loads (TMDLs)

In addition to addressing state requirements to develop WQS, § 303 of the CWA requires states to periodically assess whether waters are attaining WQS and provide a list to EPA detailing the locations of nonattainment and the suspected reasons for impairments. States submit this list for EPA approval every two years and it is referred to as the "impaired waters list" or 303(d) list. For waters placed on the 303 (d) list, states are also required to develop a TMDL. A TMDL calculates the maximum pollutant load that the water body can receive and still attain WQS. The CWA requires that the "load shall be established at a level necessary to implement the applicable WQS with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality[3].”

The CWA categorizes pollutant sources as either point sources or non-point sources. A point source is defined as any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, or container. Control of point sources is handled primarily through the NPDES permit program, in Virginia it is the state VPDES permit program. In the CWA, point sources are clearly the focal point to be controlled, as the legal prohibition against pollutant discharge without a permit or other specific allowance applies only to point source discharges.

A nonpoint source is not specifically defined in the CWA, but is any source that is not a point source. Typical nonpoint sources include runoff from rural areas, including farming, animal grazing, and timber harvesting. The CWA does not establish a control program for nonpoint sources, as it did for point sources. Nonpoint sources are primarily addressed through voluntary programs that include grant funding as incentive for reducing pollutant loads. Significant differences between the two approaches to source control are problematic, especially in situations involving TMDLs for waterbodies with both point sources and nonpoint sources. In many cases, the focus to achieve pollutant reductions will be on point sources regardless of the load delivered by point sources versus nonpoint sources.

The TMDL establishes a ceiling for the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, natural background sources, seasonal variations, and a margin of safety. EPA has issued numerous guidance documents and policy memos to assist states (and stakeholders) in developing TMDLs, as well as in developing permits and assessing WQS attainment[4].

VPDES WWTP Permit

The City has a VPDES permit for discharges into the James River from the wastewater treatment plant. The permit, issued by the Virginia Department of Environmental Quality, regulates discharges from the WWTP and the CSOs, which serve as relief points in the combined sewer system (CSS). The permit includes effluent limits and monitoring requirements, as well as nine minimum control measures required for the combined sewer system under EPA’s 1994 Combined Sewer Overflow Policy. Development of a Long Term Control Plan (LTCP) for the CSS is also required under this permit.

Richmond’s CSO LTCP involves construction of conveyance systems and retention facilities to help control discharges from the combined sewer system (Richmond DPU 2002). The goals of the LTCP are to correct or minimize the public health, water quality, and aesthetic impact on the James River caused by CSOs.

State Consent Order

Implementation of Richmond’s CSO LTCP is required under a consent order from the State Water Control Board. The consent order was issued in 2005 and includes an implementation schedule and a

[3] See CWA Section 303(d)(1)(C)

[4] Guidance and information on impaired waters and TMDLs can be found at: https://www.epa.gov/tmdl/impaired-waters-and-tmdls-tmdl-information-and-support-documents

description of LTCP projects that will be implemented. These projects were used as the basis for the CSO Infrastructure strategy that is discussed further in Chapter 5.

VPDES General Nutrient Watershed Permit

The General VPDES Watershed Permit Regulation for Total Nitrogen and Total Phosphorus Discharges and Nutrient Trading in the Chesapeake Bay Watershed is also applicable to the City. The City's WWTP has nutrient discharge limits that are established by this permit. These limits were used in the evaluation of the Clean Water Plan strategies (see Chapter 5 for additional discussion).

VPDES MS4 General Permit

The City's MS4 system is authorized to discharge into the James River and its tributaries under a general VPDES permit. The permit requires compliance with TMDL waste load allocations and implementation of minimum control measures, including public education/involvement, illicit discharge detection and elimination, runoff control at construction sites and new developments, and pollution prevention/good housekeeping to the maximum extent practicable.

Watershed Data

As discussed above, the previously developed Watershed Characterization Report compiled a significant amount of information on the following elements that was used to inform the Clean Water Planning process:

- Evaluation of existing geospatial (GIS) data including watershed features
    - Physical and natural features (including topography, soils, hydrology, geology, and land cover)
    - Land use and population characteristics
    - Infrastructure features
    - Wastewater collection system
    - Wastewater treatment system
    - Stormwater system
    - Sensitive areas

- Water quality data
    - Designated uses
    - 303(d) status / TMDLs (water quality issues - identification and characterization of water quality impairments and threats - and WLAs of approved TMDLs)
    - Monitoring programs
    - Water quality data
    - Flow data
    - Biological conditions
    - Pollutant sources
    - Stressors

A summary of some of this key information is discussed below in addition to how it has helped direct the Clean Water Planning process.

Watershed Features

The James River and its tributaries drain a watershed of over 10,000 square miles. Within the City of Richmond, the James River flows for 24 miles, providing a substantial amount of waterfront. Because of its location and access to the waterfront, Richmond was established as a shipping and industrial center. While shipping is still an important function of the river, it also provides passive and active recreation through its waterfront and rapids, and serves as the drinking water source for the City and most of the metropolitan area. Major features in the river include Bosher's Dam, which is located just upstream of the City along the James River, and smaller dams, levees, and pipe crossings within the City. There are multiple locations along the river for swimming, kayaking, and canoeing. These include:

- Huguenot Flatwater – near the crossing of N. Huguenot Road and the James River, this site provides canoes, kayaks, and inner tubes. This is also a popular fishing spot.
- Pony Pasture – a popular swimming and sunbathing area, the site provides access for Class II whitewater boating and fishing.
- Texas Beach – at the end of Texas Avenue, a trail leads to a sandy beach and sunbathing rocks and connects to the Belle Isle Pedestrian Bridge to the east.
- Ancarrow's Landing/Manchester Slave Docks – this is a popular fishing spot and includes boat ramp.
- James River Park – near the crossing of Riverside Road and Hillcrest Road, this location provides the opportunity for Class IV whitewater boating

Just downstream of the City is the Presquile Wildlife Refuge, home to several species of birds and anadromous fish, including the endangered Atlantic sturgeon.

Physical and Natural Features and Land Use Characteristics

There are a number of observations that can be made about the City's watersheds. The western and very northern portions of the City have experienced the least amount of hydrologic modification and possess the lowest intensely developed land use and most forested land cover. These more western areas also correspond with areas with higher soil infiltrative capacity. Alternatively, the eastern portion of the City corresponds with a higher intensity of developed land and industrial land use corridor as well as the City's urban core. Consequently, this area also corresponds to soils that are considered urban and tend to have less infiltration capacity and possesses a topography that includes some considerably steep slopes.

While any project slated for implementation will require a more detailed, site-specific assessment, the watershed-scale analysis in the Watershed Characterization Report provided information that helped guide the selection of high-level strategies. These strategies were created at this larger scale, rather than at a localized or neighborhood scale at which a project would be identified, to allow flexibility in the subsequent stages of integrated planning. For instance, in the assessment of green infrastructure as a strategy, GIS data were evaluated. Given the presence of steep slopes and soils in certain areas of the City that are not conducive to the infiltration necessary for green infrastructure, the total available land for this strategy was reduced by half. This conservative approach to identifying land availability incorporates an inherent flexibility that can allow for inclusion of additional acres into the strategy as more site specific data are collected. Chapter 5 includes additional discussion on strategies identification, Chapter 6 discusses the evaluation and prioritization of these strategies and Chapter 7 discusses implementation.

Infrastructure and Collection Systems

Similar to other older cities, especially in the eastern United States, the City of Richmond is served by both a CSS and a MS4. The distribution of area covered by these systems is shown in Table 3.1 and depicted in Figure 3.1.

Table 3.1. Area located within sewered sections of the City

Sewered Area	Area Served by (acres)
Combined Sewer System	12,000
Separate Sewer System	26,000 (24,500 in MS4; 1,500 in direct drainage)
Total	**38,000**

In dry weather conditions, both sanitary discharges and flows from the CSS are treated by the Richmond WWTP. The capacity of the City's WWTP, which serves approximately 215,000 people, is 45 million gallons per day during dry weather and up to 75 million gallons per day during wet weather. Combined sewer flows during wet weather events which would exceed the plant's capacity can be stored at the Shockoe Retention basin with a capacity of 44 million gallons[5] as well as the Hampton / McCloy CSS retention tunnel with a capacity of seven million gallons. Any remaining wet weather flow volumes are discharged through the City's 26 active CSOs.

The MS4 system, in the remaining portion of the City, includes over 220 miles of pipe, 280 miles of open channel and 50 miles of culverts that discharge stormwater flows at over 1,200 outfalls into receiving waters. Additional discussion of the MS4 area as well as the sanitary and combined sewer systems is included in the City's Watershed Characterization Report (2015).

[5] The basin holds 35 MGD, while in-line storage holds an additional 9 MGD

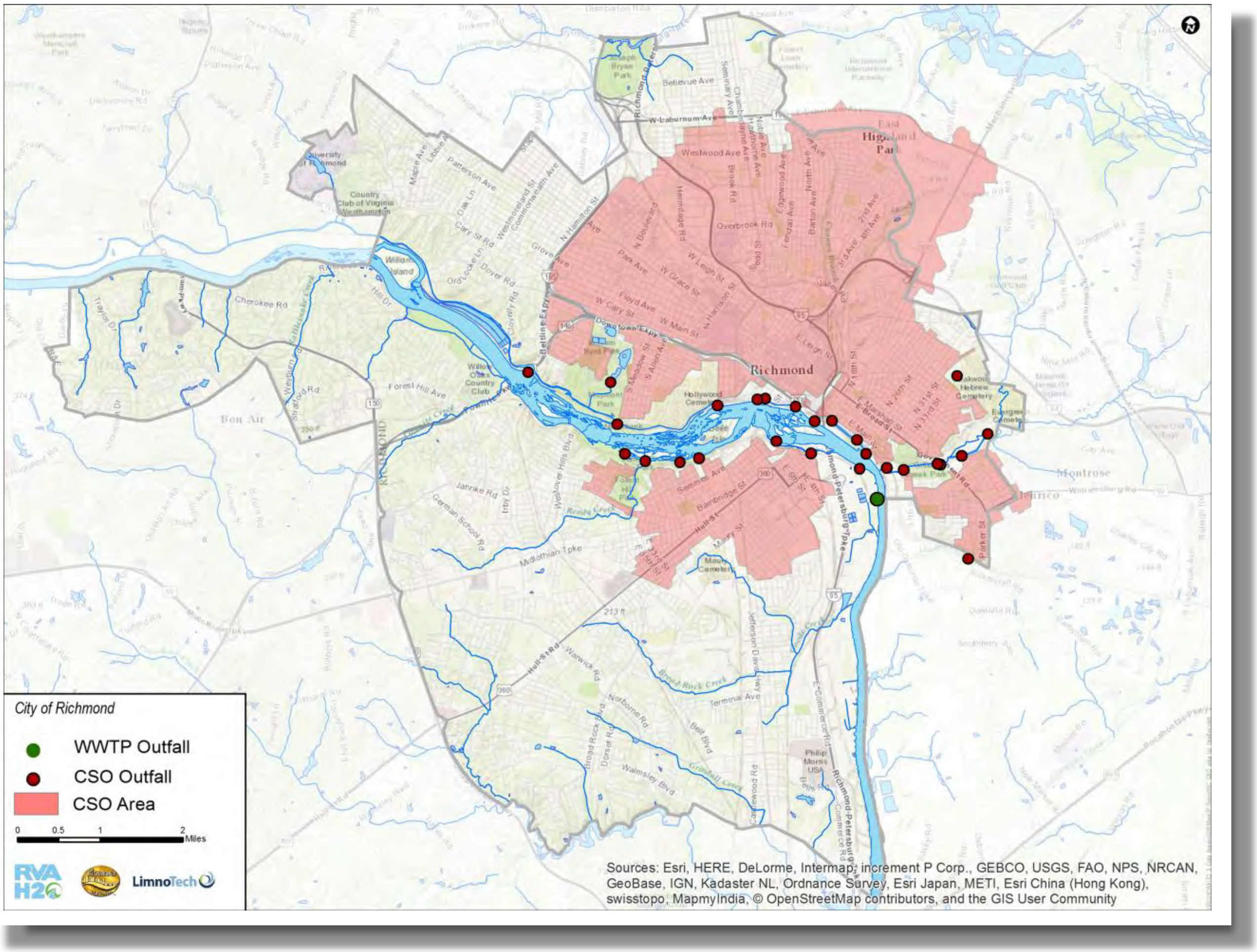


Figure 3.1. Combined sewer overflow area within the City of Richmond and location of CSOs

Understanding these areas within the City, and their associated sources and stressors, were essential to determining the extent to which they were contributing to impairments and the strategies that would be necessary to help the City mitigate these impacts.

Sensitive Areas

EPA's CSO Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) provides a framework for the control of CSO discharges through the NPDES permitting process. This policy establishes the expectation that CSO communities will give the highest priority to the control of CSO discharges within "sensitive areas". The Policy and EPA Combined Sewer Overflows Guidance for Long-Term Control Plans (EPA 832-B-95-002) define sensitive areas as:

- Outstanding National Resource Waters ("Exceptional State Waters" or "Tier III" waters in Virginia)
- National Marine Sanctuaries
- Waters with threatened or endangered species or their designated critical habitat
- Primary contract recreation waters, such as bathing beaches
- Public drinking water intakes or their designated protection areas

- Shellfish beds

While this sensitive area analysis is applicable only to Richmond's CSO area, the data and information provided do help better characterize the City and potential concerns that should be taken into consideration in the development of goals, objectives, and high-level strategies for future implementation.

The City's LTCP discusses how the six criteria for sensitive areas identified in the CSO policy were evaluated for the James River and its tributaries in the vicinity of Richmond's CSO outfalls. No Outstanding National Resource Waters have been designated in the vicinity of Richmond (State of Virginia, 9 VAC 25-260). No National Marine Sanctuaries have been designated within the state of Virginia. Additionally, no commercial shellfish harvesters operate within the area.

The Virginia Department of Conservation & Recreation (DCR) Natural Heritage Program's Database was used to assess the presence of threatened or endangered species in the CSO area of Richmond. The database did not include or indicate the presence of any species on the Federal- or State-listed threatened or endangered species or critical habitat of any species in the CSO area.

Richmond's drinking water intake is on the James River over three miles upstream of the CSO area.

The original LTCP study identified the sensitive areas associated with the City's CSS as the south and north James River Park areas. These two areas are primarily in the vicinity of public contact recreation waters, especially the south side James River Park, which receives a large number of visitors each year, particularly during the summer months. CSOs in these areas discharge into canals and pools which can be slow moving and therefore have limited capability for flushing and diluting pollutants as they progress toward the main channel of the river. For this reason, CSO discharges to these areas exerted significant public health, aesthetic and water quality impacts, although the pollutant loads of these areas are relatively small compared to the total pollutant load for all CSOs in the City.

These issues are all of particular concern with regard to localized bacteria issues, especially in areas where in-stream recreation is common or where the community would like to expand on such in-stream recreational activities in the future.

Water Quality Data

In addition to geographical data, the Watershed Characterization Report included an extensive amount of water quality-related data on the following topics:

- Pollutant sources
- Stressors
- Designated uses
- 303(d) status / TMDLs (water quality issues - identification and characterization of water quality impairments and threats - and WLAs of approved TMDLs)
- Monitoring programs
- Water quality data

- Flow data
- Biological conditions

A summary of some of this key information is also discussed below in addition to how it has helped direct the Clean Water Planning process.

Sources and Stressors of Watershed Impacts

The 2012 Integrated Report GIS data included suspected pollutant sources for each impaired waterbody segment. Common impacts include:

- MS4 discharges
- Combined sewer overflows
- Non-point sources
- Wastewater discharges
- Industrial point source discharges
- Atmospheric deposition (nitrogen, toxics)
- Clean sediments
- Internal nutrient cycling
- Loss of riparian habitat

Waterbody stressors are described as actions or impacts that may adversely affect (apply some form of stress) the ecosystem in some way. Stressors are categorized by whether or not they have an accompanying water quality standard or screening value. Virginia DEQ has identified the following stressors as being most prevalent:

- Biomonitoring Indices (VSCI/CPMI)
- Streambed Sedimentation
- pH below 6
- Habitat Disturbance
- Nickel in Sediment
- Total Phosphorus
- Dissolved Nickel
- Total Nitrogen
- Dissolved Cadmium
- CCU Metals Index
- Mercury in Sediment
- Ionic Strength
- Dissolved Oxygen

Based on the watershed characterization analysis, key regulatory drivers, and additional modeling [discussed further in Appendix A], it was determined that the sources of particular concern include CSOs and MS4 discharges. Other sources, such as clean sediment (from in-stream erosion and scouring) and loss of riparian habitat, were taken into consideration in the development of strategies (see Chapter 5 on Strategy Identification for further discussion).

Again, key regulatory drivers, watershed analysis and modeling also focused the prioritization of stressors on total nitrogen, total phosphorus, total suspended solids, and bacteria. These key pollutants were used as a priority metric for evaluating the effectiveness of strategies in achieving goals and objectives related to water quality improvements.

Existing Water Quality Data

Obtaining sufficient water quality data to assess the status of the City's waterbodies and impacts to these waterbodies is essential to developing an effective Clean Water Plan. As part of the City's

Watershed Characterization process, monitoring data from all available sources were compiled from entities such as Virginia DEQ, local universities, and watershed groups. These data supported the watershed characterization as well as the City's watershed and water quality monitoring (discussed further in Chapter 3). Moving forward, this data assessment can help the City determine how its existing monitoring program may need to be modified or how to better coordinate with local partners to integrate monitoring efforts.

The existing water quality data analysis showed that the number of available samples across data types (water quality sampling, biological sampling, and habitat assessments) are biased heavily towards the James River, with little-to-no data available in tributary streams. Additionally, there is a lack of hydraulic data within the City, with the only local USGS gauges located outside the City limits. Table 3.2 summarizes samples by data type and receiving water category. This table also highlights the dearth of biological samples and habitat assessments.

Dividing the data on a regional basis (watershed groupings discussed in the Watershed Characterization Report) reveals that the majority of available water quality samples were collected in the Lower James CSO and Lower James MS4 watershed groupings, while the majority of biological and habitat samples were collected in the Lower James CSO and the Middle James MS4. Table 3.3 summarizes samples by data type and watershed group.

Table 3.2: Overall Sample/Assessment Counts by Data Type and Receiving Water Category

Data Type	James River	Tributaries
Water Quality	4,759	368
Biological	44	5
Habitat	44	5

Table3.3: Overall Sample/Assessment Counts by Data Type and Watershed Group

Data Type	Lower James CSO	Lower James MS4	Lower James-Chickahominy MS4	Middle James MS4
Water Quality	2,012	2,341	85	689
Biological	30	1	3	15
Habitat	30	1	3	15

Other types of data, such as hydraulic and meteorological samples, are more limited. There are no hydraulic data available within the City limits. While there are two USGS stations within the City limits (James River at Boulevard Bridge [USGS #02037618] and James River at City Locks [USGS #02037705]), neither station has flow data. The two closest USGS gaging stations with daily flow data are James River and Kanawha Canal Near Richmond (USGS #02037000) and James River Near Richmond (USGS #02037500), both of which are located upstream of the city. There is meteorological data available, but there are only two stations within the City (one in the Lower James CSO and another in the Lower James-Chickahominy MS4), both of which provide daily rainfall totals.

The lack of data in certain portions of the City and in the various tributaries emphasized the need for not only the collection of additional monitoring data, but the collection of monitoring data in a more coordinated manner between the City and various partners. Various supporting actions related to monitoring were recommended in association with the development of strategies. Part of supporting actions includes the establishment of a workgroup made up of the City and technical stakeholders to plan and implement an integrated monitoring strategy to identify efficiencies across partner monitoring efforts, coordinate efforts, and facilitate the sharing of data.

Surface Water Quality Issues

As discussed above, all Virginia waters are designated for the following uses:

- Recreation (e.g., swimming and boating);
- Propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them;
- Wildlife; and
- Production of edible and marketable natural resources (e.g., fish and shellfish)[6].

Waterways may also be considered for primary shellfish harvesting status (Richmond DPU 2016).

The City's Watershed Characterization Report (2015) discusses the water quality criteria for the waterways in the Richmond area (Class II Estuarine waters for the tidal James River; Class III Non-tidal waters for the falls of the James and other tributaries).

Impairments to Richmond's waters are discussed further in the 2014 Integrated Report (VDEQ 2016) and are summarized in Table 3.4. Impairments include Chlorophyll-a, *E. coli,* Estuarine Bioassessments, benthic macroinvertebrate bioassessments, dissolved oxygen, PCB in fish tissue, PCB in water column, aquatic plants (macrophytes), pH, chlordane, DDE, DDT, and mercury in fish tissue.

> **Waterbody Impairments**
>
> *If a water body contains more contamination than allowed by water quality standards, it will not support one or more of its designated uses. Such waters have "impaired" water quality. In most cases, a cleanup plan (called a "total maximum daily load") must be developed and implemented to restore impaired waters.*
>
> *- Virginia DEQ*

The TMDLs applicable to the City include the James River bacteria TMDL and the Chesapeake Bay TMDL, which addresses total nitrogen, total phosphorus, and sediments. These TMDLs were identified as the main drivers behind this planning process. When other TMDLs, such as that for PCBs in the James River,

[6] See http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityStandards/DesignatedUses.aspx

are developed, the City will evaluate the need to adjust the Clean Water Plan as part of the adaptive management approach.

Human, Aquatic Life, and Wildlife Health Issues

Several of the City's impaired waters pose health hazards for humans, aquatic life, and wildlife. The issues specifically addressed by this Clean Water Plan are those caused by bacteria, nutrients, and sediments. These are the same pollutants addressed by the TMDLs which will be included in the City's VPDES permit.

The James River (lower and tidal reaches) and several of its tributaries (Almond Creek, Falling Creek, Goode Creek, Powhite Creek, Reedy Creek, Bernards Creek, and Gillies Creek) and Upham Brook (which is a tributary to the Chickahominy River and ultimately the James River) have all been listed as impaired due to *E. coli* levels. These stream segments do not support the primary contact recreation use. The sources of bacteria in these streams within the City limits include CSOs, the MS4, the WWTP, direct discharge of urban runoff, and wildlife. Upstream sources also impact water quality in the City. Upstream sources include livestock, land application of manure, malfunctioning septic systems, illicit discharge of residential waste, other permitted waste treatment facilities. Presence of these bacteria is strongly linked with gastrointestinal illness in recreational users of the waterways. Reducing bacteria levels in these streams is consistent with the City's goal to provide safe recreational opportunities in the river.

While the James River bacteria TMDL addresses near-field water quality issues that must be addressed with localized strategies, the Chesapeake Bay TMDL, which applies to the James River and all its tributaries, sets targets for nutrient and sediment reductions downstream in the Chesapeake Bay. An excess of nutrients (nitrogen and phosphorus) in water can lead to an overgrowth of algae in water, or harmful algal blooms. Algal blooms can produce toxins harmful to humans and animals, create dead zones, and increase drinking water treatment costs for downstream communities. Sediments and algae in the water lead to murky conditions that block sunlight from underwater grasses and create low levels of oxygen for aquatic life. Safe nutrient and sediment levels are needed to maintain safe recreational opportunities and protect aquatic life in the river.

Again, while Richmond's waterbodies have impairments for a number of different pollutants (Table 3.4), the key focus for this Clean Water Plan are bacteria, nutrients, and sediment. Additional discussion of specific targets for these pollutants is included in Chapter 6.

Table 3.4 Impairments of waterbodies within the City of Richmond

River Segment	Segment	HUC Code(s)	Length (miles)	Benthic	Chlorophyll *a*	DO	E. coli	Estuarine Bioassessments	Macrophytes	Mercury	Chlordane	DDE	DDT	PCB	pH
North of the River															
Upham Brook	Flippen Creek to confluence with Chickahominy River	JL18	1.2			X									
Upham Brook	Headwaters to confluence with Chickahominy River	JL18	55.72				X								
Stony Run Creek	Headwaters to mouth of Gillie's Creek	JL01	3.23				X								
Gillie's Creek	Headwaters to mouth of James River	JL01	6.02				X							X	X
South of the River															
Powhite Creek	Headwaters to mouth of James River	JM86	8.05	X			X								
Rattlesnake Creek	Headwaters to mouth of James River	JM86	2.32				X								
Reedy Creek	Headwaters to trib above Roanoke St.	JM86	2.34			X	X								
Reedy Creek	Trib above Roanoke St to Forest Hill Ave.	JM86	0.6												X
Manchester Canal	Manchester Canal	JM86	0.75				X								
Pocoshock Creek	Headwaters to mouth of Falling Creek Reservoir	JL02	8.7				X								
Falling Creek Reservoir	Falling Creek Reservoir	JL02	88.37 (acres)			X	X								
Broad Rock Creek	Headwaters to mouth of Goode's Creek	JL01	3.15				X								
Goode's Creek	Mouth of Broad Rock Creek to confluence with James River	JL01	1.25				X							X	
James River															
James River	Blvd bridge to fall line at Mayo's Bridge	JM86	2.91			X	X			X	X	X	X		
James River	Mayo Bridge to mouth of Appomattox River	JM86, JL01	1.47		X	X	X	X	X						
James River	Big Island Dam to I-95 bridge		13.28											X	

Water Quality Modeling

Water quantity and quality modeling was conducted to allow for longer and continuous periods to be evaluated relative to the water quality monitoring program. Therefore, a key step towards the development of the Clean Water Plan was the development of a water quantity and quality modeling framework. The purpose of the modeling framework is to quantify present day bacteria (E. coli) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the Clean Water Plan strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. The City's Clean Water Plan Modeling Report (Appendix A) includes a detailed discussion of the model development, calibration, and application. A summary of each step is provided here.

Model Development

Three models were used to achieve the modeling objectives, and together they comprise the modeling framework. These three models include:

- A watershed model to simulate flow and bacteria loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system. This model was developed using the EPA SWMM software.
- A collection system model to simulate flow and bacteria loads from the combined sewer system (CSS). The CSS model is an existing model that is used to by the City of Richmond for Wastewater Master Planning, to support implementation of the CSO Long Term Control Plan, and to prepare the Annual CSS Reports. This model was developed using the EPA SWMM software, and was adapted for use in this study.
- A receiving water quality model that computes bacteria concentrations in the James River resulting from the various sources of bacteria to the river. The outputs of the watershed and CSS models are used as inputs to the receiving water quality model. The receiving water quality model was developed using the EPA-supported EFDC software.

Model Calibration

Model calibration is the process of adjusting model parameters and assumptions within defensible ranges to achieve reasonable agreement between modeled and observed environmental conditions. The calibration process demonstrated that the modeling framework is sufficiently well calibrated to support the following modeling objectives:

- Design the modeling framework to provide a reliable and reasonably complete accounting of bacteria sources to the James River;
- Develop the modeling framework using sufficiently complete and accurate site specific data;
- Calibrate the models using reasonable assumptions consistent with the site data, literature, and professional judgment;
- Achieve a level of model accuracy that is adequate to support decision making;

- Apply the models for a period including a wide range of common environmental conditions (i.e. river flow and precipitation conditions); and,
- Evaluate and synthesize model output to interpret major sources of current water quality impairment and to forecast future water quality conditions.

Model Application

After the water quality modeling tools were developed and calibrated, they were jointly applied to assess water quality benefits associated with the selected strategies. For this purpose, the model was applied for a 3-year simulation period that includes a dry year (less than normal precipitation), and average rain year, and a wet year (more than normal precipitation). To date, the model has been applied to evaluate the following conditions or strategies:

- Current conditions: Best representation of current conditions, and includes all the Phase I and Phase II CSO improvements from the CSO Long Term Control Plan (LTCP).
- Baseline Conditions: represents the current conditions, plus all the currently funded Phase III collection system improvement projects from the LTCP.
- Green Infrastructure in the MS4 area Strategy: represents the baseline conditions, plus the implementation of 104 acres of green infrastructure on city-owned area in the MS4.
- Green Infrastructure in CSS area Strategy: represents the baseline conditions, plus the implementation of 18 acres of green infrastructure on city-owned area in the CSS area.
- CSS Infrastructure Strategy: Implementation of CSS projects included in the LTCP: represents the baseline conditions, plus all the remaining unfunded Phase III collection system improvement projects from the LTCP.

These strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges, expressed as billion CFU per year
- Percent increase in monthly geomean water quality standard compliance in the James River at the downstream city limit
- Reduction in number of CSO events per year
- Reduction in CSO volume, expressed as million gallons per year

These water quality benefits were then entered into a calculator tool that integrates the benefits of strategies across a wide range of Goals and Objectives, as further explained in the next chapter. Water quality benefits were also assessed relative to the two existing water quality standards: a monthly geometric mean standard and a statistical threshold value (STV) standard.

Assessing Current Conditions

The Clean Water Plan Modeling Framework was applied to better understand the sources and impacts of bacteria in the James River. The main metrics evaluated by the model include average bacteria loads entering the river from the main sources, *E.coli* concentration in the James River and comparison to the water quality standards, number of CSO discharge events, and CSO discharge volume.

An evaluation of current conditions helped assess the impact of the five major sources of bacteria in Richmond (upstream, CSO, stormwater, background, and WWTP sources), and how each contributes to water quality standard exceedances relative to the other sources. Figure 3.2 graphically shows these results for both the monthly geomean and statistical threshold value (STV) standard. The model results illustrate that the James River is in violation of both the geometric mean and the statistical threshold value water quality criteria for some months out of the three year model simulation period, and the primary cause of a water quality criteria violation can sometimes be linked to Richmond's combined sewer overflows, while at other times it is due to upstream sources coming in from outside of the City. Background (mainly wildlife) and stormwater sources play a smaller overall role in the bacteria water quality violations. The WWTP does not contribute significantly to bacteria water quality violations.

Because the model shows that Richmond's CSOs contribute in large part to the bacteria water quality criteria exceedances, this information was used to support the prioritization of strategies, such as CSO infrastructure, to address this source. Figure 3.3 shows the relative volume of CSO discharges at the CSO outfalls (based on data from 2004 to 2016), and may present potential opportunities for targeting specific CSO discharge points.

Other important metrics evaluated by the model are shown below in Table 3.5.

Table 3.5 Model Output for Current Conditions

Model Output	Model Value
Average yearly E.coli load (billion cfu)	9.65E6
Average annual number of CSO events	53
Average yearly CSO volume discharged (million gallons)	1,670

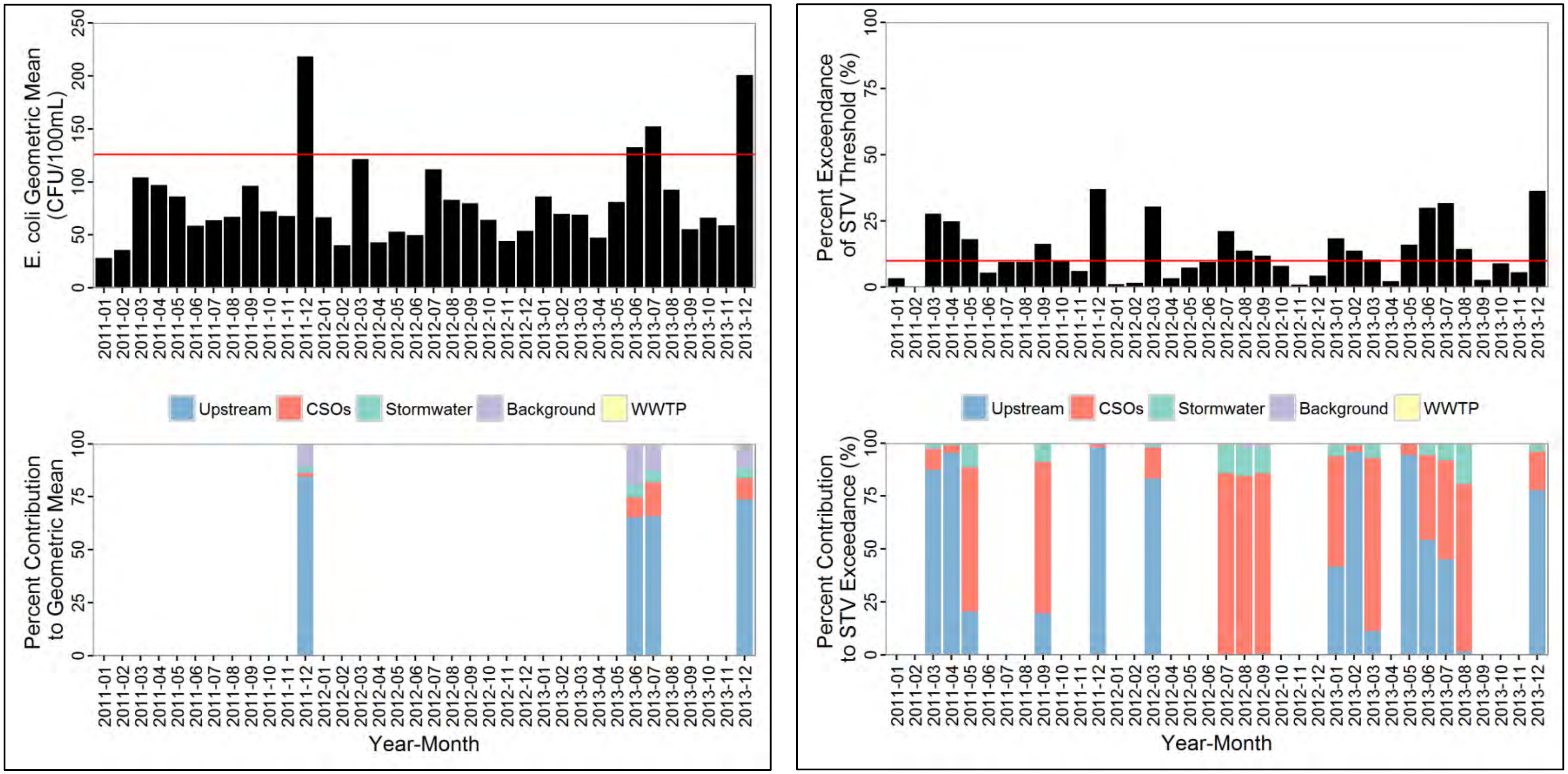


Figure 3.2. E.coli Monthly Geometric Mean and STV Standard Model Results for Current Conditions

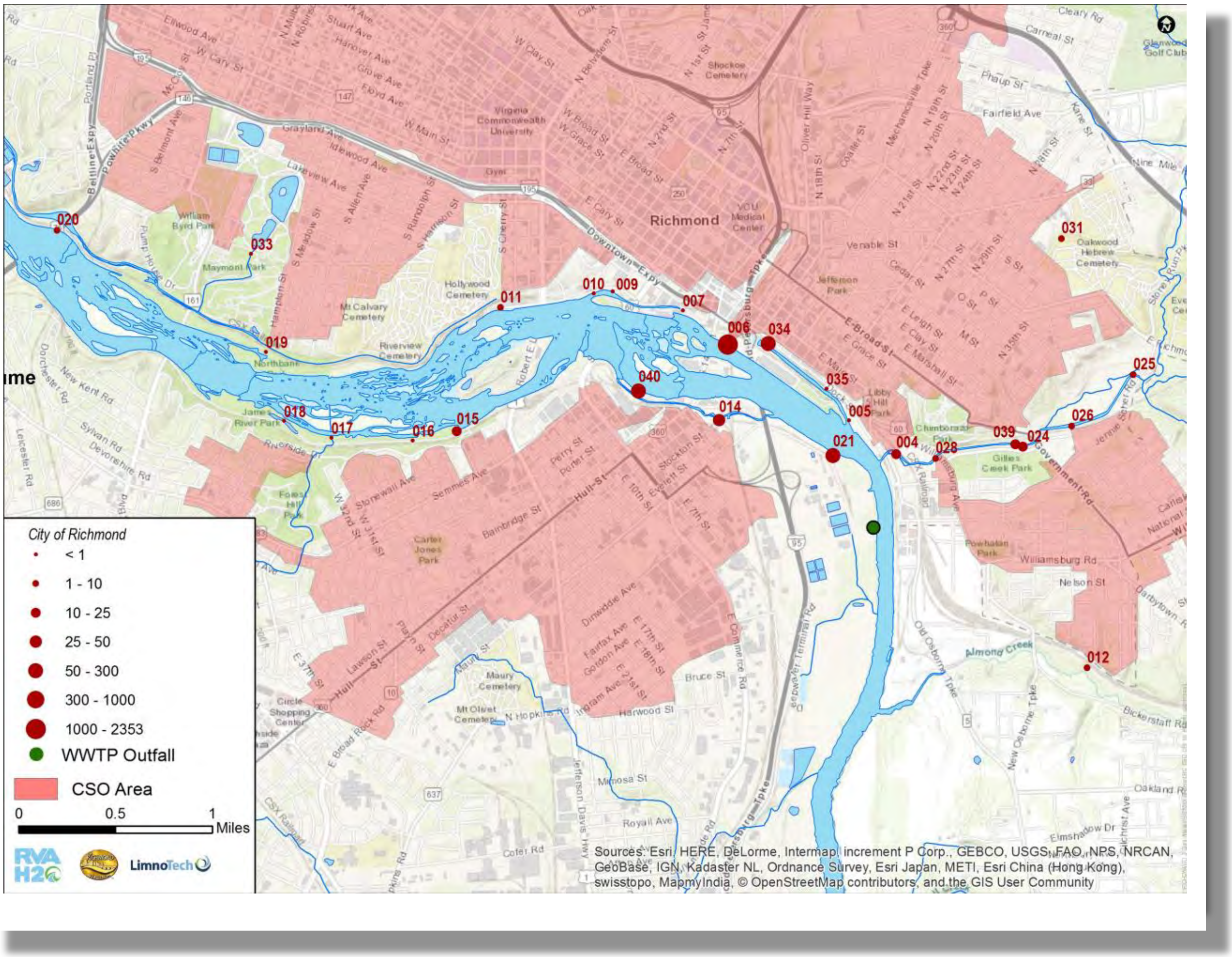


Figure 3.3. CSO Overflow volume by CSO outfall (million gallons/year)

Additional information on the modeling results can be found in Appendix A.

4. Goals & Objectives Selection

Traditional integrated planning efforts tend to focus on meeting infrastructure goals, such as reduction in the number of CSOs. The City's Clean Water Plan, however, is built around a watershed framework that accounts for the City's collective water needs and requirements (including, but not limited, to infrastructure) while considering watershed characteristics. While DPU's understanding of these needs and requirements provide a starting point for establishing the goals and objectives of the Clean Water Plan, DPU recognized that stakeholder input would also be critical to fully capturing the desired direction and outcome of the Plan. This process included not only extensive stakeholder feedback to develop the goals/objectives, but included a weighting process to assign a degree of relative importance of these goals/objectives to one another. The goals, objectives, and respective weights are summarized in Table 4.1 and the approach used to develop this is described below.

Table 4.1 Clean Water Plan goals and objectives with associated weights

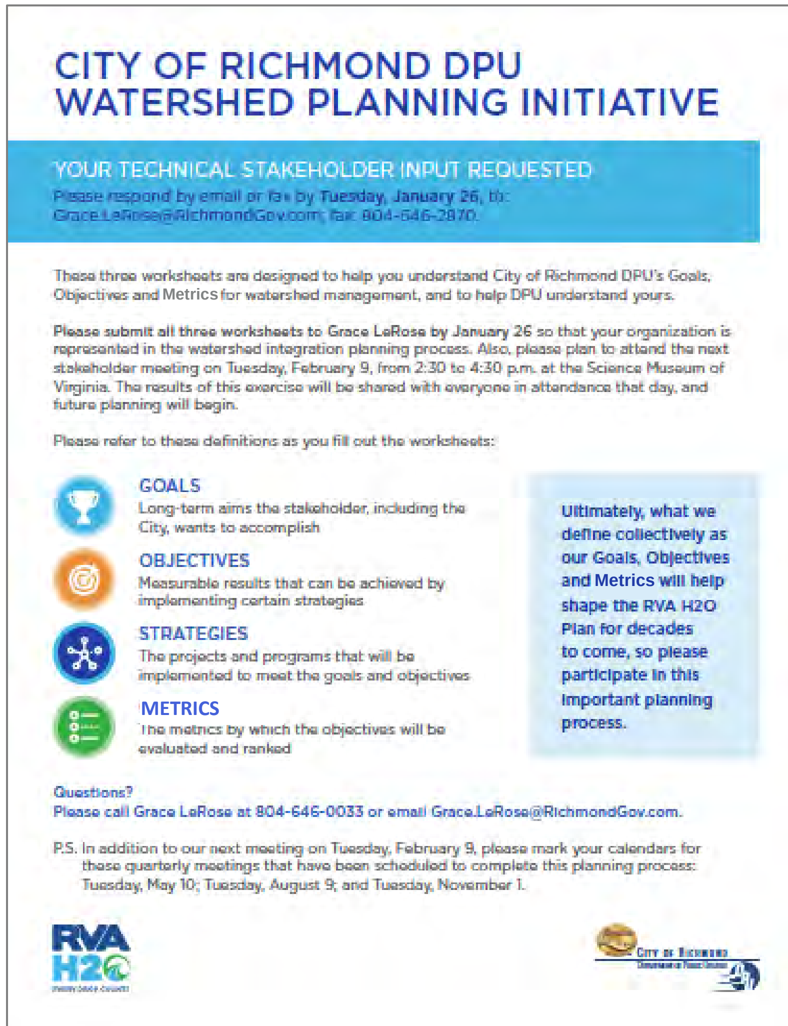
Goals (with weights)	Objectives	Weights
19%: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.	Develop one stormwater management plan to cover the City's four watershed groupings based on the City's watershed characterization report	19%
	Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL)	18%
	Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards)	18%
	Reduce toxics (e.g., mercury, PAHs, PCBs), trash and other pollutants and address TMDLs for these pollutants	17%
	Develop green infrastructure, including riparian buffers, and removal of impervious surfaces on development, existing development, and redevelopment	27%
15%: Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities	Restore streams to improve, restore, and enhance native ecological communities	25%
	Identify, protect, and restore critical habitats	36%
	Enhance aquatic and terrestrial habitat connectivity	23%
	Investigate, and where feasible, promote actions that might surpass regulatory requirements	16%
14%: Engage and educate the public to share responsibility and take action on achieving healthy watersheds.	Engage and efficiently educate the public about standards, processes, and actions associated with watershed health and public health	25%
	Assist in the education of citizens about overall water quality issues, benefits of improved water quality	30%
	Support and encourage local action to improve water quality	24%
	Provide quicker public notifications of spills or pollution from regulators or other "river watchers"	21%
12%: Implement land conservation and restoration and incorporate these into	Protect, restore, and increase riparian buffers	21%
	Reduce impervious surfaces	19%
	Increase natural land cover with a focus on preserving, maintaining, and increasing tree canopy	24%

planning practices to improve water quality.	Incorporate green infrastructure in new development and redevelopment	18%
	Conserve lands where possible and consistent with Richmond's Comprehensive Plan	18%
11%: Create partnerships across the watersheds internal and external to the City of Richmond to maximize benefits and minimize impacts to all stakeholders	Develop and implement a source water prevention plan/strategy	33%
	Establish public-private partnerships to secure funding, implement strategies and projects, and to achieve plan goals	40%
	Maintain and expand the RVAH20 group	27%
10%: Maximize water availability through efficient management of potable, storm, and wastewater.	Reduce use of potable water for industry and irrigation	39%
	Achieve water conservation by improving the existing water conveyance system	30%
	Achieve water conservation by incentivizing upgrades to end-user water fixtures where appropriate	31%
9%: Provide safe, accessible, and ecologically sustainable water-related recreational opportunities for all.	Improve water quality to promote safe recreation consistent with the City's Riverfront Plan	36%
	Promote ecologically sustainable management of riverfront and riparian areas	40%
	Improve river and waterfront access for recreation	24%
9%: Work collaboratively to gather consistent high-quality data to characterize the status and trends of water resources and to gauge the effectiveness of restoration efforts.	Conduct water quality and biological monitoring	28%
	Provide timely water quality information	19%
	Collaborate with citizens and local/state agencies for coordinated monitoring	23%
	Utilize results to target restoration efforts and convey progress	30%

Establishing Goals & Objectives

The first step of the Clean Water Planning process was determining the direction in which the City and its stakeholders wished to take this effort. To accomplish this, goals and objectives were selected through an extensive stakeholder communications process. The watershed characterization efforts, described in Chapter 3, were used as a basis for understanding the City's watershed features, water quality, and any issues of concern within the watersheds. While this helped inform the City and stakeholders, the selection of overarching goals, refined goals, and objectives was also influenced by the mission of stakeholder organizations or City department as well as stakeholder's additional first-hand knowledge of local issues.

To account for the multiple opinions and perspectives that were anticipated, the City implemented a multi-step process to form consolidated lists of overarching goals, refined goals, and objectives. The first step in this process was to survey stakeholders (Figure 4.1). The City requested that stakeholders submit what they felt were appropriate overarching goals, refined goals, objectives, and metrics (discussed further in Chapter 6) based on definitions and guidance on what these terms included.



CITY OF RICHMOND DPU
WATERSHED PLANNING INITIATIVE

YOUR TECHNICAL STAKEHOLDER INPUT REQUESTED

Please respond by email or fax by **Tuesday, January 26**, to: Grace.LeRose@RichmondGov.com; fax: 804-646-2870.

These three worksheets are designed to help you understand City of Richmond DPU's Goals, Objectives and Metrics for watershed management, and to help DPU understand yours.

Please submit all three worksheets to Grace LeRose by January 26 so that your organization is represented in the watershed integration planning process. Also, please plan to attend the next stakeholder meeting on Tuesday, February 9, from 2:30 to 4:30 p.m. at the Science Museum of Virginia. The results of this exercise will be shared with everyone in attendance that day, and future planning will begin.

Please refer to these definitions as you fill out the worksheets:

GOALS
Long-term aims the stakeholder, including the City, wants to accomplish

OBJECTIVES
Measurable results that can be achieved by implementing certain strategies

STRATEGIES
The projects and programs that will be implemented to meet the goals and objectives

METRICS
The metrics by which the objectives will be evaluated and ranked

Ultimately, what we define collectively as our Goals, Objectives and Metrics will help shape the RVA H2O Plan for decades to come, so please participate in this important planning process.

Questions?
Please call Grace LeRose at 804-646-0033 or email Grace.LeRose@RichmondGov.com.

P.S. In addition to our next meeting on Tuesday, February 9, please mark your calendars for these quarterly meetings that have been scheduled to complete this planning process: Tuesday, May 10; Tuesday, August 9; and Tuesday, November 1.

RVA H2O

Figure 4.1. Guidance provided to technical stakeholder to support the gathering of input on goals, objectives, and metrics.

Fifteen stakeholders provided input through responding to the request. Given the large amount of feedback to discuss, the City addressed the discussion of overarching goals and refined goals during the February, 2015 meeting and objectives during the May, 2015 meeting.

Prior to the February meeting, the City evaluated all of these submissions and identified a number of themes. It was important to the City that no feedback was lost in this process, so all input was incorporated verbatim into one of these themes:

Overarching Goal Themes:

- Collaboration
- Water consumption
- Preservation and restoration
- Water quality

Refined Goal Themes:

- Recreation
- Aquatic and riparian habitat
- Stormwater peak flows
- Pollution
- Land conservation and management
- Partnerships
- Monitoring
- Public engagement & action
- Water conservation

At the stakeholder meetings, attendees were broken into small groups with each group being provided one of these themes and its associated goals. Each small group was then asked to combine and synthesize the items within that theme. Goals could be combined, reworded, or moved to another goal topic area. Goals could also be re-categorized as an objective or a strategy if deemed more appropriate. Ultimately, one goal was developed for each topic area.

A similar approach was taken in developing a refined list of objectives. Stakeholders provided objectives associated with each of the proposed goals. Stakeholders then refined these objectives so there were between one and six objectives associated with each of the refined goals.

Striving for Consensus

A number of opinions and viewpoints were represented through the stakeholder process. While the City felt it was important for the Clean Water Planning process to reflect these views, it was also important for the process to move forward in a timely manner. To accomplish this, the City strived to reach consensus on each of the steps of this process and the associated decisions made.

The goal behind *striving* for consensus is that everyone will be able to live with and support the idea or issue, or, at least, no one opposes it. If the group was not able to support an element of the issue/item up for discussion, additional discussion was deemed necessary.

While stakeholders were a key part of the process for identifying goals and objectives, they did represent many different groups with interests in the City. To ensure stakeholders all shared the same amount of influence during this process, each interest group was allowed one member at the table who could participate (i.e., vote) in the consensus process.

As shown in Figure 4.2, each voting stakeholder could select either “1”, “2”, or “3” to represent their level of agreement with a particular goal or objective being discussed. If any stakeholder selected “1”, then the topic was discussed further until the stakeholder agreed, the item for discussion was modified so that all stakeholders could at least live with the decision, or the item/topic was removed from the options moving forward.

Ultimately, stakeholders achieved consensus on the overarching goal, refined goals, and objectives.

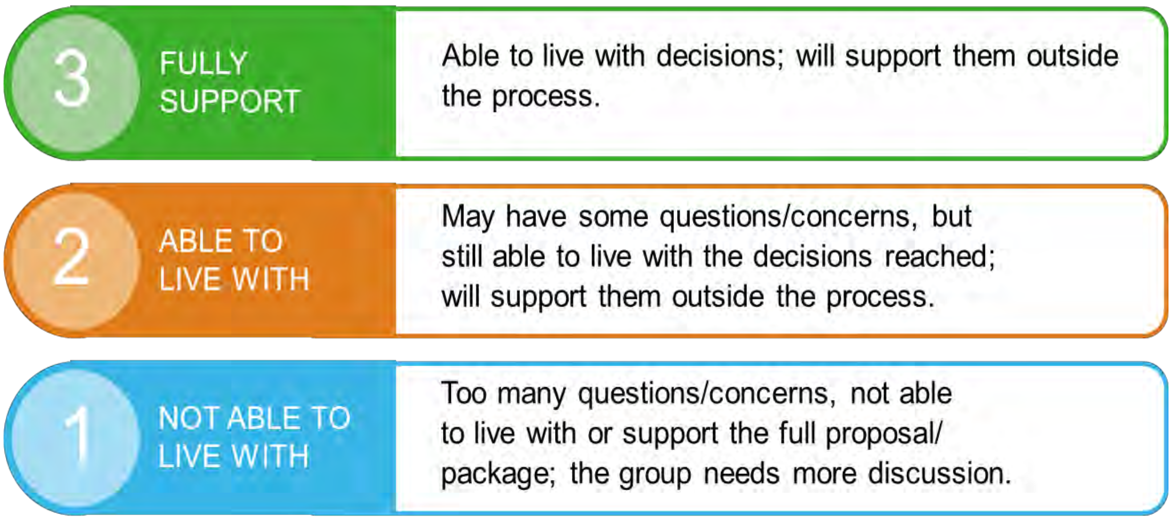


Figure 4.2 Consensus voting process for the Clean Water Plan

Prioritizing through Weighting

Weighting was incorporated into this process to reflect the priorities of the City and its stakeholders. This weighting process not only allowed for an understanding of how one goal or objective ranked in relation to another, it also provided information on the extent of the importance of these priorities to one other.

Weighting included the process of assigning a portion of 100 points to each of the items in a grouping. As shown in the example in Table 4.2, 100 points are apportioned across a grouping of refined goals. In this example, refined goal #2 was given the highest priority, with 50 points. One or more objectives were assigned to each refined goal. Each grouping of objectives

Table 4.2 Example weighting process

Refined Goals	Weight	Objectives	Weight	
Refined goal #1	15	Objective #1	50	Total: 100
		Objective #2	30	
		Objective #3	10	
		Objective #4	10	
Refined goal #2	50	Objective #1	10	Total: 100
		Objective #2	60	
		Objective #3	30	
Refined goal #3	30	Objective #1	40	Total: 100
		Objective #2	60	
Refined goal #4	5	Objective #1	20	Total: 100
		Objective #2	40	
		Objective #3	10	
		Objective #4	30	
Total:	**100**			

was also given a proportion of 100 total points.

The result of this process was a prioritization of refined goals as well as a prioritization of objectives associated with each of these goals.

Once the goals and objectives were finalized by the City and its stakeholders, Surveymonkey.com was used to circulate a questionnaire to each stakeholder organization to obtain their opinion on the weights of each goal and objective. The weights provided by each stakeholder organization were then averaged to produce a weight for each refined goal and for each objective. These averaged weights were presented and discussed at a technical stakeholder meeting. Stakeholders were allowed to suggest modifications to the weights of the goals or objectives as long as the overall ranking of these weights remained the same. Using the example in Table 4.1, while the order of the refined goals must remain #2, #3, #1, and #4, stakeholders might collectively decide that refined goal #3 should be 38 points, while refined goal #2 should be changed to 42 points.

5. Strategy Identification

The next step in this process was the identification of strategies that can be expected to achieve the previously identified goals and objectives. Strategies were defined as activities, actions, or items that will help meet goals and objectives. The process that was used to develop the strategies is discussed below.

Brainstorming Potential Strategies

Implementation of projects and programs that may benefit the City's water resources are undertaken by numerous departments within the City as well as other entities, such as local universities, watershed organizations, or private developers. While the City can coordinate or partner with these entities to implement such efforts (as was discussed in Chapter 2), DPU recognized that the starting point in determining a list of strategies for the Clean Water Plan was determining what projects and programs the Department could implement and maintain itself.

> ### Strategies vs. Projects
>
> *The Clean Water Plan-related planning is occurring at the sub-watershed to the City-scale. As such, projects or programs at a finer scale needed to be "rolled up", or grouped, to produce a higher level strategy.*

The first step in brainstorming potential strategies included a workshop for DPU staff involved in stormwater, wastewater, and CSO-related projects. Staff compiled a list of projects that had been identified or proposed to meet various programmatic needs. Because the Clean Water Plan would be implemented during the next VPDES permit cycle (beginning in June of 2018), any project that would be funded, initiated, or implemented prior to this date was removed from the list. The resulting list included the remaining potential projects that could be implemented over the next VPDES permit cycle (2018 through 2023). City staff also brainstormed other ideas, such as opportunities for expanding existing efforts like the residential stormwater credit process, to help increase implementation.

It is important to note, however, that the initial stages of the Clean Water Planning process is being developed at a high-level scale (sub-watershed, watershed, to City-scale). Because many of these projects impact small-scale areas, these City projects were "rolled up" to a strategy scale where necessary. For example, several bioretention or permeable paving projects were rolled up, or grouped, into a Green Infrastructure strategy.

In addition to these DPU projects, stakeholders were also asked to submit suggestions for strategies that they felt would achieve the agreed upon goals and objectives. Numerous ideas were gathered with varying levels of detail. Because there were a number of distinct themes to these suggested strategies, the Clean Water Plan development team created a synthesized set of draft strategies that consolidated ideas put forth by both stakeholders and DPU staff.

It was determined that a number of the ideas put forth, while important, were not strategies in and of themselves. A number of these ideas could also be tied to more than one strategy. These ideas were defined as "supporting actions". Supporting actions include efforts that may broaden the main strategy, add specificity on how a strategy could be implemented, or identify additional resources and data needs to fully implement the main strategy. These supporting actions are not necessarily quantifiable in and of themselves and may be components of multiple main strategies. Actions, such as those related to partnerships, may also involve activities on non-City property and rely on resources that are outside the DPU's authority.

Supporting actions include:

- Partnerships – establishing partners to facilitate a greater level of future implementation of projects and programs (partners include those within the City, such as the Department of Public Works (DPW), as well as with non-City agencies, such as watershed groups)
- Maintenance – including resources and funding to ensure a strategy will continue to meet its intended objectives
- Monitoring, Assessment & Planning – gathering data and information and using these results to help guide and implement future implementation
- Incentives/Credits – evaluating and implementing mechanisms to incentivize new initiatives or higher levels of future implementation
- Regulations/Ordinances/Codes – analyzing and modifying, if necessary, the framework within which implementation will occur
- Outreach – including ways to potentially expand upon future implementation by conveying information on resources available or ways for partners and the public support a strategy

Some of these Supporting Actions are specific to a particular strategy, but others, such as some related to monitoring or public outreach, cut across various strategies.

Strategy Feasibility

Once the draft set of strategies was identified, it was important to determine if these strategies were feasible. Because DPU is ultimately responsible for implementation of the Clean Water Planning program, the feasibility of strategies was defined as efforts that DPU has the authority to implement. For instance, a strategy could be identified as infeasible if it requires implementation on land not owned by the City, and where it is not possible for the City to purchase or obtain the land in some way.

Because the City's Parks, Recreation, and Community Facilities (PRCF) Department works so closely with DPU and shares similar departmental objectives for project implementation and maintenance, PRCF land was also considered to be available for the feasible implementation of a strategy.

Feasibility also takes into account the potential limitations on strategy implementation due to physical constraints such as steep slopes or soils with poor infiltration that are unsuitable for some strategies such as green infrastructure. Therefore, the acreage included in the strategies reflects a portion of DPU/PRCF in the City that is appropriate for that particular strategy. For example, based on an evaluation of slopes and soils GIS data and best professional judgement, a decision was made to conservatively include 50% of the total DPU and PRCF lands within the Green Infrastructure Strategy in both the MS4 and CSS areas. Details on assumptions made for each of the strategies is included in Appendix B.

Final Strategies

Once feasibility was evaluated, final draft strategies and supporting actions were presented to stakeholders who were given the opportunity to edit them further. Once all feedback was incorporated, a final set of strategies and supporting actions was presented to the stakeholders for a consensus vote.

Each of the strategies referenced in the remainder of the Clean Water Plan are considered to be "feasible" and agreed upon by the Technical Stakeholder group (Table 5.1).

Table 5.1. Strategies and associated details

Strategy	Strategy Details
Riparian Areas	Replace or restore 10 acres of riparian buffers according to state guidance. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Green Infrastructure in MS4	Install or retrofit GI draining 104 acres of impervious surfaces, including efforts such as: • 30 acres on DPU property • 18 acres on City-owned vacant properties • 20 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 100 trees in tree boxes (e.g., Filtera-type practices); 30 acres total drained to this practice • Retrofit 4 DPU stormwater BMPs (e.g., dry ponds to more efficient BMPs), draining at least 6 acres of impervious surface
Green Infrastructure in CSS	Install or retrofit GI draining 18 acres of impervious surfaces, including efforts such as: • 6 acres on DPU property • 2 acres on City-owned vacant properties • 2 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 24 trees in tree boxes (e.g., Filtera-type practices); 8 acres total drained to this practice
Stream Restoration	Restore 2,500 linear feet of stream: • Through removal of concrete channels, repair of incised banks, etc. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Natives/Invasives	Use 80% native plants in new landscaping at public facilities by 2023.
Trees	• Increase tree canopy on City property by 5% (80 acres added) • Protect existing tree canopy by following maintenance addressed in the Tree Planting Master Plan
Land Conservation	Place an additional 10 acres under conservation easement, prioritizing conservation of land that creates connected green corridors. • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Water Conservation	Reduce water consumption by 10% through implementation of new water conservation technologies and promotion of water conservation efforts, including: • Installing water-efficient fixtures as a policy by 2023 in all new public facility construction • Implementing incentive programs

	• Encouraging water conservation on City properties
Pollution Identification and Reduction	Reduce contribution of pollutants to the MS4 through: • Conducting at least 1 special study per year in hot spot areas to identify illicit discharges/connections. (Studies will meet the criteria necessary to achieve Bay TMDL pollutant reduction requirements. Assume that, over 5 years, 3 of these studies will result in pollutant reductions that meet Bay TMDL requirements.) • Collecting data associated with non-structural BMPs to facilitate quantification of pollutant reduction (e.g., storm drain clean-outs, pet waste stations, street sweeping)
CSS Infrastructure	LTCP projects, including: • Installing wet weather interceptor to convey more flow to the WWTP • Increasing WWT to 300 MGD at the treatment plant • Expanding secondary treatment at the WWTP to 85 MGD • Expanding Shockoe retention basin by 15 MG to capture more overflow • Disinfecting overflow at Shockoe retention basin (wet weather disinfection facility) *Note that that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost.*

Table 5.2 includes the final, agreed upon supporting actions for the strategies.

Table 5.2. Supporting Actions associated with the various strategies

Supporting Actions	Details
Partnerships	Restore 20 acres of riparian buffers on private properties through efforts such as: • Purchases of land • Partnerships with residents: Promote program for buffers on private properties (include tiers of level of involvement – (1) maintenance agreement with City, (2) conservation agreement/ easement.) • Partnerships with Master Naturalists to enlist their support for assistance with riparian restoration.
	Implement 10 acres of GI on private property
	Implement 5 acres of GI on DPW property (rights of way, roadways, green alleys) through efforts such as: • Adopt a rain garden program – coordinate with residents, non-profits, commercial entities • Partnering with the City's community garden program to identify 0.5 acres of area for additional GI implementation • Partnering with Public Works to ensure City greenways include GI
	Develop a program to encourage the use of native plants in private landscaping – sign up 20 private landscapers.
	Initiate an Adopt a Lot program (10 lots with invasive species removed, replanted and maintained)
	Partner with organizations such as the James River Park System Invasive Plant Task Force to better determine areas with significant invasive species issues and identify resources to deal with the problem.
	Partner with the public and other stakeholders, such as the Richmond Tree Stewards, to plant and maintain trees on public properties.

	Promote requests for stream restoration by private landowners and streamline the process by which these requests are addressed.
	Hire DPU staff member or assign 1 FTE to coordinate volunteers from corporate entities, watershed/environmental groups and public with partnership opportunities associated with the IP effort. Staff to enlist/maintain 6 partnerships per year.
	Hold 3 stakeholder meetings per year to continue communication with partners/stakeholders and add purpose to the IP effort.
	Evaluate partnership network in 5 years (at the end of the permit cycle) to assess gaps and identify new public/private partners.
	Partner with the public and other stakeholders to identify land to put in conservation easements.
	Partner with the Richmond Redevelopment and Housing Authority to identify homes/properties that are eligible for upgrades to water-efficient fixtures.
	Partner with upstream localities and Virginia Department of Health to update/maintain Source Water Protection Plan.
Maintenance	Include funding to support maintenance of newly replanted/restored riparian buffers (to ensure success of plantings, prevention of establishment of invasive species, etc.).
	Include funding to support maintenance of newly planted native plants and maintain newly established plantings where invasives have been removed from the landscape.
	Provide funding to support maintenance of trees on City property to ensure their survival and health.
Monitoring, Assessments & Planning	Inventory and map riparian areas to better understand loss or growth of riparian buffers.
	Inventory and map locations of trees and tree boxes to better understand loss or growth of tree coverage.
	Continue monitoring of 8 locations across the City for macroinvertebrate, habitat and in-stream water quality. Continue monitoring at 2 locations for flow. Evaluate opportunities to expand the flow monitoring network across the City.
	Evaluate the development of a monitoring data portal to facilitate sharing of data collected within the City with stakeholders and the public.
	Initiate monitoring work group in year one made up of technical stakeholders and other key groups/individuals to evaluate current monitoring efforts and identify potential efficiencies and additional monitoring needs moving forward.
	Evaluate potential for conducting pre- and post-construction monitoring of key stormwater BMPs.
	Conduct assessments of 4 stream segments across the 4 watershed groupings to support the development of watershed restoration plans to address pollutant sources and watershed stressors.
	Monitor growth/expansion of invasive species.
	Implement IDDE-related monitoring to support this effort – supported by a desktop analysis of high-risk dischargers.
Incentives/ credits	Reevaluate the stormwater credit program to determine potential to include practices such as replacing or restoring riparian buffers.
	Evaluate incentives/credits for purchasing/planting native species (such as Montgomery County, MD).
	Reevaluate the stormwater credit program to determine potential to include practices such as

	planting trees on private property. Provide 500 trees for planting on private property or equivalent incentives to purchase native trees.
	Offer grants to replace 20% of inefficient fixtures in moderate- to low-income units Evaluate expansion of incentive program to cover washing machines and dishwashers
Regulations/ ordinances/ codes	Evaluate expanding the regulatory buffer from 100 ft. to 200 ft.
	Evaluate inclusion of language in City zoning and planning-related ordinances to protect existing trees and add new trees on developed property.
	Adopt permitting standards for water-efficient appliances/fixtures in City code.
Outreach	Conduct outreach to educate the general public about the goals and objectives of RVAH2O, and the resources and services available through the City.
	Conduct outreach to advertise the resources, requirements and services available through the City related to green infrastructure for private property owners.
	Conduct outreach to advertise the resources, requirements and services available through City related to tree planting and maintenance.
	Promote ability to use grey water for toilet flushing as a way to achieve higher LEED standards
	Encourage and incentivize water capture and reuse for landscaping
	Promote water conservation for commercial, industrial and residential customers through efforts such as "Fix a Leak Week" and the City's Every Drop Counts initiative.
	Conduct targeted outreach to high-risk industries, particularly in areas of the City identified as hot spots.

6. Strategy Evaluation

Once strategies were drafted, an analysis was needed to determine which ones would be best for implementation. Figure 6.1 provides an overview of the multi-step strategy evaluation process that was used to make this determination. This process constrains proposed strategies by feasibility, relative achievement of goals/objectives, compliance with permit and regulatory drivers, and cost-related factors.

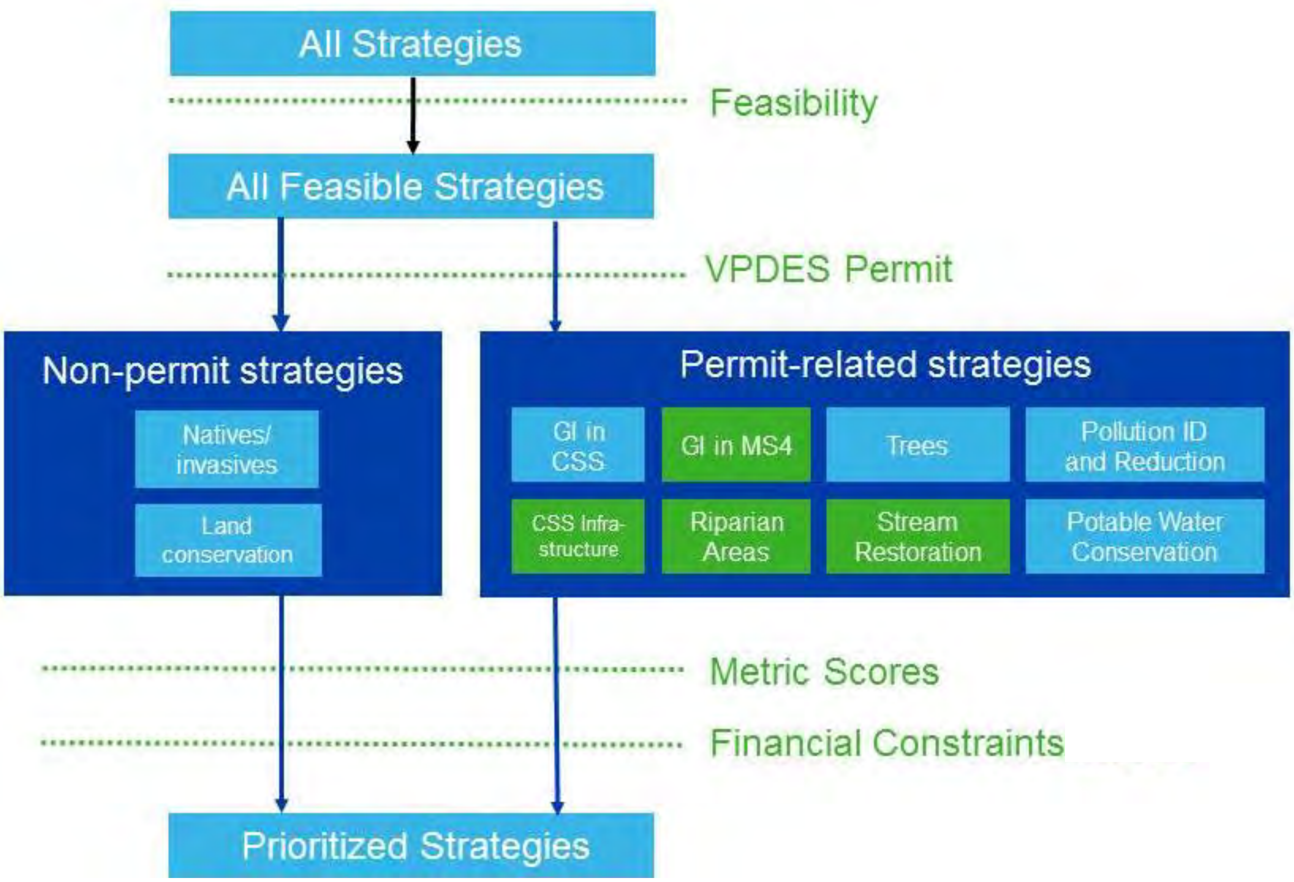


Figure 6.1. The process used for strategy evaluation

There are multiple factors at play that influence the selection of strategies. A strategy may do well with one factor, such as permit-related pollutant reductions, but not so well with others, like cost. As a result, the analysis of the various factors did not result in a clear and decisive outcome of one strategy that performed the best across all factors. What the strategy evaluation did determine was that all of the "pieces of the puzzle" needed to be evaluated collectively to achieve a complete picture of how well strategies achieve specific goals (Figure 6.2).

Each of the "puzzle pieces" (other than Feasibility, which was discussed in Chapter 5) is discussed further below.

Figure 6.2. Puzzle piece conceptual model demonstrating how various factors fit together to inform the decision making process

Strategy Scores

A comparison of the various strategies proposed through this stakeholder process was needed. To accomplish this, an Excel-based strategy scoring calculator was developed. This tool helped in the decision-making process by allowing the City and stakeholders to evaluate various alternatives by assigning scores to the alternative strategies.

The methodology used for this scoring calculator is a multi-objective decision analysis (MODA). Decision-making based on consideration of multiple goals/objectives and metrics is a widely documented research discipline. While referred to by a variety of terms in the literature, this decision-making approach is used to evaluate how well each of the alternative strategies (e.g., management practices, policy options) achieves a desired outcome (a decision-making problem, goal, etc.) through the use of metrics[7]. This approach also helps facilitate the involvement of diverse stakeholders by accounting for competing priorities and preferences in the decision-making process through inclusion of the weighting process (Saairkoski et. al. 2015).

Development of calculator-based strategy scores to support strategy evaluation includes the development of metrics that are tied to the goals/objectives. The development of these metrics is discussed below. Also discussed is how the analysis of individual metrics helped to answer specific questions related to strategy effectiveness. These metric-based strategy scores were then used in conjunction with other factors, like cost, to comprehensively evaluate strategies.

[7] There are a number of names for this approach in the literature, which share similar methodologies. These include: Multi-Criteria Decision Analysis, Multi Criteria Evaluation, Multi-Criteria Preference Analysis, Multi Objective Evaluation, Multi-attribute Decision Analysis, Multi-attribute Utility Analysis, etc.

Developing Metrics

An important component of strategy scoring is the development of metrics. While stakeholders and City staff dedicated significant time to the establishment of Integrated Planning goals and objectives, a standard of measurement was needed to evaluate how well the strategies achieved these goals and objectives and how well the strategies compared to one another.

Metrics:
Measurable properties by which efficiency, performance, or progress can be assessed

To accomplish this, a set of metrics was developed that includes a method of measurement. Table 4.2 provides examples of several metrics that were identified and how these are measured. Because metrics must be measureable, they are often quantitative. They may also be qualitative as long as there is a translation into a quantitative format. For instance, the "Stormwater Management Plan produced" in Table 6.1, is qualitative, but it is translated to a quantitative metric by incorporating a measuring

Table 6.1 Example metrics and associated methods of measurement

Metric	Method of Measurement
Average yearly pollutant load reduction	Pounds of TN, TP, and TSS reduced Billion CFU of E.coli reduced
Percent increase towards meeting monthly geomean WQS compliance	Comparison of modeled E.coli concentration in the James River with the WQS standard
Riparian buffer restored/increased	Acres of riparian buffer
Partnerships implemented for Integrated Planning	Number of partnerships
Stormwater Management Plan produced	1=yes, 0=no
Amount of water conserved	Gallons

scheme of a scale of 0 or 1.

At least one metric was identified for each objective. An example is included in Table 6.2, which shows one of the Clean Water Planning goals. This goal includes several objectives (three of which are included here). Each objective is evaluated by at least one metric.

Table 6.2 Example of goal, objectives, metrics, and how metric is measured

Goal	Objectives	Metric	Measure of Metric
Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities	Restore streams to improve, restore, and enhance native ecological communities.	Streams restored	Feet (of stream restored)
		Reduce stormwater volume discharging to streams	Millions of gallons
		Riparian buffers restored and/or increased	Acres (of buffer restored)
	Identify, protect, and restore critical habitats.	Habitat protected or restored	Acres (protected or restored)
	Enhance aquatic and terrestrial habitat connectivity.	Habitat connected by green corridor	Acres (included in "green corridor")

Appendix C includes the complete list of the goals, objectives, metrics, and Appendix D (the Excel-based Strategy calculator tool, discussed below) also includes the raw scores that were identified for each strategy.

Raw Scores for Metrics

Each strategy was then given a raw score for each metric. Table 6.3 takes the example from Table 6.2 a step further and shows how a raw score is assigned to a metric. These scores can come from sources, such as the Integrated Plan model (e.g., number of extra days of bacteria compliance), from the literature (e.g., nitrogen reduced by an infiltration-based stormwater BMP), or from stakeholder input (e.g., number of acres of conservation easements that can be added).

Table 6.3. Example of how raw scores are assigned to each metric

	Riparian Areas Strategy	MS4 Green Infrastructure Strategy	Stream Restoration Strategy
Goal: Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities			
Objective: Restore streams to improve, restore, and enhance native ecological communities			
Metric: Streams restored (in feet)	0	0	2,500
Metric: Reduce stormwater volume discharging to streams (in millions of gallons)	3	30	0
Metric: Riparian buffers restored and/or increased (in acres)	10	0	6

Once the raw scores were input into the calculator tool they were normalized and weighted. Normalization was performed to account for the various units represented (acres, pounds, feet, etc.). The normalized, weighted scores for each of strategies were summed to produce one score for each strategy. These final scores allowed strategies to be compared to one another. The calculator tool (in

Appendix D) includes all of the formulas necessary for one to understand how these final scores are developed. Additionally, a call-out box on page 53, explains the concept of normalization further.

Strategy Analysis

As discussed above, there are multiple "puzzle pieces", or factors, that were taken into consideration in the analysis of strategies (Figure 6.2). The **Permit** puzzle piece represents the VPDES permit-related requirements that establish pollutant reduction targets by which the strategies were compared.

The Strategy Score "puzzle piece" involved using the calculator tool to evaluate **strategy scores** in several different ways. These analyses included evaluating:

- Permit-related metrics – metrics that related to total Nitrogen (TN), total Phosphorus (TP), total suspended solids (TSS) and bacteria were isolated in the calculator and scores associated with just these metrics were used to evaluate the effectiveness of strategies in reducing these pollutants of concern
- Standardization of strategies addressing permit-related metrics – strategies, which varied in size, were all standardized to 10 acres to compare these permit-related metrics in an "apples to apples" manner
- All metrics – including the full set of metrics associated with all of the objectives in addition to the pollutant-related metrics
- Standardization of all metrics – comparing how the same sized strategies (all 10 acres) address all metrics

The calculator tool was also tied to the **Strategy Cost** information. Metrics specific to pollutant reductions (e.g., pounds of pollutant removed by a strategy) were used to calculate Cost Effectiveness. Overall, strategy costs were then evaluated in association with Affordability.

Another puzzle piece, **Modeling Results**, provided the bacteria reductions associated with several strategies that were used as raw score inputs into the calculator. Modeling results also provided information pertaining to the relative nature of bacteria sources to the James River and tributaries.

Each of these specific analyses is discussed in more detail below.

The Permit

Establishing Targets

Stakeholders and City staff have dedicated significant time to the establishment of Integrated Planning goals and objectives as well as strategies to help ensure these are achieved. While stakeholder concerns ranging from pollutant reduction to habitat restoration and invasive species removal are all considered in the Clean Water Plan, it is essential to remember that there are VPDES permit-related requirements that must be addressed and therefore, these requirements are key drivers behind the Plan. Therefore, it is important to understand that these VPDES permit requirements are water quality-focused and this permit-driven approach inherently prioritizes efforts that help improve water quality in Richmond's waters. Determining the extent to which water quality needs to be improved and the targets that help guide these improvements is a key step in the strategy analysis. Once these targets are determined, the next step is to evaluate how the strategies themselves help the City best (efficiently and effectively) achieve these targets.

One pollutant the City must work toward reducing is bacteria. Table 6.4 includes the existing bacteria (*E.coli*) loads and the allowable pollutant loading (the Waste Load Allocation, or WLA) for the City's MS4 (as documented in the Bacteria TMDL Action Plan based upon the James River Bacteria TMDL) and for the CSO/WWTP discharges (as documented in the James River Bacteria TMDL). These loads and the WLAs are summed in this table to provide an overall bacteria reduction by watershed addressed by the TMDL.

Table 6.4. E.coli Bacteria reduction requirements for Richmond's WWTP/CSS and MS4 systems

	MS4			WWTP			CSO		
	Existing Load	WLA	Load Reduction Target	Existing Load	WLA	Load Reduction Target	Existing Load	WLA	Load Reduction Target
Bacteria (BCFU)	606,312	221,842	384,470	6,792	444,000	(437,208)	16,511,684	3,025,710	13,485,974

What Table 6.4 shows is that the MS4 and CSOs in particular are still the biggest sources of bacteria and will drive additional reductions. The WWTP is reducing bacteria efficiently. The existing bacteria load from the plant, therefore, is far below the WLA, which produces a "credit" for bacteria (this negative number is denoted by parenthesis around the load reduction target).

The City also has total Nitrogen (TN), total Phosphorus (TP), and total suspended solids (TSS) pollutant loading reduction targets driven by the Chesapeake Bay TMDL. TN and TP reductions are also reflected in the VPDES Watershed General Permit for Nutrient Discharges to the Chesapeake Bay. Table 6.5 identifies the WLA and reduction goals associated with the City's WWTP and its CSOs as well as with its MS4 program.

Table 6.5. TN, TP, and TSS reduction requirements for Richmond's WWTP/CSS and MS4 systems

	MS4			WWTP			CSO		
	Existing Load	Waste Load Allocation	Load Reduction Target	Existing Load	Waste Load Allocation	Load Reduction Target	Existing Load	Waste Load Allocation	Load Reduction Target
TN (lbs)	166,955	154,901	12,054	338,328	1,093,652	(755,324)	141,759	409,557	(267,798)
TP (lbs)	19,813	17,262	2,550	29,411	55,754	(26,343)	17,720	31,642	(13,922)
TSS (lbs)	6,327,579	5,223,204	1,104,375	361,031	847,754	(486,723)	2,303,581	3,396,550	(1,092,969)

Table 6.5 shows that the WWTP is very efficient in reducing these pollutants and resulting load reduction targets for Nitrogen, Phosphorus, and sediment are not only met, but exceeded.

As will be discussed in further in Chapter 9, the intent of the watershed-based integrated VPDES permit is to look at the City's source sectors collectively to determine greatest impacts. In an effort to do this, bacteria, nutrient and sediment targets for the MS4, WWTP, and CSOs are aggregated (Table 6.6).

Table 6.6. Aggregated annual load reduction targets

	Waste Load Allocation	Existing Load	Load Reduction Target
TN (lbs)	1,658,110	647,042	(1,011,068)
TP (lbs)	104,658	66,943	(37,715)
TSS (lbs)	9,467,508	8,992,191	(475,317)
Bacteria (BCFU)	3,691,552	17,124,789	13,433,236

These aggregated annual load reduction targets reflect the effectiveness of the WWTP in reducing nutrients and sediment in general. While this Clean Water Plan will still continue to emphasize additional reductions of these pollutants in the MS4 and its impacts to tributaries in particular, this information helps inform DPU as to where its most significant pollutant reductions are needed. This information will be taken into consideration in the following analyses and how this influences strategy prioritization.

Strategy Scores

Permit-Related Metrics

Permit-related metrics are defined as those that address TN, TP, TSS, or bacteria (the pollutants of concern). Through the population of the Excel-based strategy scoring calculator, each strategy was evaluated to determine what amount of, if any, pollutant reduction was achieved. Table 6.7 includes the strategies that are expected to result in reductions in permit-targeted pollutants associated with the Chesapeake Bay TMDL (TN, TP, and TSS) and bacteria TMDL (for compliance with recreational water quality standards). The values in Table 6.7 are excerpted from the strategy scoring calculator. How well each of these strategies addresses these pollutants is also conveyed in this table by color coding the cells based on the strategies that best address these pollutants of concern:

- **Green** – address all pollutants of concern (light green addresses fewer metrics)
- **Orange** – Address nutrients and sediments, but not bacteria
- **Red** – don't address any pollutants of concern, but can be used as supplemental strategies that can be incorporated as appropriate and as resources and opportunities allow

*Table 6.7. How strategies address pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID	CSOs / WWTP Infrastructure
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).										
Average yearly TN load reduction (lbs)	19	414	74	188	0	30	0	11	448	7,066
Average yearly TP load reduction (lbs)	4	90	16	170	0	4	0	1	162	903
Average yearly TSS load reduction (lbs)	1,081	42,397	7,393	75,013	0	447	0	422	57,893	116,843
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).										
Percent increase in monthly geomean WQS compliance	0	0	0	0	0	0	0	0	0	11
Average yearly E.coli load reduction (billion cfu)	83	3,531	40,642	0	0	0	0	0	0	3,551,112
Average yearly reduction in CSO events (number)	0	0	0	0	0	0	0	0	0	1
Average yearly reduction in CSO volume discharged (million gallons)	0	0	5	0	0	0	0	0	0	962

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)

The results of this comparison show the following:

- Strategies that address all pollutants including TN, TP, TSS and bacteria
  - CSO/WWTP Infrastructure
  - Green Infrastructure (in the MS4/CSS areas)
  - Riparian Areas
- Strategies that address TN, TP, TSS, but not bacteria
  - Stream restoration
  - Trees
  - Water conservation
  - Pollution identification

Additionally, strategies that can be implemented, but do not help achieve permit requirements include:

- Native/invasives
- Land conservation

The "raw" scores in Table 6.7 were then normalized and weighted (additional information on these processes is included on the call-out box on the following page). These values are included in Table 6.8.

*Table 6.8. Normalized and weighted scores of strategies in addressing pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID	CSOs / WWTP Infrastructure
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).										
Average yearly TN load reduction (lbs)	0.3**	6.8	1.2	3.1	0.0	0.5	0.0	0.2	7.4	116.0
Average yearly TP load reduction (lbs)	0.5	11.6	2.0	21.8	0.0	0.5	0.0	0.2	20.9	116.0
Average yearly TSS load reduction (lbs)	1.1	42.1	7.3	74.5	0.0	0.4	0.0	0.4	57.5	116.0
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).										
Percent increase in monthly geomean WQS compliance	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Ave. yearly E.coli load reduction (billion cfu)	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Average yearly reduction in CSO events (number)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Average yearly reduction in CSO volume discharged (million gallons)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Score	1.9	61.4	12.9	99.4	0.0	1.5	0.0	0.8	85.7	696.2
Rank	**6**	**4**	**5**	**2**	**9**	**7**	**9**	**8**	**3**	**1**

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)
** All scores multiplied by 100 for clarification purposes. Total score may be off due to rounding.

Normalizing & Weighting Scores

The intent of the strategy scoring process is to produce a value that demonstrates how well each strategy addresses the metrics of interest. The metrics used to evaluate the strategies; however, can vary in the way they are measured (e.g., pounds of total Nitrogen reduced, acres of impervious surface treated, etc.). Because of the varying units represented, raw scores cannot simply be added together to obtain a score for each strategy. A normalization process is required to adjust these raw scores to a common scale.

To accomplish the normalization process, the raw score is divided by the maximum of the raw scores associated with that particular metric. In the example below, each of the numbers in the red box would be divided by 7,066 to produce the associated normalized scores for this metric.

Additionally, because the metrics may not all be of equal importance, various weights were also applied to them. In the example below TN reduction was considered most important and given a higher weight (50%) than the other metrics. Normalized scores are multiplied by the associated weight to produce a final weighted, normalized score. In the example below, each of the normalized scores in the orange box is multiplied by 50% to produce the associated values in the green box. A strategy's weighted, normalized scores are added together to produce a final score for that strategy. In the example below, Strategy B, with a score of 30, best achieves these four metrics.

Example scoring process

		Raw Scores			Normalized Scores			Weighted, Normalized Scores		
	Weight	Strategy A	Strategy B	Strategy C	Strategy A	Strategy B	Strategy C	Strategy A	Strategy B	Strategy C
Average yearly TN load reduction (lbs)	50%	19	11	7,066	0.003	0.002	1.0	0	0	1.2
Average yearly E. coli load reduction (BCFU)	20%	83	0	3,551,112	0	0	1	0	0	0.9
Impervious Surface reduced or treated (acres)	15%	2	5	0	0.4	1	0	6	15	0
Potable water consumption reduced (gallons)	15%	0	0	250	0	1.0	0	0	15	0
Total	100%							6	30	2.1

The normalized, weighted scores for each strategy are summed, which results in a final score for the strategy. The top ranked strategies for achieving key pollutant reduction include:

1. CSO/WWTP Infrastructure
2. Stream Restoration
3. Pollution Identification
4. GI in MS4

"Standardization" of Permit-Driven Metrics

As previously stated, the numeric targets of the strategies were based on the amount of DPU/PRCF land/resources available for that particular strategy. As a result, each strategy addresses a different amount of area (e.g., 10 acres of land for riparian area restoration vs. 104 acres of land in the MS4 for implementation of green infrastructure, etc.). To evaluate strategies in a "standardized" manner (all strategies being comparable in size to one another in an "apples to apples" manner), strategies were evaluated as if they would be implemented on 10 acres of land (Table 6.9).

It is important to note that the CSO/WWTP strategy is based on reducing the combined sewer overflow volume and frequency, which is not based on acreage of implementation. As such, this strategy cannot be standardized in this way and is not included in the analysis reflected in Table 6.9.

*Table 6.9. How "standardized" strategies address pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).									
Average yearly TN load reduction (lbs)	19	40	41	327	0	4	0	22	1
Average yearly TP load reduction (lbs)	4	9	9	296	0	4	0	1	0
Average yearly TSS load reduction (lbs)	1,081	4,077	4,107	130,702	0	56	0	845	341
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).									
Percent increase in monthly geomean WQS compliance	0	0	0	0	0	0	0	0	0
Average yearly E.coli load reduction (billion cfu)	83	340	22,579	0	0	0	0	0	0
Average yearly reduction in CSO events (number)	0	0	0	0	0	0	0	0	0
Average yearly reduction in CSO volume discharged (million gallons)	0	0	3	0	0	0	0	0	0

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)

Table 6.10 shows the normalized, weighted scores for these strategies standardized across 10 acres. Again, note that the CSO/WWTP strategy is not included in Table 6.10 as it cannot be standardized across 10 acres of land.

*Table 6.10. Standardized strategies that have been normalized and weighted for pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).									
Average yearly TN load reduction (lbs)	6.6	14.1	14.7	116.0	0.0	1.4	0.0	8.0	0.5
Average yearly TP load reduction (lbs)	1.5	2.8	3.0	116.0	0.0	0.2	0.0	1.1	0.0
Average yearly TSS load reduction (lbs)	1.0	2.4	2.5	116.0	0.0	0.0	0.0	0.8	0.3
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).									
Percent increase in monthly geomean WQS compliance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ave. yearly E.coli load reduction (billion cfu)	0.3	1.3	87	0.0	0.0	0.0	0.0	0.0	0.0
Average yearly reduction in CSO events (number)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average yearly reduction in CSO volume discharged (million gallons)	0.0	0.0	87.0	0.0	0.0	0.0	0.0	0.0	0.0
Score	9.4	22.5	195.8	348	0	1.6	0	9.9	0.8
Rank	**5**	**3**	**2**	**1**	**8**	**6**	**8**	**4**	**7**

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)

** All scores multiplied by 100 for clarification purposes

All Metrics

While evaluating key permit related pollutants is important, numerous other metrics were also identified for other goals and objectives (Appendix C). Table 6.11 shows the score (obtained from the strategy scoring calculator) for each strategy that takes all of the metrics collectively into consideration.

Table 6.11 – Scores and ranks of all feasible strategies – total acres/resources available

	Riparian	GI in MS4	GI in CSS	Stream Restoration	Natives/ Invasives	Trees	Land Conservation	Water Conservation	Pollution ID	CSO/ WWTP
Scores	54.90	57.53	39.88	47.82	43.10	44.80	42.02	45.00	35.29	46.22
Rank	2	1	9	3	7	6	8	5	10	4

The results of the scoring process (including all metrics and strategies) results in the following ranking of strategies:

1. Green Infrastructure in the MS4
2. Riparian Area Restoration
3. Stream Restoration
4. CSO/WWTP Infrastructure

"Standardization" of All Metrics

While these available acreages are very important for future implementation purposes, a "standardized" comparison of the strategies with regard to all other metrics was also performed. Again, this analysis assumed 10 acres of implementation for each of the strategies and, as discussed above, the CSO/WWTP strategy was not included in this standardized analysis as it cannot be evaluated on a 10-acre basis. The CSO/WWTP strategy is therefore evaluated separately below. Table 6.12 shows the scoring of the strategies if all were implemented on the same amount of acreage.

Table 6.12 – Scores and ranks of feasible strategies – 10 acres for each strategy

	Riparian	GI in MS4	GI in CSS	Stream Restoration	Natives/ Invasives	Trees	Land Conservation	Water Conservation	Pollution ID
Scores	66.87	55.46	57.67	67.74	44.44	43.83	46.49	56.33	36.27
Rank	2	5	3	1	7	8	6	4	9

The results of these scores produce in the following top-ranked strategies:

1. Stream Restoration
2. Riparian Area Restoration
3. Green Infrastructure in the CSS area
4. Water Conservation

Evaluation of CSS Infrastructure Projects

The CSS Infrastructure strategy was evaluated in previous sections as a whole, but this strategy consist of several different projects outlined in the LTCP, including:

- Installing wet weather interceptor in Lower Gillies to convey more flow to the WWTP
- Increasing WWT (wet weather treatment) at the WWTP to 300 MGD and expanding secondary treatment at the WWTP to 85 MGD
- Replacement of CSO 021 regulator and additional 2MG storage at CSO 021
- Expanding Shockoe retention basin by 15 MG to capture more overflow
- Disinfecting overflow at Shockoe retention basin (wet weather disinfection facility)

Each project was evaluated in isolation to determine individual impact on bacteria load reduction. These CSS "scenarios" are summarized in Table 6.13, below.

Table 6.13. Description of CSS Projects Evaluated by the Water Quality Model

CSS Scenario	CSS Project Name	CSS Project Description
Existing	Existing Conditions	Existing sewer conditions, including all LTCP Phase I and Phase II projects.
14-3	Baseline Conditions	Includes the currently funded projects: --CSO 028A & 028E disconnection --WWTP wet weather treatment up to 140 MGD
14-2	Gillies Conveyance	Lower Gillies Wet Weather Conveyance Interceptor to convey more flow to the WWTP
15-4	300 MGD Wet Weather Treatment	WWTP wet weather treatment up to 300 MGD
15-5	CSO 21 Replacement	Replacement of the CSO 21 regulator and additional 2MG storage
18-4	SRB Expansion	Shockoe retention basin (SRB) expansion to 15MG
18-5	SRB Expansion and Disinfection	SRB Expansion to 15MG and chlorine disinfection of the SRB discharge at CSO 06
19-3A	Full LTCP	All 10 Phase III projects, Full LTCP achieved.

Bacteria load reductions from each CSS scenario is shown in Figure 6.4, below.

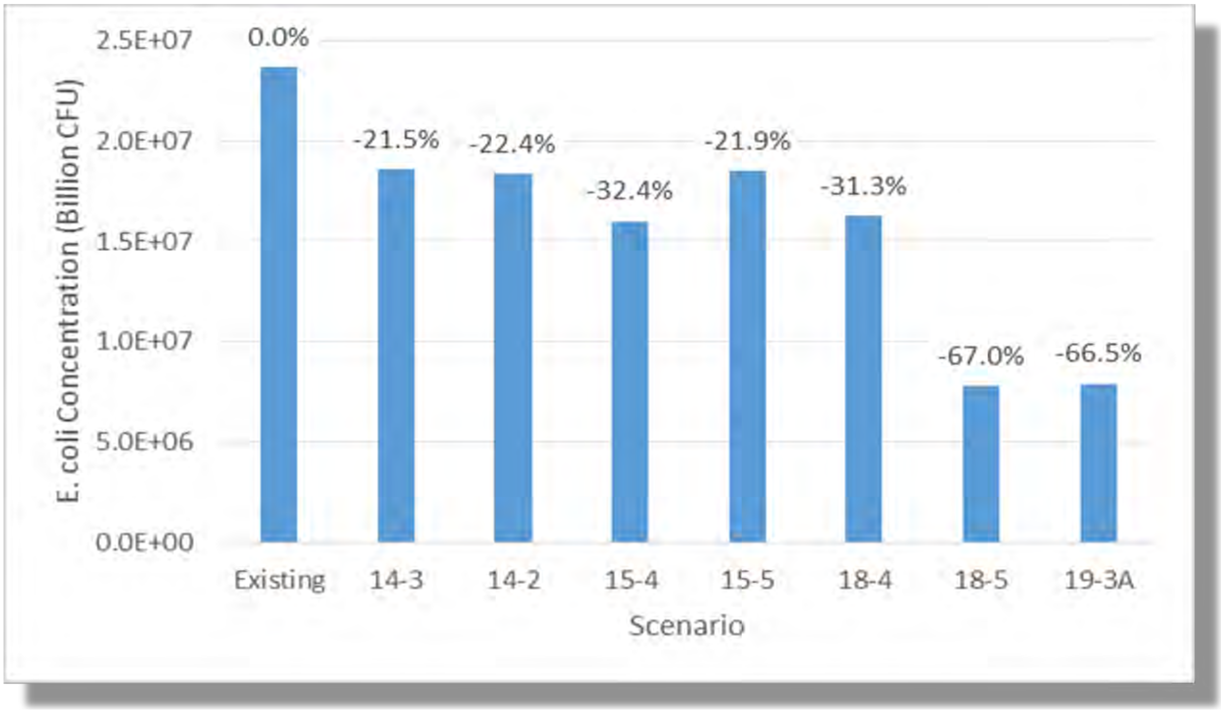


Figure 6.4 Bacteria load reductions from each CSS Infrastructure Project

Additional new projects, or variations to the existing projects, are currently being evaluated to determine if these alternative projects could accomplish similar or greater bacteria load reductions compared to the existing projects, and if this could be done in a more cost efficient way. Those alternative evaluations are currently ongoing, and include projects such as controlling discharge from CSO-040 and other combined sewer outfalls, and different types of disinfection for wet weather treatment at the wastewater treatment plant and at Shockoe retention basin.

Comparison of Targets with Load Reductions

The aim of the Integrated VPDES permit is to more efficiently control the discharge of pollutants from all DPU sources. In order to do this, it is necessary to look at the ultimate targets and all the sources together and assess where it is possible to get the greatest gains. It is also important to recognize not all pollutants will be assessed in the same way, different pollutants have different impacts. Some pollutants have far field effects and can be assessed based upon total load delivered while others must be looked at based on localized effects. For instance, an aggregate approach can be done for TN, TP, and TSS because the TMDL allows the targets to be assessed for the City as a whole to ultimately achieve improvements downstream to the Chesapeake Bay. The bacteria numbers can also be aggregated to show the overall scale of needed reductions, but it must be remembered that bacteria allocations exist for specific watersheds, and those need to be met at the local scale, rather than at the aggregate scale. These aggregated targets are depicted in Table 6.14.

Table 6.14. Aggregated Annual Load Reduction Targets

	Existing Load	Waste Load Allocation	Load Reduction Target
TN (lbs)	647,042	1,658,110	(1,011,068)
TP (lbs)	66,943	104,658	(37,715)
TSS (lbs)	8,992,191	9,467,508	(475,317)
Bacteria (BCFU)	17,124,789	3,691,552	**13,433,236**

While Table 6.14 shows (on an aggregated scale) targets for TN, TP, TSS are already met, bacteria still needs additional reductions in order to meet targets. These targets can be compared to the load reductions achieved by the strategies, shown previously in Table 6.6.

Costs

Financial constraints referred to in Figure 6.1 include the costs of the strategies and supporting actions and cost effectiveness of these strategies. Affordability is considered the overarching mechanism within which these elements can be paid for in an affordable manner by DPU. Each of these factors is discussed in more detail below.

Strategy Costs

The cost associated with the full implementation of the strategies included in Table 5.1 was also estimated (Table 6.15). For the purpose of estimating costs most consistently across strategies, the assumption was that the strategy would be implemented in the first year of the permit (capital costs) with maintenance being required for the strategy in years two through five of the permit.

Table 6.15. Cost of main strategies broken out by capital and maintenance

Main Strategy	Capital	O&M	Total
Riparian Areas	$900,000	$200,000	$1,100,000
Green Infrastructure in the MS4	$10,500,000	$2,000,000	$12,500,000
Green Infrastructure in the CSS	$2,600,000	$750,000	$3,350,000
Stream Restoration	$1,700,000	$1,200,000	$2,900,000
Native/ Invasives	$70,000	$95,000	$165,000
Trees	$1,600,000	$600,000	$2,200,000
Land Conservation	$ -	$ -	$ -
Water Conservation	$220,000	$ 50,000	$270,000
Pollution Identification & Reduction[8]	$16,385,000	$ -	$16,385,000
CSO Infrastructure[9]	$374,800,000	$17,400,000	$392,200,000
Total	**$408,775,000**	**$22,295,000**	**$431,070,000**

The cost of additional supporting actions was also estimated in Table 6.16.

[8] As street sweeping and catch basin clean-outs are ongoing efforts for the City, these activities are calculated for each of the five years of the permit.

[9] Note that the cost for the CSO Infrastructure strategy is over 30 years, while the costs of the other nine strategies are over five years.

Table 6.16. Cost of supporting actions

Supporting Actions	
Partnerships	$700,000
Monitoring, Assessments & Planning	$1,300,000
Incentives/ Credits	$1,250,000
Regs/ Ordinance/ Code	$ -
Outreach	$500,000
Total	**$ 3,750,000**

The source of all cost information as well as any assumptions that were made in association with the calculation of final cost estimates is discussed further in Appendix E.

Cost Effectiveness

While cost is important from the perspective of how it can be achieved within a certain budget, cost effectiveness of a particular strategy can be more informative because it provides an indication of the return on the investment. Cost effectiveness was evaluated for each strategy for the permit-driven metrics (TN, TP, TSS, bacteria) discussed above, and expressed as cost per unit pollutant removed. Cost effectiveness comparisons in Table 6.17 are also based on the strategies that included the fill size/acreage/ resources (again it should be noted that the Natives & Invasives strategy and the Land Conservation strategy are not included in this table because neither, as they are written, results in the reduction of these key pollutants).

Table 6.17. Pollutant reduction and associated cost effectiveness of strategies

	Riparian areas	GI in MS4	GI in CSO	Stream restoration	Trees	Water conservation	Pollution Identification	CSOs / WWTP Infrastructure
Average yearly TN load reduction (lbs)	19	414	74	188	30	11	448	7,066
Average yearly TP load reduction (lbs)	4	90	16	170	4	1	162	903
Average yearly TSS load reduction (lbs)	1,081	42,397	7,393	75,013	447	422	57,893	116,843
Average yearly E.coli load reduction (billion cfu)	83	3,531	40,642	0	0	0	0	3,551,112
Cost	$1,100,000	$12,500,000	$3,350,000	$2,900,000	$2,200,000	$270,000	$16,385,000	$392,200,000
Cost per pound TN removed	$58,902	$30,181	$45,270	$15,467	$72,158	$24,092	$36,597	$55,507
Cost per pound TP removed	$292,553	$138,687	$209,375	$17,059	$520,833	$195,744	$100,882	$434,293
Cost per pound TSS removed	$1,017	$295	$453	$39	$4,925	$639	$284	$3,357
Cost per billion E.coli removed	$13,190	$3,540	$82	--	--	--	--	$110

The green highlighted items in Table 6.17 identify those strategies that are most cost effective for the various pollutants.

Affordability

The intent of the Clean Water Planning process is to make sure that each dollar spent gets the greatest environmental benefit. While this is important to rate payers in general, it is additionally important because the City already has a large number of people who are below the poverty line and currently can't afford their utility bills. So, while the City was evaluating ways to make smart water quality decisions, it was also looking for ways to keep rates affordable.

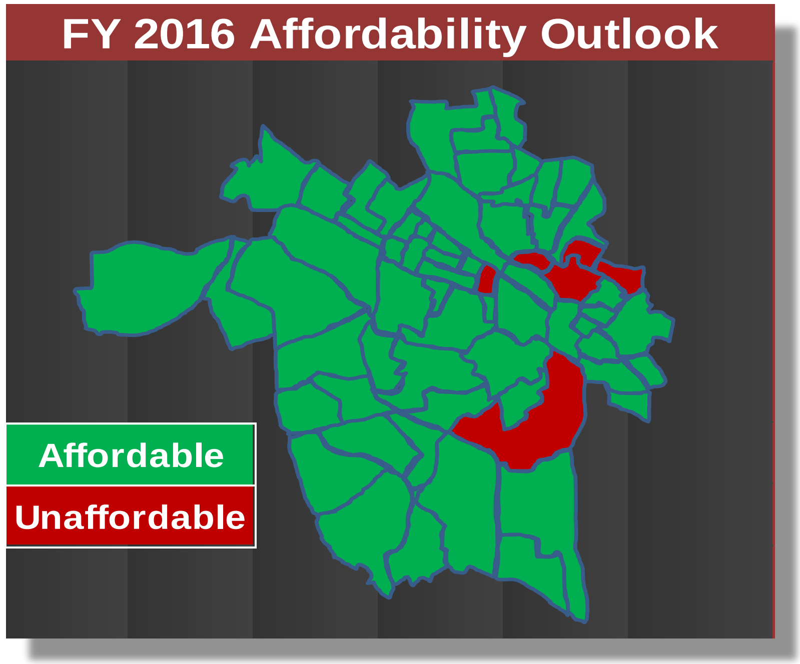


Figure 6.2 With current rates, those census tracks that cannot afford utility rates in 2016

While developing its Integrated Plan, DPU analyzed the impact annual spending would have on rates over time, and subsequently customer bills. This analysis was done to define and measure affordability, so that unaffordable bills and financial impacts can be mitigated to the greatest degree on an annual basis.

To accomplish this, DPU evaluated customer impacts on a localized level (at the census track level shown here) throughout the City by measuring bill impacts against various affordability and income metrics, like "living wages".

The results of this affordability analysis are summarized in Figure 6.2, demonstrating where rates are unaffordable by census tract. Between 2016 and 2045, the financial model shows the situation would get much worse (assuming rate increases remain at their current pace and economic conditions remain constant).

What this also shows is that if the City continues to attempt to comply with various water quality regulations with the "do everything, everywhere simultaneously" approach this is the probable outcome. Alternatively, the Clean Water Plan focuses strategic decisions for cleaner water faster, but in a more affordable way.

The budget within which strategies will be implemented within the Clean Water Planning effort have been set, or constrained, by affordability. It is important to note that a high cost of a given strategy may not take it off the table, but simply require it to be implemented over time or other strategies are prioritized ahead of it.

Strategy Prioritization

The various "pieces of the puzzle", discussed above, were used to understand how to best prioritize activities for implementation. As each of these analyses tells only a piece of the story, it is important to look at these analyses collectively. What these analyses have shown is that no one strategy consistently scores the highest or performed the best across the analyses, however, several strategies consistently performed well (a summary of the analyses are included in Table 6.18; green highlighted information depicts those that consistently score highest).

To allow for the consideration of multiple factors in determining priorities, it was determined that rather than ranking 10 strategies individually, that strategies would be grouped into one of three tiers based on effectiveness (Figure 6.3). Tier 1 includes those strategies that best address metrics associated with the pollutants of concern (TN, TP, TSS, bacteria) as well as the non-pollutant related metrics. These strategies were also the most cost effective. Tier 2 also addressed pollutant and non-pollutant related metrics, but not as efficiently or cost effectively as those in the Tier 1 grouping. Tier 3 includes those strategies that do not address the pollutants of concern.

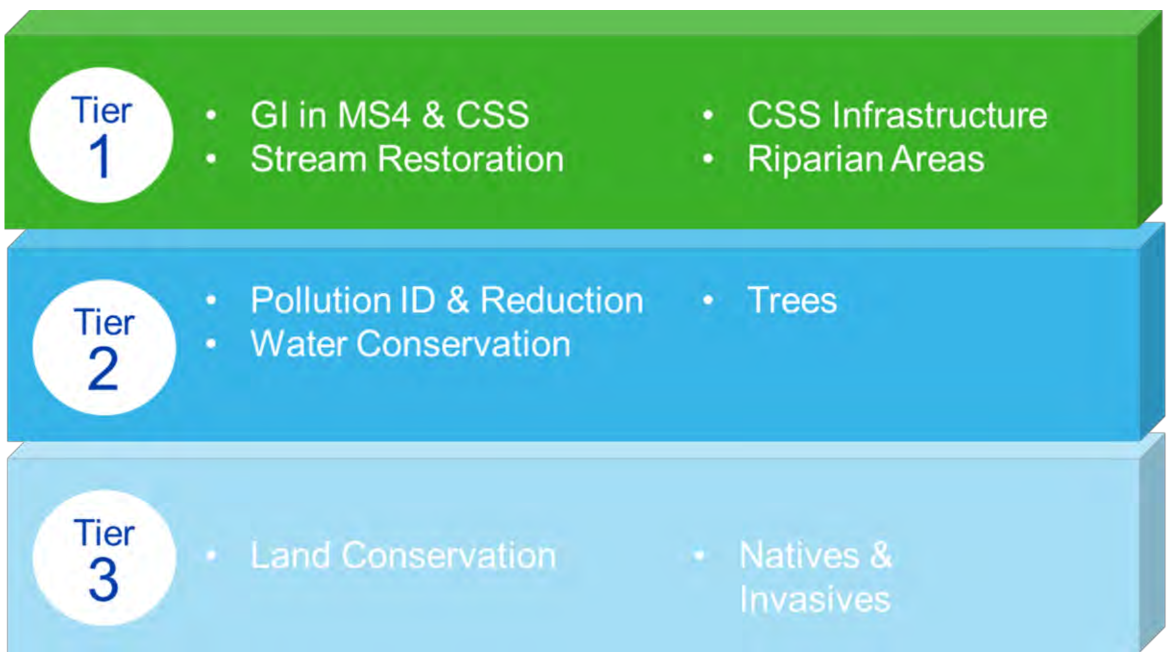


Figure 6.3. Organization of strategies into tiers for prioritization

It is important to note that while select strategies may be *prioritized* it does not mean that the remaining strategies will be disregarded. Implementation of these strategies will be assessed based on additional resources available to DPU or priorities and resources available from other City departments or other partners.

It is also important to note that this analysis was done at a high level. As DPU moves toward implementation and conducts a more refined evaluation of strategies, there may be modifications to this prioritization. For instance, the Green Infrastructure strategy includes bioretention, green roofs, permeable pavement, engineered tree boxes, rain barrels, and stormwater pond retrofits. If other green infrastructure practices are identified as alternatives, details, such as cost, amount of pollutant reduction, and how the practices achieves other metrics, will all be taken into consideration.

Table 6.18 Summary of Strategy Analysis and Strategy Prioritization

Rank	Pollutants of Concern Metrics	Pollutants of Concern Metrics: Standardized*	All Metrics	All Metrics: Standardized*	Cost Effectiveness (TN)	Cost Effectiveness (TP)	Cost Effectiveness (TSS)	Cost Effectiveness (bacteria)
1	**CSO Infrastructure**	**Stream restoration**	**GI in MS4**	**Stream restoration**	**Stream restoration**	**Stream restoration**	**Stream restoration**	**GI in CSS**
2	**Stream restoration**	**GI in CSS**	**Riparian areas**	**Riparian areas**	Water conservation	Pollution ID and reduction	Pollution ID & reduction	**CSO Infrastructure**
3	Pollution ID & reduction	**GI in MS4**	**Stream restoration**	**GI in the CSS**	**GI in MS4**	**GI in MS4**	**GI in MS4**	**GI in MS4**
4	**GI in MS4**	Water conservation	**CSO Infrastructure**	Water Conservation	Pollution Identification	Water conservation	**GI in CSS**	**Riparian areas**
5	**GI in CSS**	**Riparian areas**	Water Conservation	**GI in MS4**	**GI in CSS**	**GI in CSS**	Water conservation	Water conservation
6	**Riparian areas**	Trees	Trees	Land Conservation	**CSO Infrastructure**	**Riparian areas**	**Riparian areas**	
7	Trees	Pollution ID & reduction	Natives/ invasives	Natives/ invasives	**Riparian areas**	**CSO Infrastructure**	**CSO Infrastructure**	
8	Water Conservation	Natives / invasives	Land Conservation	Trees	Trees	Trees	Trees	
9	Natives/ invasives	Land Conservation	**GI in the CSS**	Pollution Identification				
10	Land Conservation		Pollution ID and reduction					

*WWTP/CSO strategy cannot be evaluated on a 10-acre basis so it is not included herein

7. Implementation Program

As discussed in Chapter 5, high-level strategies to achieve goals and objectives were developed to include quantifiable targets that DPU can work towards implementing (e.g., 10 acres of riparian buffer restoration, implementation of 104 acres of green infrastructure in the MS4 area of the City, etc.). An important part of this Clean Water Plan is developing an approach that can help the City implement these strategies in the most efficient and cost effective manner possible.

Framework Planning

In order to most efficiently and effectively implement its IWPM Plan, DPU will use a "Framework Planning" approach. The Framework Planning approach provides a methodology that ties together different strategies (and, subsequently, site-specific projects) and, where possible, aligns these strategies with other City or stakeholder-driven initiatives.

This Framework Planning approach is intended to be:

- A comprehensive and action-oriented blueprint for near- and long-range decision making
- A planning guide for the implementation of a set of strategies and serves to create a "framework" around multiple other efforts (e.g. Master Plan, guidelines for new/existing development, other City planning efforts, etc.) to guide planning in a cohesive way
- Designed for flexibility and choices that will enable different entities (City Departments, partners, etc.) to act both collaboratively and independently, over different periods of time, but in a coordinated way

The goal of the Framework Planning approach is to identify and sequence a blend of activities that yield the greatest environmental benefit (as measured by identified metrics) in the most cost-effective (and affordable) manner.

Framework Planning Process

As discussed in previous chapters, the Clean Water Planning process involved the development of goals and objectives, and high-level strategies that could meet these goals and objectives. For implementation purposes, these strategies will be translated into projects (e.g., 104 acres for the Green Infrastructure in the MS4 strategy could be implemented as 50 engineered tree boxes, 10 acres of permeable pavers, etc., which will, in total, drain 104 acres).

As depicted in Figure 7.1, strategies are prioritized (into Tiers, as discussed in Chapter 6) (#1), but they are still disparate strategies (#2). An example is the Green Infrastructure in the MS4 area strategy (which targeted 104 acres, 44 acres of which were estimated to include bioretention). Assuming each of these bioretention facilities drains one acre, 44 facilities would then be implemented across the City's MS4 area. Implementing these facilities in a piecemeal approach would still meet the target of implementing 44 acres and would still achieve pollutant load reductions estimated for these facilities.

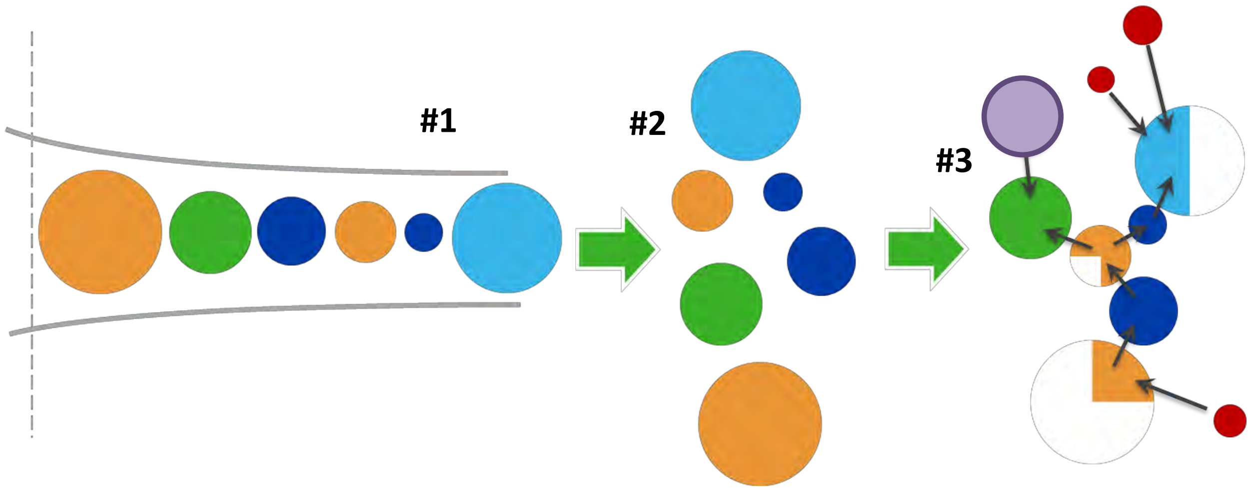


Figure 7.1 Framework Planning includes the interface of various elements together in the landscape in a way that makes the most sense for implementation.

Alternatively, DPU and its stakeholders can look collectively at the City for not only where the opportunities are for implementing bioretention, but where these practices can be implemented within the context of a more comprehensive planning and coordination effort under a Framework Planning umbrella. This Framework Planning process provides the structure for implementation of strategies/projects in a more integrated and cohesive way by leveraging opportunities with other city-led projects such as, for example, Richmond's Riverfront Plan, or stakeholder efforts such as, for example, EnRichmond's tree planting efforts (shown with the red and purple circles in Figure 7.1, #3). The Framework Planning process may also lead to the identification of new ideas and opportunities that can be pushed forward by DPU itself.

While DPU recognizes that some implementation may need to occur in a piecemeal fashion, its goal, where feasible, is that Framework Planning will drive implementation of the strategies. Framework Planning will meet the objectives and goals of the Clean Water Plan, while at the same time supporting and leveraging the overall growth and planning at the City or Stakeholder level.

An example of a Framework Planning-based clustered project is depicted in Figure 7.2, which is included in Arkansas' Conway Urban Watershed Framework Plan (2016). This example depicts Green Streets and parks that tie together the implementation of various types of green infrastructure while addressing other community needs, such as traffic calming, inclusion of recreational opportunities, and expanding parking. Figure 7.3 shows another example from the Conway Urban Watershed Framework Plan, which includes transportation corridors (streets and trails) and recreational amenities with riparian area restoration and green infrastructure. Additional detail on the Conway Framework Plan is included in the Case Study below, and provides additional context about what Framework Planning includes, and is consistent with the Clean Water Plan Framework Planning approach.

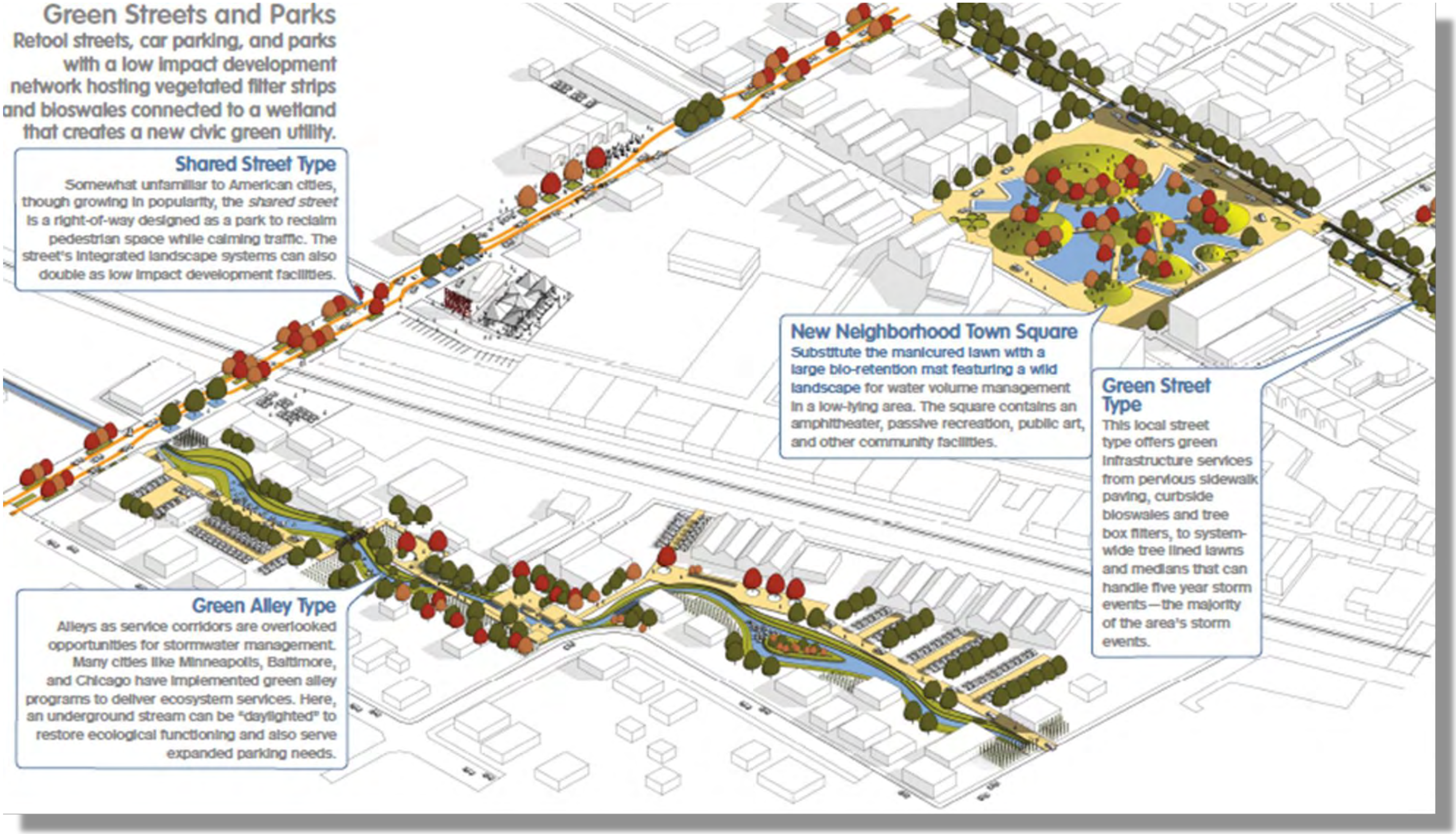


Figure 7.2. Example from the Conway Urban Watershed Framework Plan that shows how multiple strategies (green infrastructure, trees, riparian areas, natives/invasives) can be implemented in holistic way that also addresses other City priorities (traffic calming, recreation, beautification, etc.)

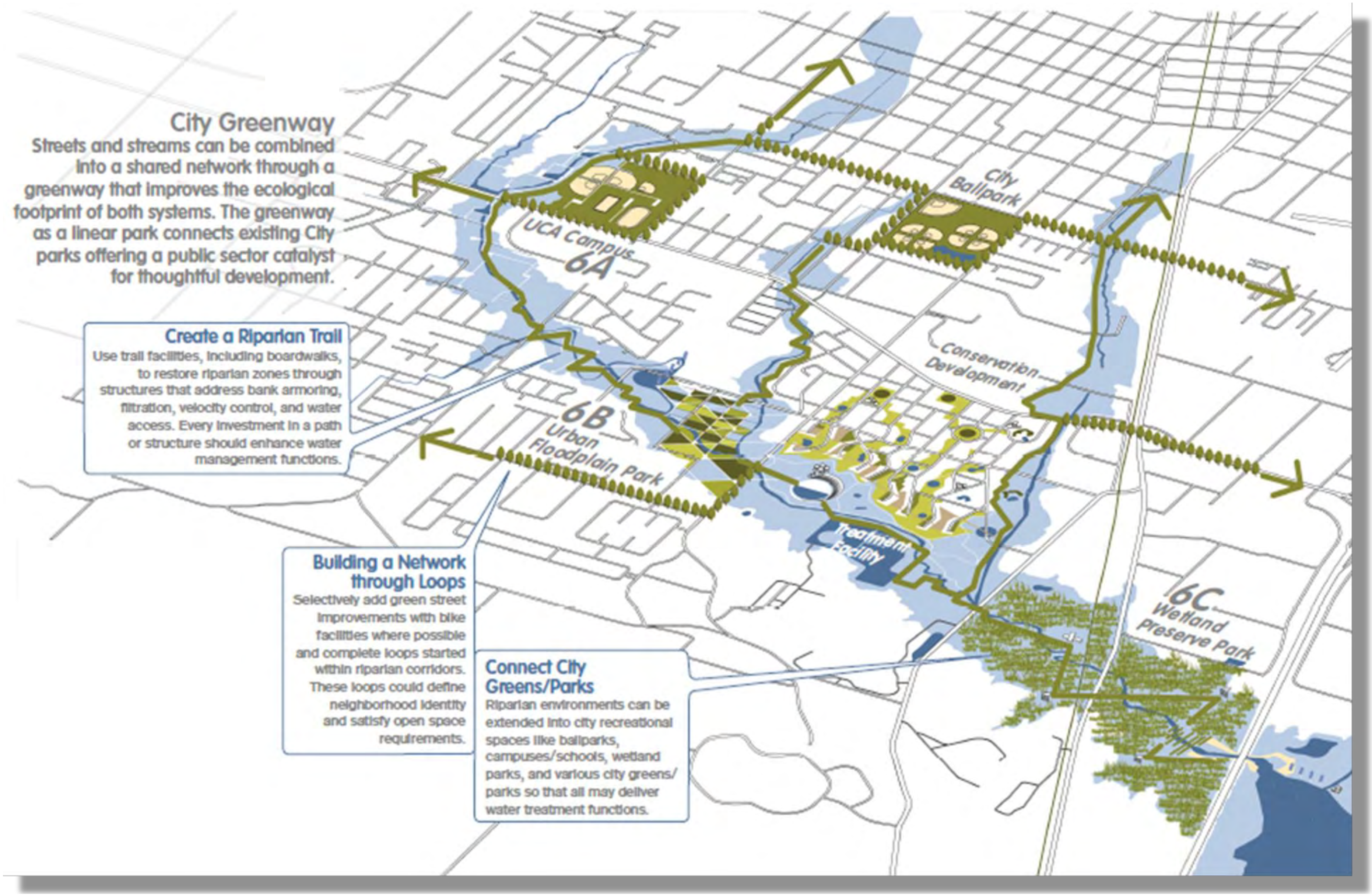


Figure 7.3. Example from the Conway Urban Watershed Framework Plan that shows how Greenways can incorporate strategies like green infrastructure and riparian area restoration with transportation corridors, parks, etc.

Case Study on Urban Framework Planning: Conway, Arkansas

An excerpt from the Conway Urban Watershed Framework Plan

The Framework Plan operates evolutionarily through a set of retrofit types that are incremental, contextual, and successional. The Framework Plan is incremental, relying on participation from various interests— public, private, or a combination thereof—to develop projects as funding and opportunity permit. Projects can be implemented step-wise and successively across various fronts in the urbanized area. Unlike the master plan which is totalizing and shows only a climax condition, the Framework Plan can be pioneered beginning with modest cumulative efforts that cohere from shared ecological design practices.

The Framework Plan is contextual, working through landscape architectural adaptations responsive to local ecologies and urban water problems. Soft engineering accounts for local soils, and vegetative and wildlife communities in place-based solutions that substitute for universal metrics and costly "over-engineered" outcomes driven by worst-case scenarios. The goal is to deliver ecological services through installing sustainable soft infrastructure. Soft engineering's use of adaptive management lessens long-term maintenance burdens associated with hard-engineered infrastructure.

The Framework Plan is successional, understanding that cities are not built at once and that pioneer stages of development are rudimentary as they minimize start-up costs. The Framework Plan works initially through tactical demonstration projects, which if approved after assessment, can be mainstreamed into future projects and policies. This way the city or project developer can evaluate new practices without committing permanently to an untested development and business model. Cities do not have to retool policies without the chance to pursue due diligence. Stakeholders in decision-making, including the city and the area's new watershed alliances (e.g., the Lake Conway-Point Remove Watershed Alliance), can collaborate as learning communities removing adversarial relationships so redolent in municipal planning processes. Without demonstration projects, conventional development approaches will remain entrenched despite the presence of more value-added approaches.

The Framework Plan places Conway ahead of the curve in addressing the greatest ongoing challenge to planning: development of urban form in human-dominated ecosystems. More cities are tasking urban infrastructure with regeneration of diminished ecosystems to support livable communities. Besides solving for water management problems like flooding, the collateral benefits of implementing the plan include greater livability, sustained economic development, improved community resilience to disruption and shocks, and exemplary beauty in the civic realm that creates enduring value and symbolism.

(University of Arkansas Community Design Center 2016)

The Framework Planning approach includes the following elements that are discussed further below:

1) Data and information gathering
2) Identification of potential opportunities
3) Prioritization
4) Plan development
5) Implementation

Data and Information Gathering

A significant data gathering effort was undertaken early in the City's Clean Water Planning process with the development of the Watershed Characterization Plan and Water Quality Model that helped characterize Richmond's watersheds and the James River and tributaries. The type of data that was collected for these two efforts included, for example, impervious surfaces, impaired waterways, City-owned properties, existing stormwater BMPs, and water quality sampling data. The Framework Planning process will facilitate the identification of additional information deemed important to the City and stakeholders, including information such as, for example, ongoing or planned restoration projects or watershed-scale initiatives, places (parks, neighborhoods) that draws people in, and areas challenged by socio-economic issues. DPU initiated discussion of such information at its March 21, 2017 Technical Stakeholder meeting (Figure 7.4). This initial meeting included discussion of what stakeholders felt were existing needs or challenges in the City. This included not only water quality-related issues, but transportation or other socially-driven challenges.

Figure 7.4. Initial Technical Stakeholder brainstorming session on challenges and opportunities to be considered in the Framework planning process

Figure 7.5 depicts examples of other data types that will be looked at collectively through this process, including location of parks (or lack thereof), bike paths, priority conservation areas, commercial areas targeted for revitalization, etc.

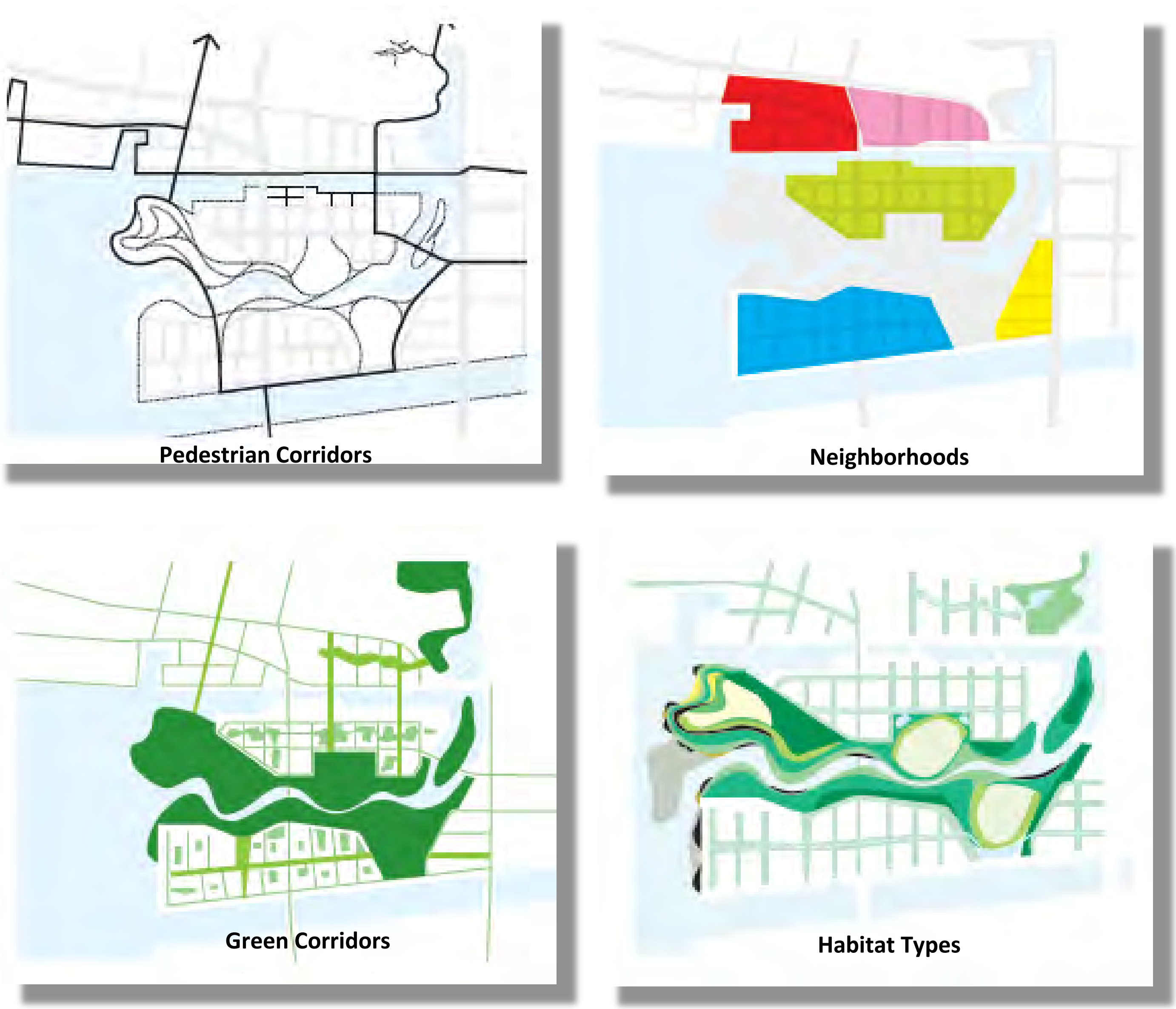


Figure 7.5 Examples of data types that will be considered within the Framework Planning Process

Several additional brainstorming meetings are scheduled to occur with Technical Stakeholders over the course of this project. Additionally, DPU will meet with other City departments to discuss opportunities for collaboration that will allow DPU to not only address its goals and objectives, but those of the City as a whole.

Identification of Potential Opportunities

As meetings with stakeholders and City staff continue, they are expected to evolve from identifying available information, concerns, and areas of interest within the City, to evaluating and assessing this information, and ultimately identifying areas of potential opportunities where strategy implementation could occur through the leveraging of planned or existing initiatives.

For example, a stream, such as Goodes Creek requires bacteria reductions per the James River bacteria TMDL. In this same watershed, there are also Commercial Area Revitalization Effort (CARE) neighborhoods (yellow areas in Figure 7.6) that could be targeted for tree planting or implementation of green infrastructure for beautification purposes. Additionally, GIS analysis has identified stretches of Goode Creek as having deficient stream buffers (pink lines within the circled area in Figure 7.6). DPU and

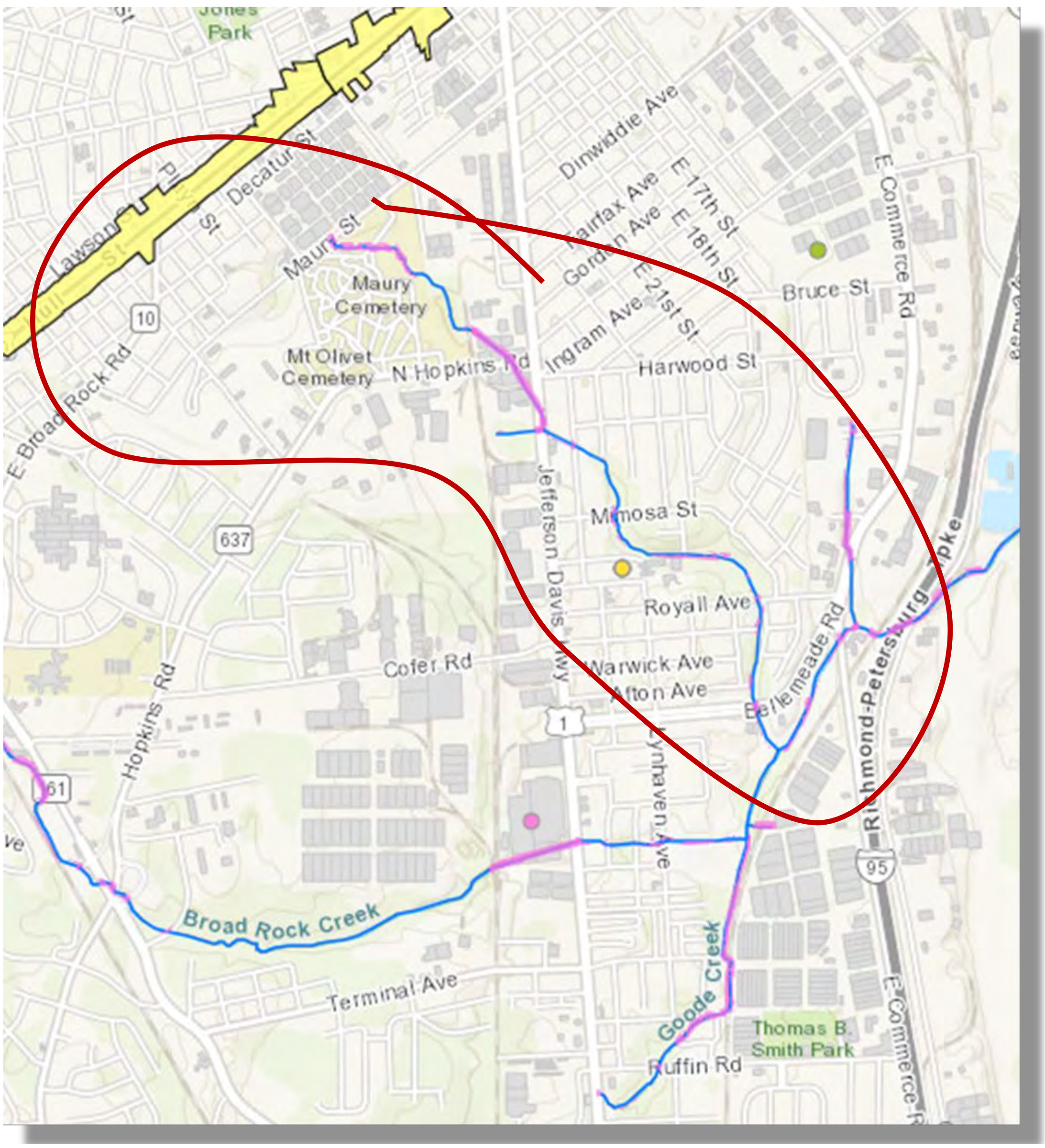


Figure 7.6. ArcGIS online map depicting the region near Goode Creek that contains City park property (Maury Cemetery), CARE neighborhoods (yellow), and buffer deficient streams (pink)

its stakeholders could identify potential project clusters such as these for additional evaluation of opportunities for strategy implementation.

Prioritization

Once data and information have been assessed and opportunities for projects or project clusters have been identified, these must be prioritized for further analysis and subsequent implementation. Regardless of projects being implemented piecemeal or in an integrated manner, there may continue to be diverging priorities driving implementation. A key element of this Framework Planning effort will involve identifying criteria by which these projects or project clusters are prioritized. This criteria development process will involve discussions with Technical Stakeholders over the summer of 2017. Several examples of criteria that may be used to evaluate projects or project clusters include if they:

- Address priority pollutants (and how much)
- Address other metrics identified by stakeholders (and how much)
- Address public health concerns
- Can be enhanced by partner resources (staff, funding, etc.)
- Include an educational component
- Address the social or economic elements of the Triple Bottom Line (Figure 7.7)
    - Are environmental justice concerns addressed?
    - Are lower SES neighborhoods targeted?
- Account for the City's Affordability Analysis
    - Can it be implemented with existing resources or does it require additional funding?
- Have stakeholder support

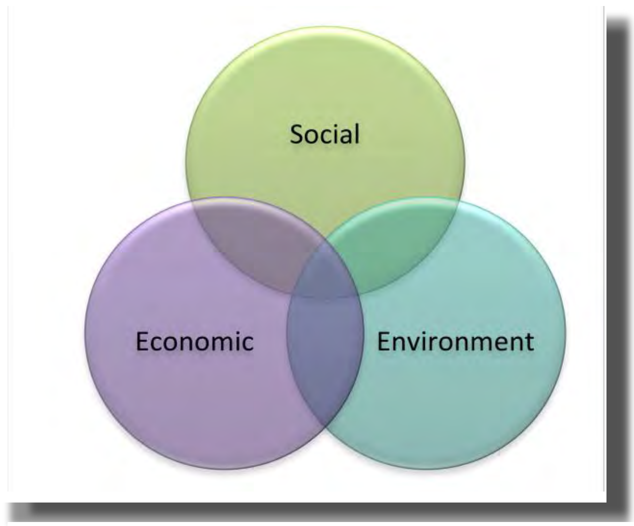


Figure 7.7 Elements of the Triple Bottom Line

Based on the number of criteria met, the projects/project clusters will be sorted into "very high", "high", "medium", and "low" priority projects. Additional detail on this prioritization process will be developed over the summer of 2017.

Plan Development

The Framework Planning process and the identification and prioritization of projects and project clusters will be documented in the Framework Plan. The Framework Plan will also demonstrate how the projects and project clusters will meet the goals and objectives of the Clean Water Plan, including the numeric targets of the strategies.

Schedule

The Framework Plan will reflect efforts to be implemented over the course of the five year permit cycle. While most of the strategies that have been developed for the Clean Water Plan are based on a five year timeframe, other, more resource intensive projects, such as those related to the CSO Infrastructure strategy, may require a longer time frame for full implementation. NPDES permits typically allow flexible compliance schedules for meeting the state WQS. These schedules can be as long as necessary to achieve the water quality objectives. The federal regulations specifically require the schedule in the permit to achieve limits "as soon as possible."

Funding

An appropriate level of funding will be important to the success of the City's approach to integrated planning on a watershed basis. The various programs involved in this planning process (i.e., stormwater, wastewater, CSOs, drinking water) have funding mechanisms available to them. Specific project funding will be developed concurrently with the development of the City's annual budget cycle. DPU's funding sources will be evaluated to determine the anticipated costs, funds available, and any anticipated funding gaps. Overall, it will be imperative that implementation takes into account the findings of the City's affordability analysis, which is expected to be finalized in 2017.

Implementation

The framework planning process will lead to the identification and prioritization of projects or project clusters that the City will fund for implementation. The sum of these projects will be consistent with the high level strategies defined in the Clean Water Plan.

There are several important concepts that will be taken into account through implementation. For instance, it is envisioned that implementation will occur incrementally over the course of the permit cycle (e.g., 10 acres of riparian buffers will not necessarily be restored all at once or within only one project, but may be addressed through the implementation of several projects/project clusters). Additionally, it may be determined that once more refined analysis is performed during or prior to the design/build phase of a project, that a particular project or project element cannot be achieved in its entirety. Flexibility is incorporated into implementation through adaptive management. If it is found that one strategy cannot be implemented in whole or in part, DPU will work to identify an alternative approach to achieving the same or similar pollutant reductions and other identified goals and objectives.

Implementation of projects, particularly those that involve stakeholders or other City departments, will require significant coordination. In addition to regular Technical Stakeholder meetings to provide updates on progress, DPU will convene a workgroup of those organizations involved in these implementation efforts. As projects are implemented, associated benefits (pollutant reductions, area treated, other metrics addressed) will be tracked as well. Measuring progress made under the Clean Water Plan as a result of project implementation is discussed further in Chapter 8.

8. Measuring Progress

Once targets have been established and strategies have been identified to address watershed goals, an approach must be developed to monitor and measure progress made in association with these implementation efforts. As the City's implementation moves forward, measuring progress will include determining if goals have been met, if progress has been deemed sufficient, or if changes should be made within the program to try to improve the level of progress made.

Determining the level of progress that has been made as a result of the City's investments is a key element to the success of the Clean Water Plan and its ultimate support by the public, stakeholders, and elected officials. Measuring progress; however, can be complex. Targets may be established at various scales (i.e., site scale, sub-watershed, watershed, city scale). Implementation actions can also include a wide range of options including structural and non-structural practices as well as practices that address various source sectors (i.e., stormwater, wastewater, non-point sources). As a result, the approach used for measuring progress under the City's program must be flexible enough to account for these variations in scale and options that will be employed to mitigate pollutants and meet the City's goals.

Measuring progress will be done in a holistic manner based on data from the City's monitoring programs, modeling efforts, and other programmatic information (e.g., implementation targets, such as miles of stream buffers restored per year or number of residents reached by outreach efforts). Each of these elements is outlined in Table 8.1 and is discussed further below.

Table 8.1. Monitoring activities and associated outcomes implemented under the Clean Water Plan

	Activities	Outcomes
Water Quality Monitoring	Instream water quality, biological (e.g., macroinvertebrates), CSO and WWTP discharge monitoring	Progress made toward pollutant reduction targets in permit
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
		Identify sources, stressors, or pollutants of concern
		Identify trends over time
	BMP monitoring	Effectiveness of specific BMPs or source reduction efforts
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
Programmatic Monitoring	Tracking strategy implementation	Progress made toward strategy implementation goals (e.g., acres of green infrastructure implemented)
		Progress made in pollutant reduction through strategy implementation (e.g., pounds of TN reduced through green infrastructure implemented)

		Progress made toward pollutant reduction targets identified in permit
Modeling	Receiving water, CSS, and watershed modeling and analysis	Progress made in bacteria WQS compliance
		Progress made in bacteria load reduction
		Progress made in reduction of CSO events or volume discharged

Each element of this process to evaluate Clean Water Plan progress will occur on a regular/annual basis over the course of the permit. Reporting on each of these elements will occur annually per VPDES permit requirements. At the end of the permit cycle a more comprehensive review of the progress made within this integrated planning framework will be compiled and included with the next VPDES permit application.

Water Quality Monitoring

As part of the watershed characterization effort, described in Chapter 3, historical water quality monitoring was compiled and evaluated including:

- James River monitoring carried out by VCU and other agencies
- In-stream monitoring of streams like Gillies Creek and other small tributaries within the city
- End-of pipe monitoring of CSO and WWTP discharges
- Data on other sources of pollution within the City

These data were organized and incorporated into a GIS-based geo-database. These water quality data were used to assess spatial and temporal trends, identify data gaps, and provide the water quality monitoring data needed to assess baseline conditions. Once implementation of the projects and programs in the Clean Water Plan has commenced, newly collected monitoring data can be used to evaluate changes from these baseline conditions.

Monitoring Program Development

Drivers behind the development of a monitoring program are often the regulatory requirements specifying monitoring objectives or collection of specific data elements. For DPU, these requirements will stem from the VPDES permit. As the Clean Water Plan and associated integrated watershed-based VPDES permit is finalized, DPU will assess its existing monitoring program to determine if it will provide the data needed to achieve the objectives of the permit. Examples of monitoring objectives include:

- Assess spatial and temporal trends of monitoring sites along the James River and its tributaries
- Evaluate the performance of specific BMPs or source reduction efforts
- Evaluate the health of the City's waterbodies
- Identify or evaluate parameters of concern
- Identify or evaluate potential sources of stressors
- Assess progress toward permit targets

Permit-driven objectives along with the identification of any additional data needs will ultimately determine the monitoring design. For instance, to evaluate stressors in a watershed, targeted monitoring would be conducted upstream and downstream of a key source(s). Monitoring could include sampling during different environmental conditions (e.g. dry and wet weather, high and low flow, seasonal effects), and point source and BMP flow and quality sampling. Conducting biological and habitat assessments also provide links between instream conditions and pollutants.

Alternatively, to evaluate the overall health of the City's waterbodies, a probabilistic monitoring design would be developed that includes multiple randomly selected sites throughout the City. This approach would allow DPU to show overall conditions and, as Clean Water Plan implementation occurs over time, how integrated planning is benefitting the City's waterbodies.

In addition to DPU's own objectives, the City may want to determine if other local stakeholders have monitoring objectives that complement its own. Broader coordination can result in the development an integrated monitoring program that could broaden the scope of the monitoring plan while identifying efficiencies to reduce resources directed at monitoring efforts.

Programmatic Monitoring

As a number of the City's watersheds reach past Richmond's borders and are impacted by sources outside the City's control, water quality monitoring efforts alone will not necessarily provide an accurate representation of the City's progress in achieving the goals and objectives of the Clean Water Plan. In addition to water quality monitoring, a programmatic approach will be evaluated to determine its effectiveness.

As discussed in Chapter 4, an extensive effort was undertaken to develop goals and objectives for this Clean Water Plan as well as strategies that would achieve these goals and objectives. Tracking these strategies to measure progress will occur in several ways.

Tracking Strategy Implementation Targets

Each strategy was written to include quantifiable targets for implementation (e.g., acres of green infrastructure, acres of riparian area restored, miles of stream reengineered, etc.). Evaluating the extent to which the strategies are being implemented and targets are being met will be an important mechanism for tracking progress. If targets are not being met or strategies are not being implemented, the City will evaluate why this is the case and determine if other alternatives are available that will result in achieving the same or similar progress towards goals and objectives.

Strategies are comprised of multiple implementation efforts (e.g., all of the projects that would result in 104 acres of green infrastructure implementation in the MS4 area). DPU will continue to use several tools to track these projects. Currently, a database is used to track practices as they are implemented. The City's existing GIS will also serve as the basis for this tracking effort.

Tracking Strategy Pollutant Reductions

Tracking the anticipated pollutant reductions associated with these strategies will also be an important component of measuring progress of the Clean Water Plan. EPA's Chesapeake Bay Program (CBP) has established pollutant reduction credits for many of the stormwater BMPs proposed in association with the Clean Water Plan strategies. To ensure consistency with the CBP and the targets established for the City through the Chesapeake Bay TMDL, these BMP credits will be used as the basis for tracking of pollutant reductions through implementation of strategies.

As strategies are implemented, associated pollutant reductions for total nitrogen, total phosphorus, and total suspended solids will be calculated. These credits will be tracked in a geodatabase, which will allow for the geolocation of associated projects within the City's various watersheds.

While the Chesapeake Bay TMDL pollutants have established pollutant reduction credits assigned to various practices, bacteria, the other key pollutant in this Clean Water Plan does not. As a result, bacteria reductions achieved through strategy implementation will be based on literature values as well as the results of modeling efforts (discussed further below).

Comparing Pollutant Reductions to Targets

As discussed previously in Chapter 6, pollutant reduction targets (see Table 6.6) will be included in the City's VPDES permit. Tracking of progress toward these targets will help assess strategy implementation in the various watersheds[10]. This will help DPU determine if sufficient progress is being made, if larger implementation efforts are required, if more funding is necessary, or if additional partners are needed to increase implementation. To help make these determinations, funding and other staff resources and amount of stakeholder participation will be evaluated in comparison to implementation of programs and practices and, ultimately to environmental improvements. Based on Clean Water Plan evaluation, modifications will be made to the program as part of the Plan's adaptive management approach.

Evaluating pollutant reductions as well as locations of these reductions within the City will help DPU not only determine if targets are being achieved, but if various watersheds or sections of the City should receive additional focus for implementation.

Modeling

The Modeling Framework will continue to be used as needed to evaluate the water quality improvements related to the implementation of projects and strategies. Metrics that will be evaluated by the Modeling Framework include progress made in bacteria WQS compliance, progress made in overall bacteria load reduction, and progress made in reducing CSO events or volume discharged. The quantification of these metrics will be used as part of the programmatic monitoring efforts (as discussed in the previous section).

[10] While water quality monitoring will be used, in part, to evaluate progress toward achieving targets, EPA's CBP promotes tracking of progress through credits applied to various implementation types. This approach will also be used to evaluate Clean Water Plan progress.

9. Next Steps

The Clean Water Plan has resulted in a comprehensive understanding of the City's watersheds and associated water resources. This includes an understanding of the pollutant sources and stressors within the City; the monitoring data that has been collected to date, as well as where additional data area needed; and the characteristics of the watersheds, such as soils and impervious surfaces. Additionally, the Clean Water Planning process has identified the goals and objectives and associated metrics that will guide the City moving forward. It also includes a plan for identifying control projects and programs that can be updated and adapted throughout the plan's implementation.

The next step is to use the Clean Water Plan to develop a watershed-based VPDES permit. Watershed-based permitting has been long supported by EPA and allows multiple pollutant sources to be managed under one permit. For Richmond, these pollutant sources are CSO, wastewater, and stormwater via the MS4 and direct drainage. The Clean Water Plan provides the planning framework and strategies to manage these sources and prioritize control projects based on their improvements to local waterways. Therefore, the Plan will be included in the VPDES permit as a source of data and provide information to be included in the "Special Condition" section related to BMPS to be implemented and additional monitoring to be done to track progress. The Clean Water Plan will also be included in the Permit Fact Sheet as an information source.

Once the watershed-based VPDES permit is issued to the City, next steps include implementing the projects and programs in the Clean Water Plan and conducting monitoring and modeling to measure progress towards the goals of the plan. While this first permit cycle will include targets consistent with the strategies identified in the planning process, continued implementation will be a long-term process that will span multiple five-year VPDES permit cycles. Therefore, the Clean Water Plan will require updating for each successive VPDES permit using the adaptive management approach described in the previous section. Future VPDES permits will be pursued as watershed-based permits until the Clean Water Plan is fully implemented.

The City will also continue to engage stakeholders to inform them of activities and associated progress towards the goals of the Clean Water Plan, and solicit their input on Plan updates. This engagement process will likely be simplified now that the considerable effort to develop the initial Plan has been completed.

More information on EPA's perspective on watershed-based permitting as it pertains to a watershed-based VPDES permit for the City is provided in the following section to illustrate the consistency between its requirements and the Clean Water Plan elements.

Adaptive Management

The adaptive management approach to water resources and regional wastewater management is increasingly recognized as the most appropriate and economically efficient way to identify problems, assess alternative solutions, and implement targeted corrective actions. The adaptive management approach has been, and will continue to be, implemented during each step of the Clean Water Planning process.

Adaptive management will be critical for the success of Richmond's plan as any new data collected through the course of this effort will need to be reviewed on a regular basis and used to refine/modify the Clean Water Plan so it is up-to-date and accurate. An adaptive management approach will also be a key component of the framework the City will use to monitor the progress made through the Clean Water Plan. As mentioned above, assessment of progress will involve periodic comparison to the various targets established through previous steps of this process.

While strategies include targets, the Clean Water Planning process includes an adaptive management component that provides flexibility should some unforeseen issue arise regarding a particular strategy. For example, it may be determined over time that green infrastructure in the MS4 is only feasible on 80 acres (rather than 104 acres), or it may be riparian area restorations will require more implementation on private land than originally calculated. In such situations, the City will have to evaluate ways to expand other strategies/opportunities to work toward achieving the Clean Water Plan's goals and objectives. This may include expanding other strategies so that a similar pollutant reduction is accomplished or measures of additional metrics are reached. Alternatively, as implementation moves forth, stakeholders or additional Departments within the City may participate more than originally planned. This could add resources, expand implementation, and potentially result in efficiencies that can further streamline the Clean Water Plan effort.

Adaptive management can also be informed by the monitoring conducted by the City. If water quality monitoring data are not showing expected improvements, the Clean Water Plan can be modified to increase levels of implementation, accelerate implementation schedules, alter BMP types planned for the watershed, etc. For example, a watershed where BMPs have been implemented, but in which the water quality or biological communities do not show improvement, may need additional implementation efforts. Alternatively, upstream water quality monitoring (e.g., from outside the City's boundaries) may show that the water quality upstream is also not meeting WQS, which may explain the lack of improvement despite BMP implementation. In contrast, improved water quality or functioning of biological communities may show that the implementation has been successful. It should be emphasized, however, that BMP implementation often results in a significant (years, decades) lag time in instream response to this implementation. This will be taken into consideration when evaluating progress. An alternative situation may occur where WQS are not being met, but a local biological community is no longer impaired. In such an instance, a use attainability analysis (UAA) may be warranted and would offer an alternative to expending money and resources to implement projects in areas that are not causing exceedance of the WQS.

While adaptive management will play a key role in keeping the City's planning efforts on track, it should be noted that implementation of a sufficient amount of control to meet the City's goals may take many years. Once controls are implemented, it may take even more time for in-stream benefits to be measurable, especially in the biological community or habitat conditions. The tracking framework will take long-term implementation into account and will be reflected within the tracking of targets.

Watershed-based VPDES Permit

The intent of the Clean Water Plan is to feed into an Integrated VPDES permitting process. The CWA (§ 402) established the NPDES permit (VPDES in Virginia) as the primary tool for controlling point source discharges, and therefore municipal discharges. An integrated approach would then allow the City to address all of its regulatory requirements (stormwater, CSOs, wastewater) as well as source water protection within the same plan thereby providing better and more efficient coordination of requirements.

Watershed-based permitting is an integrated approach to developing VPDES permits for multiple point sources within a defined geographic area (watershed boundaries).

The primary difference between this and the traditional approach to permitting is the consideration of watershed goals and the impact of multiple pollutant sources and stressors, including nonpoint source contributions, to receiving waters.

For many years, the EPA has supported and encouraged a watershed approach to addressing water quality problems. The approach is very flexible so watershed-based permitting can encompass a variety of activities ranging from synchronizing permit issuance, review and renewal of NPDES permits within a basin, to developing water quality-based effluent limits using a multiple discharger modeling analysis. One key component in the overall watershed-based permitting process is the integration of programmatic requirements. The watershed-based permitting framework provides the structure for examining a specific area and all of the stressors within that area, data related to the stressors and water quality goals, and prioritizing actions based on those data.

US EPA Support of Watershed-based Permitting

As discussed in more detail in Richmond's Methodology for Integrated Watershed Management (2014), EPA developed several guidance documents upon which the City has based its approach for Watershed-based permitting. These guidance documents include:

- Committing EPA's Water Program to Advancing the Watershed Approach (2002)

- Watershed-based National Pollutant Discharge Elimination System (NPDES) Permitting Implementation Guidance (2003)

- Watershed-based NPDES Permitting Technical Guidance (2007)

Additionally, as described in EPA's 2003 Watershed-based Permitting Policy:

> *A holistic watershed management approach provides a framework for addressing all stressors within a hydrologically defined drainage basin instead of viewing individual sources in isolation. Within a broader watershed management system, the watershed-based permitting approach is a tool that can assist with implementation activities. The utility of this tool relies heavily on a detailed, integrated and inclusive watershed planning process. Watershed planning includes monitoring and assessment activities that generate the data necessary for clear watershed goals to be established and permits to be designed to specifically address the goals.*

This Clean Water Plan provides the mechanism for identifying goals and pollutant sources that may impact the goals. This Plan also provides the framework for consolidating DPU's sources (MS4, CSO, WWTP) together and determining the best distribution of investment in these sources to produce the greatest environmental gain.

The watershed-based permitting process provides the tools to apply resources to protect the goals and serves as the mechanism to drive integrated planning in the City. The permit will include a "Special Condition" that will recognize specific components of the Clean Water Plan. The permit will require data collection that will serve to support the evaluation of program effectiveness. The permit will also include controls (limits or pollutant reduction targets) that look collectively at DPU's various sources and allow the City to work toward the goal of greater environmental benefit.

This approach was successfully demonstrated with the issuance of the watershed-based permit to Clean Water Services in Oregon. The permit provided for trading between point and nonpoint sources to address temperature issue in the receiving water. Additionally, the Neuse River Compliance Association holds a permit for discharges from 20 WWTPs in the watershed. These entities all share a collective nutrient limits that they must achieve collectively.

In the case of Richmond, a single permit will be appropriate given the discharges are all controlled by DPU. Regardless of format, the permit will focus on watershed needs.

References

EPA. 2007. Watershed based National Pollutant Discharge Elimination System (NPDES) Permitting Technical Guidance. EPA 833-B-07-004.

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect our Waters. EPA 841-B-08-002.

EPA. 2011. Memorandum from Nancy Stoner and Cynthia Giles on Achieving Water Quality through Integrated Municipal Stormwater and Wastewater Plans. October 27, 2011.

EPA. 2012a. Memorandum from Nancy Stoner and Cynthia Giles on Integrated Municipal Stormwater and Wastewater Planning Approach Framework. June 5, 2012.

EPA. 2003. Watershed-based National Pollutant Discharge Elimination (NPDES) Permitting Implementation Guidance. EPA 833-B-03-004.

EPA. 2013. A Quick Guide to Developing Watershed Plans to Restore and Protect our Waters. EPA 841-R-13-003.

Richmond DPU. 2002. Combined Sewer Overflow (CSO) Study: Long-term CSO Control Plan Re-evaluation

Richmond DPU. 2015. Watershed Characterization Report.

Richmond DPU. 2016. Richmond James River Bacteria TMDL Action Plan.

Saarikoski, H.; Barton, D.N.; Mustajoki, J.; Keune. H.; Gomez-Baggethun, E. and J. Langemeyer. 2015. Multi-criteria decision analysis (MCDA) in ecosystem service valuation. In: Potschin, M. and K. Jax (eds): OpenNESS Ecosystem Service Reference Book. EC FP7 Grant Agreement no. 308428. Available via: http://www.openness-project.eu/sites/default/files/SP_MCDA.pdf

Virginia DEQ. 2016. Final 2014 Integrated Report

Appendix 1. Modeling Report

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1 Executive Summary

1.1 Introduction

In 2014, the City of Richmond began a multi-year effort to develop an Integrated Water Resources Management Plan (herein after called the RVA Clean Water Plan). The goal of this plan is to achieve improvements to water quality that will help the city meet its regulatory obligations under the Clean Water Act (CWA). Part of the Clean Water Plan involves developing strategies for the coordinated management of the City's water utilities, including wastewater treatment, drinking water treatment, stormwater runoff, combined sewer overflows (CSOs), and sanitary sewer overflows (SSOs), all of which are assets that are typically permitted and managed separately. By holistically considering all of the City's water utilities in the development of the Clean Water Plan, the City will be more efficient and cost-effective with their ratepayer-funded resources, and provide greater benefit to local waterways than the traditional siloed approach used for permitting and management.

A key step towards the development of the Clean Water Plan was the development of a water quantity and quality modeling framework. The purpose of the modeling framework is to quantify present day bacteria (*Escherichia coliform [E.coli]*) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the RVA Clean Water Plan-related strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. Additionally, the modeling framework provides a platform for comparing the CSO reduction projects included in the City's CSO Long Term Control Plan (LTCP) against alternative CSO reduction projects that may provide similar benefits but at a reduced cost.

The purpose of this report is to document the development, calibration, and application of these models.

1.2 Model Development

Three models were used to achieve the modeling objectives, and together they comprise the modeling framework (Figure 1-1). These three models include:

- A watershed model to simulate flow and bacteria loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system (CSS) service area. This model was developed using the EPA Storm Water Management Model (SWMM) software.
- A collection system model to simulate flow and bacteria loads from the CSS. The CSS model is an existing model that is used by the City of Richmond for Wastewater Master Planning to support implementation of the CSO Long Term Control Plan and to prepare the Annual CSS Reports. This model was developed using the EPA SWMM software, and was adapted for use in this study.
- A receiving water quality model that computes bacteria concentrations in the James River resulting from the various sources of bacteria to the river. The outputs of the watershed and CSS models are used as inputs to the receiving water quality model. The receiving water quality model was developed using the EPA-supported Environmental Fluid Dynamics Code (EFDC) software.

Water quality data were used to inform the development and calibration of the models. Section 2.2 contains detailed figures showing the extent and key features included for each model.

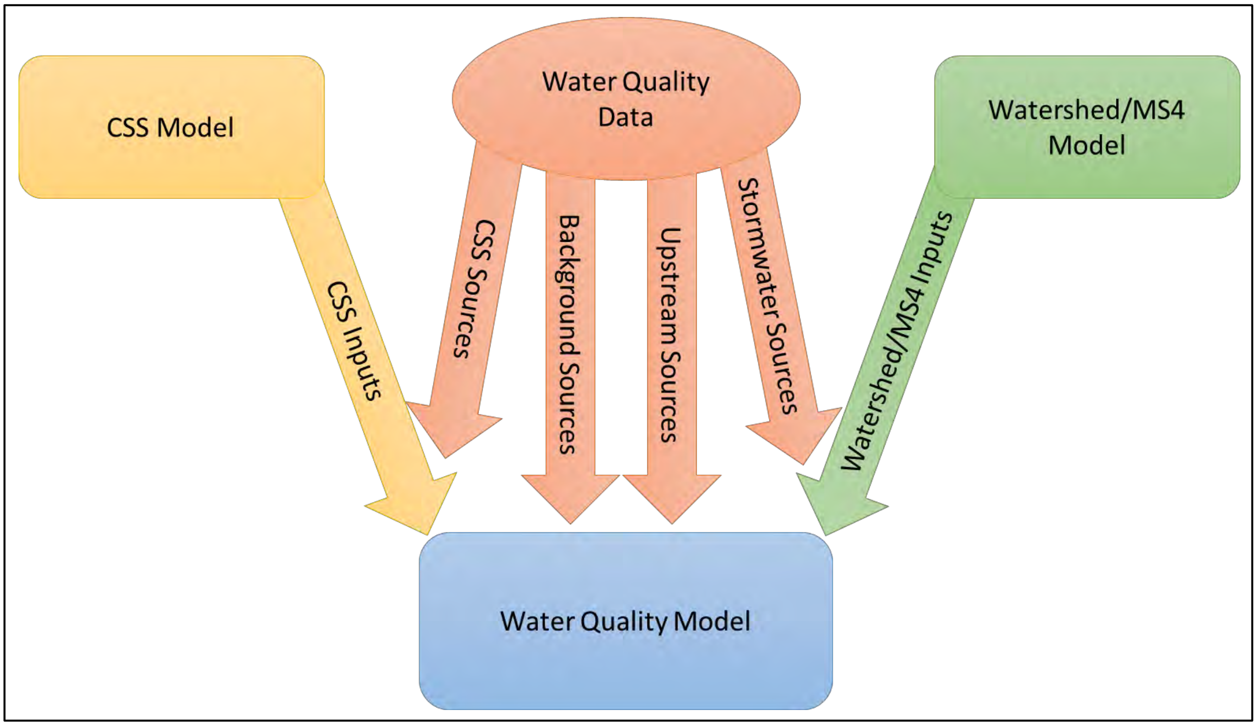

Figure 1-1: Modeling Framework Schematic

1.3 Model Calibration

- Model calibration is the process of adjusting model parameters and assumptions within defensible ranges to achieve reasonable agreement between modeled and observed environmental conditions. The calibration process demonstrated that the modeling framework is sufficiently well calibrated to support the following modeling objectives:
- Design the modeling framework to provide a reliable and reasonably complete accounting of bacteria sources to the James River;
- Develop the modeling framework using sufficiently complete and accurate site specific data;
- Calibrate the models using reasonable assumptions consistent with the site data, literature, and professional judgment;
- Achieve a level of model accuracy that is adequate to support decision making;
- Apply the models for a period including a wide range of common environmental conditions (i.e. river flow and precipitation conditions); and,
- Evaluate and synthesize model output to interpret major sources of current bacteria water quality impairment and to forecast future bacteria water quality conditions.

1.4 Model Application

After the water quality modeling tools were developed and calibrated, they were jointly applied to assess water quality benefits associated with the selected strategies. For this purpose, the model was applied for a 3-year simulation period, 2011 through 2013, that includes an average rain year (2011), a dry year (2012, less than normal precipitation), and a wet year (2013, more than normal precipitation). To date, the model has been applied to evaluate the following conditions or strategies:

- Current conditions: Best representation of current conditions, and includes all the combined sewer system improvement projects that were included in Phase I and Phase II of the CSO Long Term Control Plan.
- Baseline Conditions: represents the current conditions, plus all the currently funded Phase III CSS improvement projects from the LTCP.
- Green Infrastructure in the MS4 Area Strategy: represents the baseline conditions, plus the implementation of 104 acres of green infrastructure on city-owned area in the MS4.
- Green Infrastructure in CSS Area Strategy: represents the baseline conditions, plus the implementation of 18 acres of green infrastructure on city-owned area in the CSS area.
- CSS Infrastructure Strategy: Implementation of CSS projects included in the LTCP: represents the baseline conditions, plus all the remaining unfunded Phase III collection system improvement projects from the LTCP.

The sequencing of the modeling applications is shown in the figure below.

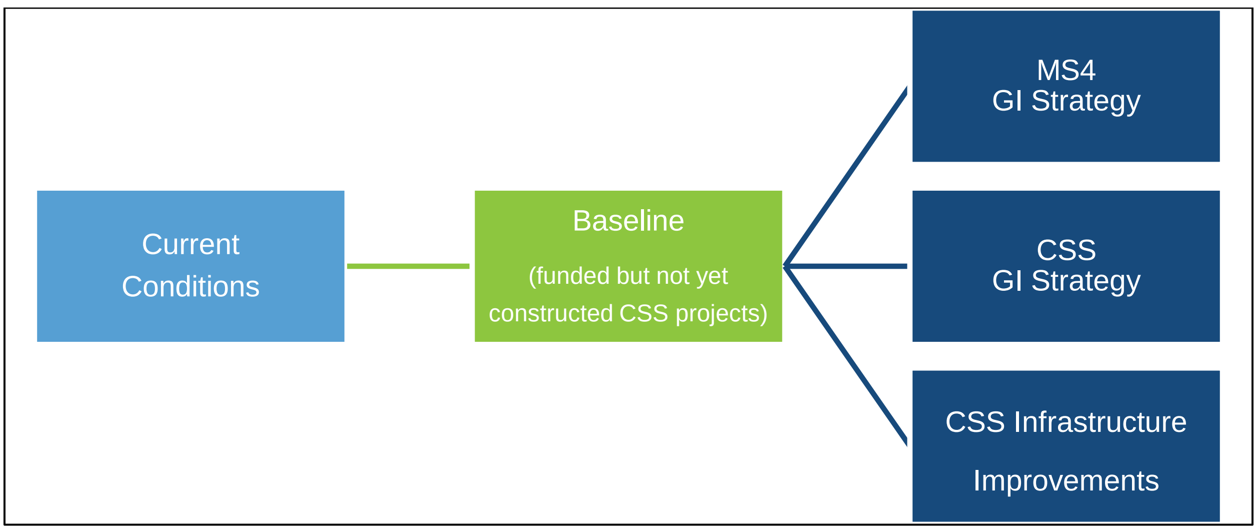

Figure 1-2: Sequencing of Model Applications

These strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges (which can include pollutant loads from the City's MS4), expressed as billion CFU per year
- Overall average percent increase in monthly geometric mean (geomean) water quality standard (WQS) compliance in the James River at the downstream city limit
- Reduction in number of CSO events per year
- Reduction in CSO volume, expressed as million gallons per year

These water quality benefits were then entered into an Excel-based strategy scoring calculator tool that integrates the benefits of strategies across a wide range of Goals and Objectives. More information on the strategy calculator can be found in Appendix D of the RVA Clean Water Plan. Water quality benefits were also assessed on a monthly basis relative to the two existing water quality standards: a monthly geometric mean standard and a statistical value threshold (STV) standard.

1.5 Major Model Findings

Major findings of the water quality modeling are as follows:

- Current *E.coli* bacteria water quality standards are sometimes exceeded in the James River in Richmond.
- The two largest contributors to exceedances of WQS are sources upstream of the City of Richmond and CSOs.
- Eliminating the City of Richmond bacteria sources alone would not achieve compliance with WQS in the James River.
- Reducing CSOs via the RVA Clean Water Plan strategies would improve compliance with WQS.

1.6 Future Use of Model

The Modeling Framework will continue to be used as needed to evaluate the water quality improvements related to the implementation of projects and strategies. Additionally, it is anticipated that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost. Metrics that will be evaluated by the Modeling Framework include progress made in bacteria WQS compliance, progress made in overall bacteria load reduction, and progress made in reducing CSO events and volume discharged.

2 Introduction

In 2014, the City of Richmond began a multi-year effort to develop an Integrated Water Resources Management (IWRM) Plan (herein after called the RVA Clean Water Plan). The goal of this plan is to achieve improvements to water quality that will help the city meet its regulatory obligations under the Clean Water Act (CWA). Part of the Clean Water Plan involves developing strategies for the coordinated management of many of the City's water utilities, including wastewater treatment, drinking water treatment, stormwater runoff, combined sewer overflows (CSOs), and sanitary sewer overflows (SSOs), all of which are assets that are typically permitted and managed separately. By holistically considering all of the City's water utilities in the development of the Clean Water Plan, the City will be more efficient and cost-effective with their ratepayer-funded resources, and provide greater benefit to local waterways than the traditional siloed approach used for permitting and management.

A key step towards the development of the RVA Clean Water Plan was the development of a water quantity and quality modeling framework. The purpose of the modeling framework is to quantify present day bacteria (*Escherichia coliform [E.coli]*) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the Clean Water Plan-related strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. The purpose of this report is to document the development, calibration, and application of these models.

2.1 Model Purpose, Objectives, and Functions

The purpose of the modeling framework is to quantify present day *E.coli* concentrations in the James River and to predict future *E.coli* concentrations under management strategies that were developed by the city and stakeholders. The following modeling objectives supported the attainment of this project goal:

- Design the modeling framework to provide a reliable and reasonably complete accounting of *E.coli* sources to the James River;
- Develop the modeling framework using sufficiently complete and accurate site specific data;
- Calibrate the models using reasonable assumptions consistent with the site data, literature, and professional judgment;
- Achieve a level of model accuracy that is adequate to support decision making;
- Apply the models for a period including a wide range of common environmental conditions (i.e. river flow and precipitation conditions); and,
- Evaluate and synthesize model output to interpret major sources of current water quality impairment and to forecast future water quality conditions.

The following report documents how these objectives were achieved through the process of selecting, developing, calibrating, and applying the water quality modeling framework.

2.2 Model Selection

Three models, which comprise the Modeling Framework (Figure 2-1), were used to achieve the modeling objectives. These three models include:

- A watershed model to simulate flow and *E.coli* loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system service area;
- A collection system model to simulate flow and *E.coli* loads from the combined sewer system (CSS); and
- A receiving water quality model that computes *E.coli* concentrations in the James River resulting from the various sources of *E.coli* to the river.

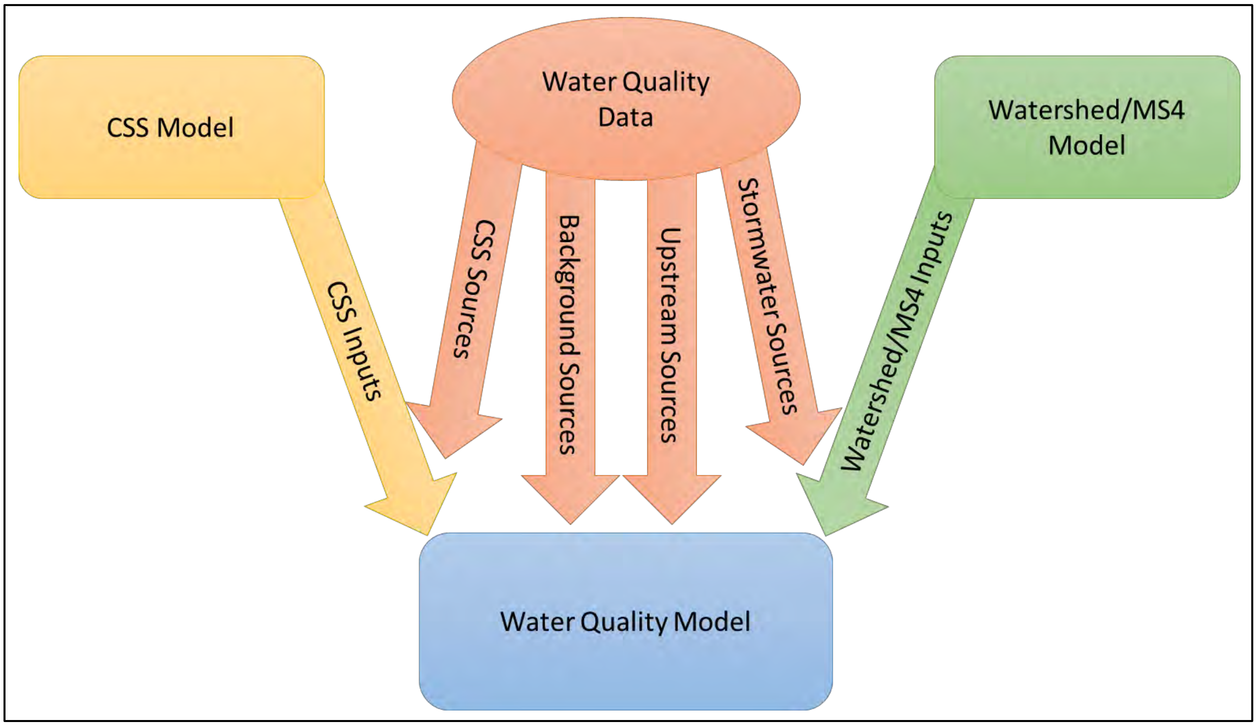

Figure 2-1: Modeling Framework Schematic

2.2.1 Watershed Model

Many watershed model software packages are available and these models vary in their recognition by USEPA and their applicability to the James River and its tributaries. The watershed model framework applied for this project is EPA Storm Water Management Model (SWMM), which is supported by the USEPA and has been successfully applied by the project team at similar sites and for related purposes. SWMM is a dynamic rainfall-runoff simulation model used for single event or continuous simulation of runoff quantity and quality from primarily urban areas (USEPA, 2015). Additionally, the CSS model was also developed using the SWMM software, so choosing SWMM for the watershed model provides consistency.

A variety of enhanced SWMM platforms are available that integrate the EPA SWMM software with user friendly interfaces and GIS capabilities. For this project, PCSWMM, developed by Computational

Hydraulics International (CHI), was used. The watershed model was developed using SWMM engine version 5.1.010, which is consistent with the version used for the CSS model.

2.2.2 CSS Model

The combined sewer system (CSS) model used for this study is based on the Wet Weather Combined Sewer (WWCS) model developed by Greeley and Hansen (GH) to support Richmond's wastewater collection system master planning, Long Term Control Plan (LTCP) implementation, and combined sewer system annual reporting. The CSS model is based upon the EPA Storm Water Management Model (SWMM) framework and uses the SWMM engine version 5.1.010. The model is operated within the PCSWMM environment.

2.2.3 Receiving Water Quality Model

The receiving water quality model was developed based on the EFDC modeling framework (Environmental Fluid Dynamics Code). This model has been applied to support numerous CSO water quality projects and is suitable for representing hydrodynamic conditions occurring in the James River, including the transition from riverine to estuarine conditions, and low head dam hydraulics. EFDC is a state-of-the-art finite difference model that can be used to simulate hydrodynamic and water quality behavior in one, two, or three dimensions in riverine, lacustrine, and estuarine environments (TetraTech 2007a, 2007b). The model was developed by John Hamrick at the Virginia Institute of Marine Science in the 1980s and 1990s, and it is currently maintained under support from the USEPA. The model has been applied to hundreds of water bodies, including Chesapeake Bay and the Delaware River.

The EFDC model is both public domain and open source, meaning that the model can be used free of charge, and the original source code can be modified to tailor the model to the specific needs of a particular application. As a result, EFDC provides a powerful and highly flexible framework for simulating hydrodynamic behavior and water quality dynamics in the James River.

2.3 Model Extent

The model extent defines the spatial or geographic boundary to which the model applies. The extents of the three models are described further below.

2.3.1 Watershed Model

The watershed model incorporates watersheds for 23 tributaries that contribute flow to the portion of the James River that falls within the receiving water quality model extent, and is shown in Figure 2-2 below. The tributaries represented in the watershed model were selected based on two criteria: they have been classified as impaired for *E.coli* on the 2014 VADEQ 303(d) list, or they are expected to contribute significant flows or *E.coli* loads to the James River receiving water quality model. Key features represented in the model include time-variable meteorology, watershed land use and land cover, topography (slopes), land use based pollutant loading, CSO flows and *E.coli* loads (simulated with the CSS model) to tributaries, and basic stream network geometry. The area serviced by the combined sewer system was excluded from the watershed model, as this area is represented in the CSS model. The final watershed model includes 44 square miles within the City of Richmond and 133 square miles outside the city.

2.3.2 CSS Model

The City of Richmond Collection System model simulates all sanitary flows from areas that are connected to the wastewater treatment plant as well as surface runoff from within the combined area. The model is described in the Wastewater Collection System Master Plan (Greeley and Hansen, 2015), and includes the following major features, as shown in Figure 2-3:

- The model contains 227 subsheds, including 99 subsheds representing 44,346 acres of sanitary area and 128 subsheds representing 11,523 acres of combined area. Storm water runoff from the sanitary areas is included in the watershed model.
- The total length of sewer pipes in the model is 235,683 ft. (44.6 miles) distributed over 1,020 individual pipe elements with diameters between 12 inches and 120 inches.
- The model represents all currently active CSO outfalls (29) plus the WWTP outfall used to discharge treated effluent.
- The model represents the Shockoe Retention Basin as well as the Hampton – McCloy Storage Tunnel.

2.3.3 Receiving Water Quality Model

The James River receiving water quality model extends from South Gaskins Road upstream of the Richmond city boundary, to Osborne Park downstream of the Richmond city boundary. The upstream limit of the model was chosen to be just upstream of Richmond's city limits. The downstream limit was chosen to be downstream of Cornelius Creek and near a frequently sampled water quality station. Twenty three miles of the James River are represented in the model with average grid cell dimensions of 140 feet wide and 340 feet long. Each grid cell spans the average depth of the river within their cell boundary. Six cells typically span the width of the river. Key features represented in the model include upstream James River flows; low head dams; the James River Falls near downtown Richmond, runoff; base flow, and *E.coli* loads from tributaries and MS4 areas; the City wastewater treatment plant, CSO discharges and *E.coli* loads; and tidal conditions in the Lower James River. Several of these features are shown in Figure 2-4.

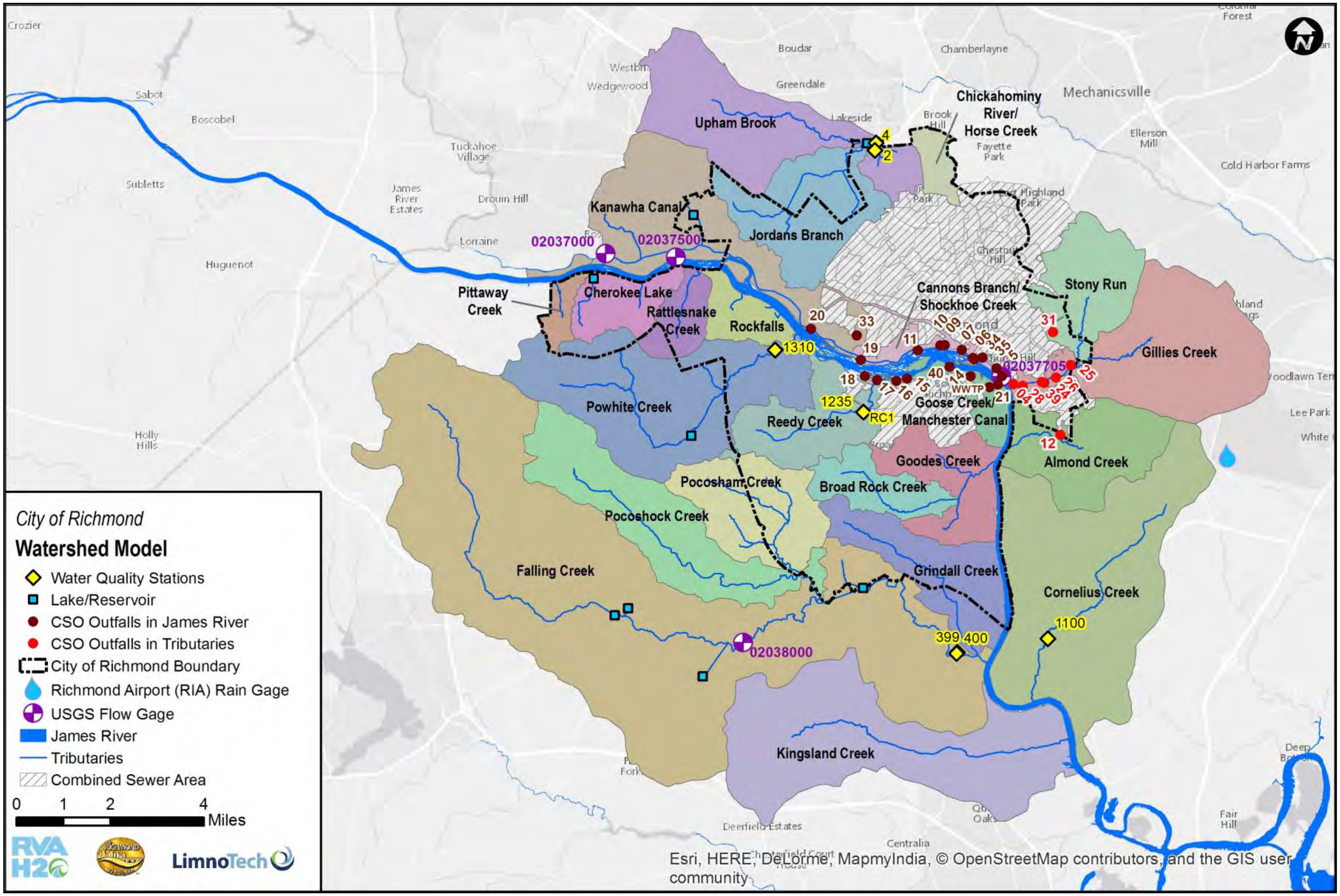

Figure 2-2: Extent and Key Features of the Watershed Model

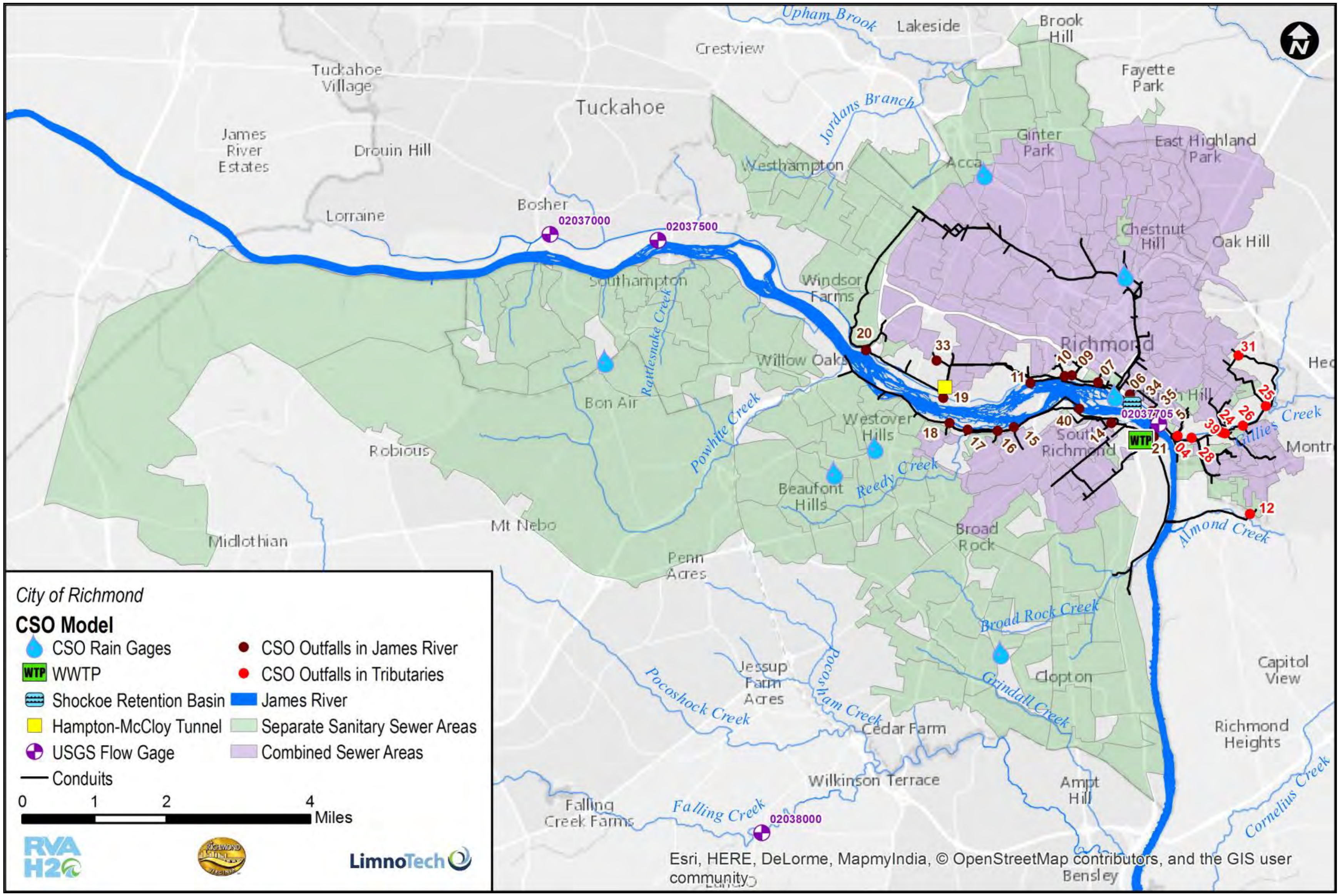

Figure 2-3: Extent and Key Features of the Richmond CSS Model

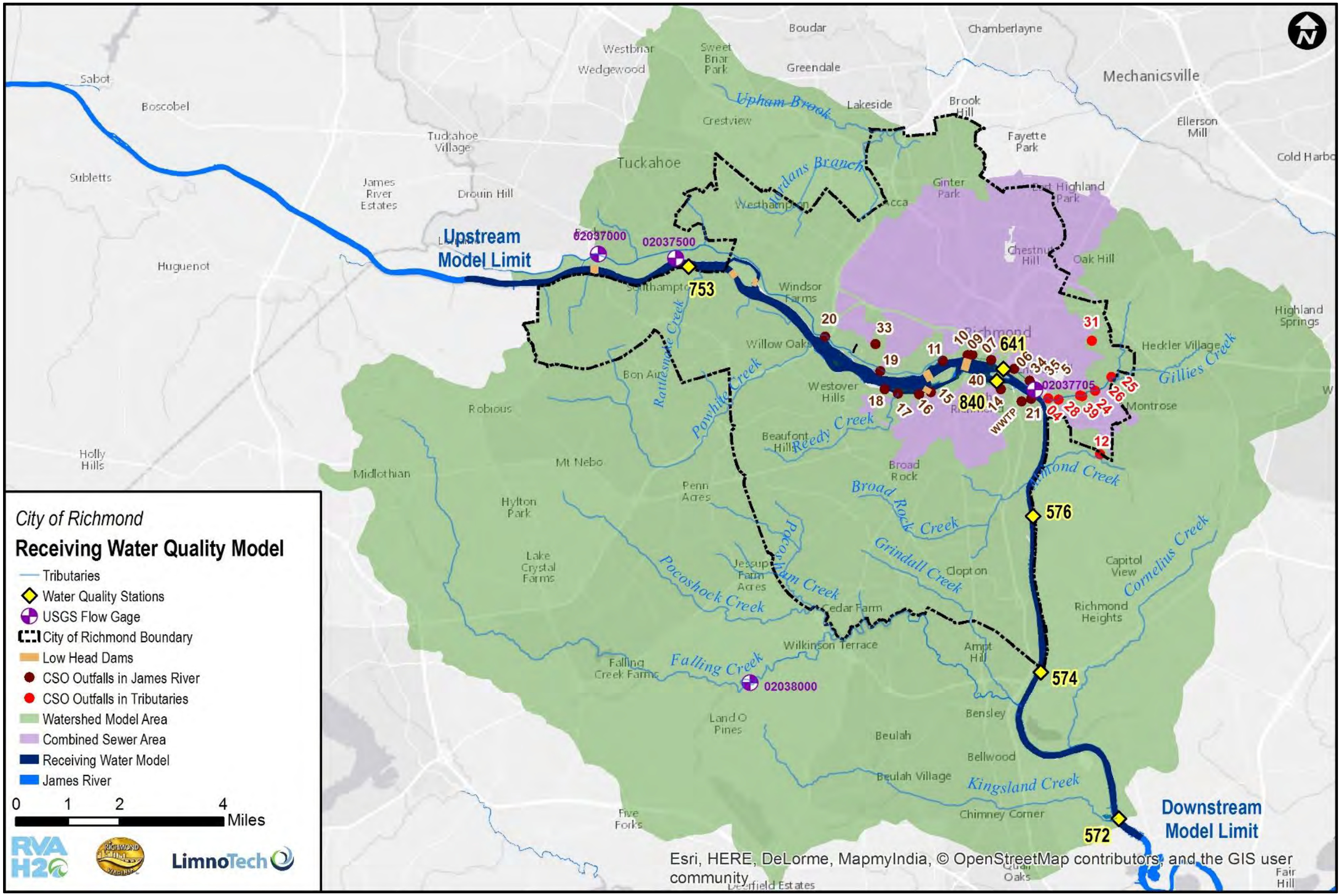

Figure 2-4: Extent and Key Features of the Receiving Water Quality Model

3 Model Development

Model development is the process of configuring a model to represent certain conditions of interest (e.g. combined sewer overflows, or bacteria concentrations) at a particular site. The model development process for the James River water quality modeling framework included definition of 1) important physical and chemical processes, 2) model inputs and assumptions influencing the modeled processes, 3) the spatial extent of model calculations, and 4) the time span of model calculations. This process is described below for each of the three components of the modeling framework.

3.1 Watershed Model

The Richmond watershed model consists of a set of subcatchments (representing the hydrology of the system) that are connected to a network of streams and impoundments (representing the hydraulics of the system). During wet weather events, runoff and associated pollutants are transported from the subcatchments to the stream network, and ultimately discharge to the James River (representing water quality in the system). To set up the watershed model in SWMM, processes influencing the system's hydrology, hydraulics, and pollutant transport must first be characterized. Several different types of data are needed to properly develop a SWMM model. These data characterize the properties that affect the hydrology and hydraulics of a SWMM model. The processes that were modeled and the relevant data that were collected and analyzed for the purpose of setting up the Richmond watershed model are described below.

3.1.1 Process Model Selection

The first step in model development is determining what hydraulic and water quality processes should be included. SWMM is capable of modeling six processes: rainfall/runoff, infiltration, snow melt, groundwater, flow routing, and water quality. To meet the objectives of this model four of these processes were used: rainfall/runoff, infiltration, flow routing, and water quality. It was assumed that snow melt typically does not generate significant runoff in the Richmond area. The contribution of groundwater to stream flow was approximated using a baseflow time pattern for select model nodes, so explicitly modeling groundwater was unnecessary.

3.1.2 Hydrology

3.1.2.a Subcatchments

The 23 tributary watersheds (Figure 2-2) were divided into smaller subcatchments through interpretation of a digital elevation model (DEM), political boundaries, and consideration of culverts, major roads, and water quality stations.

For several watersheds, delineated subcatchments existed from previous modeling efforts by Greeley and Hansen for the Richmond Stormwater Master Watershed Plans (Greeley and Hansen, 2012-2014). For these watersheds, the Greeley and Hansen delineations were re-evaluated using the above considerations, and the subcatchment boundaries were adjusted to meet the needs of this modeling effort. In total, the watershed model is comprised of 427 subcatchments.

To simplify model characterization, some subcatchments located outside of the Richmond city limits were replaced with inflow time series when data was available. Four subcatchments in the upstream portion of the Kanawha Canal watershed were replaced with data from USGS gage #02037000, which had an instantaneous flow time series available from 2007-2015.

3.1.2.b Meteorology

SWMM requires two meteorological inputs: a precipitation time series to generate runoff, and temperature data to calculate evaporation. Complete time series for precipitation (hourly and daily), daily minimum temperatures, and maximum temperatures were available at Richmond International Airport (RIA) from 1949 through current condition. All meteorological data at RIA were obtained from the National Centers for Environmental Information[1] (NCEI) which is operated by the National Oceanic and Atmospheric Administration (NOAA).

3.1.2.c Baseflow

Baseflow comprises the majority of stream flow during extended periods of dry weather, and can be estimated from measured flow data time series. The only gaged tributary within the model extent is in the upper portion of the Falling Creek watershed (USGS 02038000, Figure 2-2), so the flow record from this gage was used to approximate baseflow for all tributaries within the model. Using 30 years of flow data (1965-1994), monthly 7Q10 flows were calculated using methods from Risley et al (2008). These values were then normalized to watershed area (in mi^2) and applied to subcatchments that contribute to the streams and creeks that are included in the watershed model (Figure 3-1).

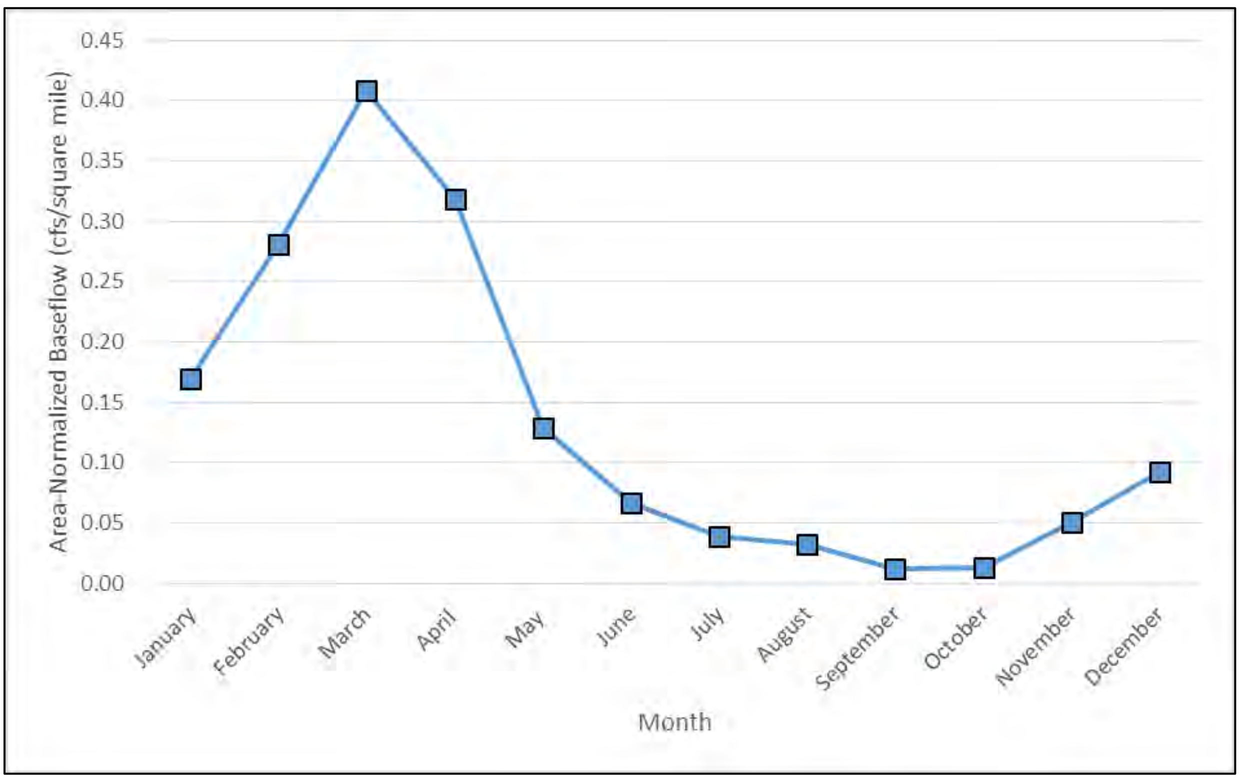

Figure 3-1: Monthly Baseflow Values Used in the Watershed Model

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[1] Formerly the National Climatic Data Center (NCDC). In 2015 NCDC merged with the National Geophysical Data Center (NGDC) and the National Oceanic Data Center (NODC).

3.1.2.d Soil infiltration

SWMM offers several methods for soil infiltration (listed in order of increasing complexity): Curve Number, Horton's, and Green-Ampt. The Green-Ampt method requires site-specific knowledge to characterize infiltration parameters, which were not readily available for this project. Therefore, the Horton method was selected for the watershed model. Horton's method uses a set of parameters that defines the maximum infiltration rate, the minimum infiltration rate, the decay rate for changing from maximum to minimum infiltration rates, a recovery rate for changing from minimum to maximum infiltration rates, and an overall maximum infiltration volume. These parameters are determined based on the hydrologic soil groups that are present in the watershed model extent.

The hydrologic properties of soils influence the how quickly and how much precipitation is converted to runoff. In general, soils can be classified by hydrologic soil group (HSG). There are four basic HSGs, called HSG A, HSG B, HSG C, and HSG D. Soils in group A have the lowest runoff potential, while soils in group D have the greatest runoff potential (Mockus et al., 2004). These four basic classifications can then be broken down into dual classifications such as A/D or B/D. Dual classifications represent soils that are classified as group D because of a high water table, making them behave as though they have a high runoff potential. However, if the water table were lowered, these soils would have a lower runoff potential (such as group A or B).

To characterize the soils within the model extent, data were downloaded from the Soil Survey Geographic (SSURGO) database provided by the National Resources Conservation Service (NRCS). A wide range of HSGs are represented within the SWMM model extent (Table 3-1). In addition to the four standard categories (HSG A through D), several dual classifications are also represented. These dual classifications were assumed to be undrained, and were therefore assigned the same soil properties as HSG D. There were also nine soil types with no official hydrologic soil group classification (Table 3-2). Based on the descriptions provided by NRCS, it was assumed that most of these unclassified soils were poorly drained and would have a high potential for runoff (Mockus et al., 2004). Therefore, they were assigned the same soil properties as HSG D.

The soil infiltration parameters associated with each HSG were estimated from tables provided in the *User's Guide to SWMM 5* (James et al., 2010). An average minimum and average maximum value from the suggested range was used for the infiltration rate. In the absence of detailed soil data, the decay constant and drying time were assumed to be the same for all soil types within the model extent, and a maximum infiltration volume was not specified.

Table 3-1: Description of hydrologic soil groups within watershed model extent

Hydrologic Soil Group	Description	Area (mi^2)	% Total
A	Soils with low runoff potential	17.9	9.1%
A/D	Soils with high runoff potential unless drained. Otherwise classified as HSG A.	0.4	0.2%
B	Soils with moderately low runoff potential	75.8	38.7%
B/D	Soils with high runoff potential unless drained. Otherwise classified as HSG B.	20.0	10.2%
C	Soils with moderately high runoff potential	30.3	15.5%
C/D	Soils with high runoff potential unless drained. Otherwise classified as HSG C.	10.9	5.6%
D	Soils with high runoff potential	5.5	2.8%

Table 3-1: Description of hydrologic soil groups within watershed model extent			
Hydrologic Soil Group	**Description**	**Area (mi^2)**	**% Total**
Unknown	See Table 3-2	33.0	16.8%
Water	N/A	2.2	1.1%
	TOTAL	**196.0**	**100.0%**

Table 3-2: Description of the "Unknown" Hydrologic Soil Group within watershed model extent			
Hydrologic Soil Group	**Soil Type**	**Area (mi^2)**	**% Total**
Unknown	Urban land	20.1	10.2%
Unknown	Udorthents-Dumps complex, pits	6.7	3.4%
Unknown	Udorthents, loamy, borrow pits	0.2	0.1%
Unknown	Udorthents, loamy	1.4	0.7%
Unknown	Gravel pit	2.2	1.1%
Unknown	Udorthents, clayey	0.001	0.0%
Unknown	Borrow pit	0.004	0.0%
Unknown	Orthents-Udults-Mine pits complex	0.4	0.2%
Unknown	Made land	2.0	1.0%
	TOTAL	**33.0**	**16.8%**

3.1.2.e Impervious Area and Slope

Percent impervious area and percent slope strongly influence the amount of precipitation that becomes stormwater runoff. Large amounts of impervious area and/or high slopes can lead to high-volume and "flashy" runoff. To estimate median percent impervious area for each subcatchment, a percent impervious area raster was downloaded from National Land Cover Database (NLCD) (Xian et al., 2011). Percent slope for each subcatchment was estimated using the National Elevation Dataset (NED) (Gesch et al., 2002).

3.1.2.f Additional Subcatchment Parameters

In addition to the major subcatchment parameters listed in the sections above, there are five additional parameters that were characterized for each subcatchment: Manning's n coefficient for overland flow over pervious and impervious areas, depression storage for pervious and impervious areas, and percent of impervious area with zero depression storage. These parameters can be used to adjust the shape and the timing of the hydrograph. For simplicity, these parameters were set to constant values for all subcatchments. The values were selected based on literature values from the SWMM5 manual (James et al., 2010)

Table 3-3: Additional SWMM Subcatchment Parameters			
Parameter	**Value**	**Description**	**Source**
Manning's n for overland flow over impervious area	0.018	Average value	Mc Cuen et al. (1996)
Manning's n for overland flow over pervious area	0.25	Dense grass	Mc Cuen et al. (1996)
Depression storage for impervious area	0.075	Average value for impervious surfaces	ASCE (1992)
Depression storage for pervious areas	0.15	Average value for lawns	ASCE (1992)
Percent of impervious area with no depression storage	25%	Default value in SWMM	

3.1.3 Hydraulics and Routing

SWMM offers three methods for routing water through the stream network (listed in order of increasing complexity): steady flow, kinematic wave, and dynamic wave. Dynamic wave was selected for the routing portion of the model. The dynamic wave model can account for channel storage, backwater, entrance/exit losses, flow reversal, and pressurized flow. The dynamic wave model allows for more complex flow conditions than the other routing methods, but requires the use of smaller computational time steps, so choosing this method generally increases the model run times. Theoretically, it produces more accurate results.

3.1.3.a Stream network

Modeling efforts focused on tributaries within the watershed model extent that are currently impaired for bacteria or have active or planned stream restoration projects. Some of these streams originate outside of the city of Richmond, but flow through the city. Two types of small, intermittent streams were not explicitly modeled: unimpaired tributaries within the City of Richmond and unimpaired tributary streams outside the City of Richmond. Unimpaired small tributaries within the city limits were omitted largely because there were no data on stream geometry or characteristics. Upon visual inspection of aerial photography, it was noted that most of these waterbodies were ditches. The small, intermittent streams outside the city were omitted because they are not within Richmond's service area.

The network of streams modeled was developed using two sources. Hydrography data were acquired from the National Hydrography Dataset (NHD Plus), which is developed by USEPA Office of Water and the US Geological Survey (USGS) (USEPA, 2005). This dataset includes nationwide spatial information about a variety of waterbodies, including streams, rivers, lakes, and ponds. NHD Plus was modified using a digital elevation model developed from LiDAR mass points. Modifications of the NHD Plus flow lines were made to align with the lowest nearby digital elevation model (DEM) elevation and with aerial photographs.

The DEM was also used to characterize irregular transects for each section of the stream channel. Using the DEM, one transect was drawn for each subcatchment in the model. Each transect was drawn at a location that was considered to be most representative of the stream channel within a subcatchment.

3.1.3.b Infrastructure

The modeling of culverts was limited to structures that were located on modeled tributaries. Culvert data were provided by the City of Richmond for portions of the watersheds within the city limits. Culvert locations and geometry were estimated for culverts located outside of the city. An initial estimate of culvert geometry was based on aerial photos from Bing maps and the DEM. Initial estimates were then adjusted during calibration under the assumption that culverts were designed to avoid flooding roadways.

The hydrology calibration process revealed that lakes and reservoirs significantly influence the timing of peak flows and their magnitudes. Nine lakes and impoundments were identified through the NHD dataset and subsequently modeled within the model extent, including Cherokee Lake, Cornelius Creek Lake, Falling Creek Reservoir, Gregory's Pond, Lower Beaver Pond, Lower Young's Pond, Rock Creek Park Lake, Upper Lake Bexley, Upper Young's Pond, and Westhampton Lake. When possible, data for these impoundments, associated weirs, and spillways were obtained from the US Army Corps of Engineers (USACE, 1979-1981). Otherwise, impoundment, weir, and spillway characteristics were estimated from aerial photographs, 2-ft contours created from Light Detection and Radar (LiDAR) data, and the DEM. Two conditions constrained the hydraulic behavior of impoundments in the model. First, impoundments were assumed to have a minimum constant water depth that was equal to the primary spillway elevation. Second, it was assumed that lakes and impoundments did not regularly overflow their banks. This seemed like a reasonable assumption because several of the impoundments are surrounded by buildings. If an impoundment regularly flooded in the model, the depth of the storage node was increased and the stage-storage curve was linearly extrapolated.

3.1.4 Water Quality

3.1.4.a Land use/land cover

For water quality modeling in SWMM, land uses must be defined in order to assign pollutant loading. To characterize land use within the model extent, land use data were acquired from the National Land Cover Database (NLCD). The data are generated by the Multi-Resolution Land Characteristics (MRLC) consortium and provided in a raster data format with a spatial resolution of 30 meters (MRLC 2016). NLCD 2011, the most recent version of this dataset, was used to characterize land use in the SWMM model (Homer et al., 2011).

The NLCD also provides data on percent impervious area (Xian et al., 2011), and this dataset was modified and used to estimate the median percent impervious area for each subcatchment. The modification of these data was necessary because the initial model runs during the hydrology calibration process underestimated gaged flows. This discrepancy was discovered through a watershed-scale analysis comparing NLCD impervious cover and a planimetric impervious layer provided by the City of Richmond. It revealed that the NLCD impervious layer underestimated the median percent impervious area, especially in less urban areas. A linear regression was used to develop a relationship between the two datasets and to adjust the NLCD impervious area to better match the planimetric data from the City. After the initial adjustment, the percent impervious area for each subcatchment was adjusted downward by 15%, in order to account for impervious areas that are not directly connected to a waterway or storm sewer. This is standard practice in watershed modeling because runoff from unconnected impervious areas typically first flow onto pervious areas where infiltration can occur, and any excess is then routed to the stream or storm sewer. Because the amount of directly connected impervious area is not known, this adjustment factor was used as a calibration parameter.

3.1.4.b Pollutant loading

In the watershed model, pollutants enter the tributaries in three ways: runoff from the tributary watersheds, baseflow, and CSO overflows. Build-up of pollutants on the watershed and their subsequent wash-off during runoff events are the dominant mechanisms for pollutant loading into tributaries. Pollutant concentrations in baseflow is effectively a calibration parameter that is set for consistency with dry weather pollutant data in the streams. CSO overflows to the tributaries are estimated using combined sewer model output and event mean concentrations (as described below in Section 3.3).

During dry weather periods, pollutants accumulate on subcatchments through a process called build-up. The two parameters that govern build up are the build-up rate, which is the rate at which pollutant accumulates on a subcatchment (expressed in units of cfu/acre/day), and the maximum buildup, which is the maximum amount of pollutant that can accumulate on a subcatchment (expressed in units of cfu/acre). Both of these parameters are represented in the model as a function of land use. To assign reasonable build-up rates and maximum build up to each land use, a review of literature values from across the country was conducted (see tables below). Literature values were not available for all land uses in the model, so in the absence of available data, the build-up parameters for the most similar land use were assigned. Initial model runs used the median build-up rate and the median of maximum build-up for each land use. These parameters were then were fine-tuned during calibration, using the 25th and 75th percentiles as reasonable limits on the range of potential values.

Table 3-4: Land Use Build-Up Rates (cfu/acre/day) Used in the Watershed Model

Land Use	Count	Q1	Median	Q3
Developed - High Intensity	21	6.24E+07	1.27E+09	2.12E+09
Developed - Low Intensity	12	8.13E+07	1.65E+09	2.60E+09
Developed - Medium Intensity	14	9.09E+07	1.50E+09	2.60E+09
Developed - Open Space	8	2.31E+08	1.57E+09	7.81E+09
Undeveloped	32	1.09E+08	1.43E+09	9.62E+09
Forest	9	5.07E+06	8.52E+06	1.41E+08

Table 3-5: Maximum Build-Up Rates Used in the Watershed Model

Land Use	Count	Q1	Median	Q3
Developed - High Intensity	7	9.57E+09	1.06E+10	1.41E+10
Developed - Low Intensity	4	1.06E+10	1.14E+10	3.44E+11
Developed - Medium Intensity	5	5.33E+09	1.02E+10	2.33E+11
Developed - Open Space	4	1.03E+10	1.40E+10	1.75E+11
Undeveloped	9	1.53E+09	2.95E+10	8.51E+10
Forest	5	1.53E+09	1.53E+09	1.67E+09

During wet weather periods, pollutants are depleted from subcatchments and delivered to streams through a process called wash-off. Similar to build-up, the amount of pollutant that washes off during a runoff event is dictated by land use-specific wash-off rate called the event mean concentration (EMC). EMCs for each land use were informed by a literature review. Runoff will continue to generate pollutant load until the available source of pollutant build-up has been exhausted. Literature values were not available for all land uses in the model, so in the absence of available data, the build-up parameters for the most similar land use were assigned. Initial model runs used the median EMC for each land use, and were then were fine-tuned during calibration, using the 25th and 75th percentiles as reasonable limits.

Table 3-6: Landuse Based E.Coli EMC Values Used in the Watershed Model

NLCD 2011	*E.coli* (CFU/100 mL)		
Cultivated Crops	1,945	8,440	26,567
Pasture/Hay	2,682	3,989	28,102
Forest	380	504	565
Wetlands (Woody/Herbaceous)	565	10,339	10,756

Table 3-6: Landuse Based E.Coli EMC Values Used in the Watershed Model			
NLCD 2011	***E.coli*** **(CFU/100 mL)**		
Developed - Open	2,479	2,479	25,856
Developed - Low Intensity	3,157	15,294	29,723
Developed - Medium Intensity	4,480	5,620	15,527
Developed - High Intensity	884	3,700	11,000

An *E.coli* baseflow concentration was assigned at each model location where baseflow was added. A literature review of urban TMDLs was conducted to determine a reasonable range of values. Initial model runs used the median *E.coli* concentration of 50 CFU/100 mL, which was then were fine-tuned during calibration, using the 25th (28 CFU/100 mL) and 75th (599 CFU/100 mL) percentiles as reasonable limits. The assigned baseflow *E*.coli concentration is the same for each tributary, and is a constant value over time.

CSO flows from the CSS model and *E.coli* concentrations were added to more accurately reflect water quality within CSO-impacted tributaries. There are eight CSOs that overflow into two tributaries in the model: Gillies Creek and Almond Creek. Inflow time series for these eight CSOs were generated by the CSS model. EMCs were assumed for the CSO discharges and were based on previous work on typical fecal coliform concentrations for CSOs in Richmond. The fecal coliform values were then adjusted to represent *E.coli* concentrations using the VADEQ translator (Lawson, 2003). An *E.coli* EMC of 205,000 CFU/100 mL was used for seven of eight CSOs in Gillies Creek. An EMC of 215,000 CFU/100 mL was used for the remaining Gillies Creek CSO and the one CSO in Almond Creek. Further information on the values selected for the CSO EMCs can be found in Section 4.1.

3.1.4.c In-Stream Decay Rate

In-stream bacteria fate and transport processes include die-off, settling to and resuspension from the streambed. The net effect of these processes are represented in the model through the use of a first-order decay rate. Typically, all of the streams in a modeled system will have the same decay rate, with the resulting losses of bacteria in each waterbody varying as a function of travel time through the stream network. An initial in-stream decay rate was set to 1.0/d based on the initial decay rate estimated in the 2010 James River TMDL (MapTech, 2010). This parameter was then adjusted during calibration. The decay rate was varied incrementally between 0.5/d and 2.0/d during the calibration phase.

3.2 CSS Model

The combined sewer system (CSS) model used for this study is based on the Wet Weather Combined Sewer (WWCS) model developed to support Richmond's Long-Term Control Plan Re-Evaluation (Greeley and Hansen, 2002). This CSS model was recalibrated and revised by Greeley and Hansen (GH) between 2010 and 2015 as part of the Wastewater Collection System Master Plan (Greeley and Hansen, 2015). This version of the CSS model is currently used by the city to produce the Combined Sewer System Annual Reports. This CSS model relies on boundary forcings (operating rules, observed flow time series and control decisions) that makes it unsuitable for hindcasting extended time periods and modeling CSS operational alternatives.

The primary SWMM processes and parameters used in the CSS model are similar to the ones described in Section 3.1 above with the exception that the CSS model does account for evapotranspiration as part of the rainfall - runoff process and does not include any internal system pollutant loading (pollutant EMC are assigned to the outfall discharge only). During the CSS model calibration process, 7 local rain gages were used while the NCDC gage at Richmond Airport was used for the IRWMP, due to limited data availability and reliability of the 7 local rain gages.

To prepare the CSS model for use in this study, it was reviewed and modified by Brown and Caldwell, as described in the “CSO Model Review and Advancement Strategy” technical memorandum by Brown and Caldwell (Brown and Caldwell, 2016). As part of this work, the following major changes and modifications were done:

- Reduction of the number of pipe elements to focus on the main interceptor network and improve model stability. This reduced the number of model pipes from 2,357 to 1,019.
- Definition of standard operating procedures for the WWTP by replacing the flow boundary condition, which required an observed plant influent time series with a simple outflow pipe limited to the plant capacity (e.g. 75 MGD for the model calibration)
- Definition of standard operating rules to control the major facilities like the Shockoe Retention Basin and eliminating the need of an external time series forcing for flow boundary condition at this location.
- Elimination of various inactive control rules
- Reduction of the number of subcatchments (and receiving nodes) by deleting those that flow to the neighboring county collection system
- Reduction of the number of unit hydrographs describing the baseflow I & I conditions

These changes were necessary in order to be able to run the model in hindcast mode for a long-term continuous period, and in order to operate the model for evaluating CSS alternatives.

3.3 Receiving Water Quality Model

Site specific data supported the development of both the hydrodynamic and water quality components of the EFDC receiving water model. Bathymetric data from the current FEMA Flood Insurance Study (FEMA, 2014) and from a USACE survey of the estuarine reach (USACE, 2013) were averaged over the model grid. In the upper, riverine reach, a cross-sectional average bed elevation was computed for each row of grid cells. In the lower, estuarine reach, a DEM was computed from the detailed USACE elevation data and averaged over the model grid. The modeled James River bed elevation profile is illustrated in the figure below.

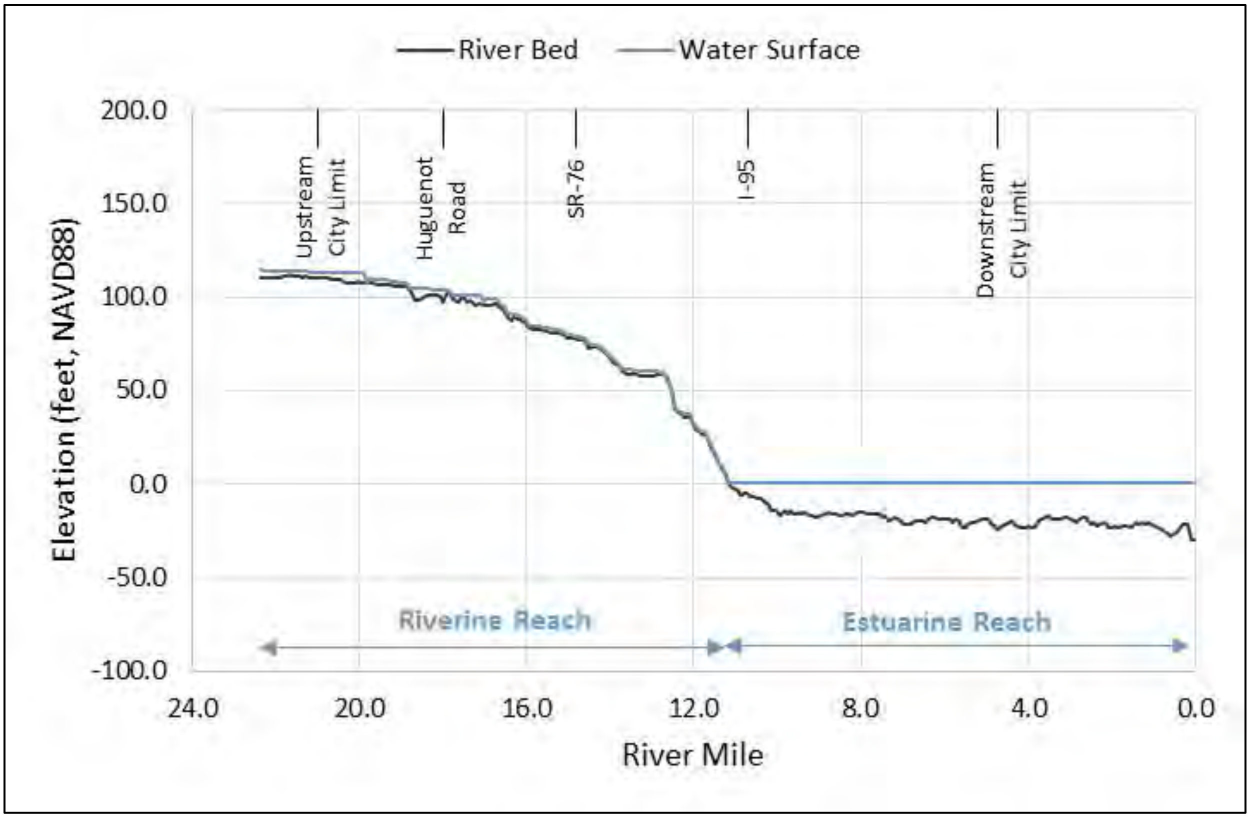


Figure 3-2: James River Elevation Profile

Tidal water levels from USGS Station #02037705 (James River at City Locks at Richmond, VA) were applied at the downstream boundary and the model was calibrated to adjust for the change in water levels between the gauging station and the downstream model boundary. This calibration, which is described in Section 4, accounts for differences in timing (phasing) of the tides between the two locations, and differences in non-tidal water levels associated with river flows.

Upstream James River flows from USGS Station 02037500 (James River near Richmond, VA) were directly applied at the upstream model boundary. For days when *E.coli* were sampled near the upstream boundary, these data were directly inputted to the model. For days when *E.coli* data were unavailable, upstream James River *E.coli* concentrations were estimated based on sampling data from a station at Huguenot Bridge. 112 samples at this location collected between 2011 and 2013 were used to develop a regression of flow and *E.coli* using the USGS LOADEST software package.

LOADEST is a program for "estimating constituent loads in streams and rivers" (USGS, 2017). The figure below illustrates the predicted relationship between James River flow and *E.coli* concentrations upstream of Richmond. The regression equation is as follows:

$$a_0 + a_1 * \ln Q + a_2 * lnQ^2 + a_3 * \sin(2pi * dtime) + a_4 * \cos(2pi * dtime)$$

Where:

- a_0, a_1, a_2, a_3, and a_4 are constants equal to 3.17, 1.27, 0.41, -0.79, and -0.04 respectively,
- Q is streamflow (cubic feet per second), and,
- dtime is time relative to the center time (days)

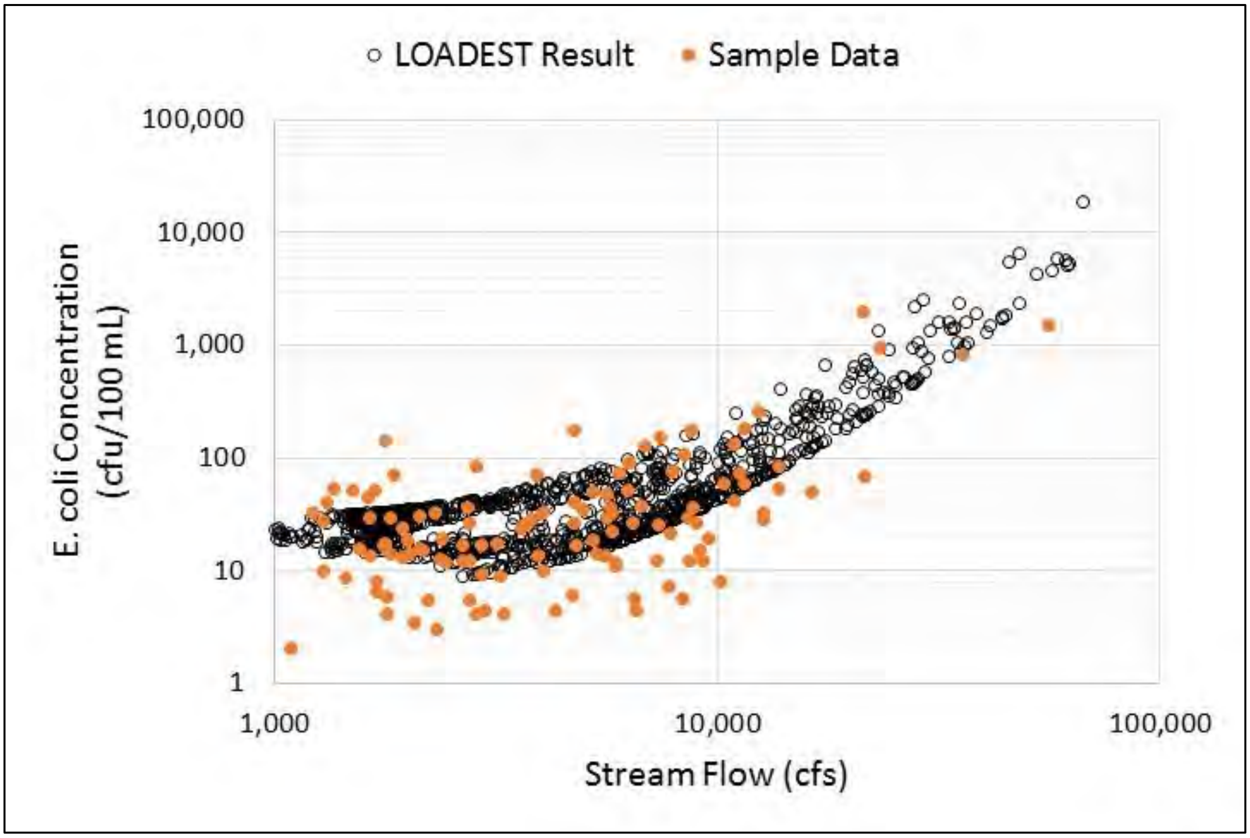


Figure 3-3: Regression of James River flow and *E.coli* concentration

Flows and *E.coli* concentrations associated with MS4 and watershed areas, and CSO discharges were computed from the watershed and CSS models, respectively. Flows and concentrations from the watershed model were input to EFDC at an hourly interval. Flows from the CSS model were input to EFDC at a five-minute interval due to the faster response time of the combined sewer system to rainfall relative to the watershed.

Fecal coliform event mean concentrations (EMCs) were previously calculated (and accepted by VADEQ) for the CSO discharges during the development of the Long Term Control Plan. These EMCs were calculated based on CSO outfall monitoring at several CSOs (Greeley and Hansen, personal communication, 11/15/2016). For this modeling effort, fecal coliform EMC concentrations were converted to *E.coli* concentrations using the VADEQ translator (Lawson, 2003). Table 3-7 summarizes the original fecal coliform EMCs and the translated *E.coli* values.

Consistent with the Long Term Control Plan, all influent to the WWTP was assumed to have an *E.coli* concentration of 235,000 CFU/100mL. It was assumed that influent receiving full treatment would result in an effluent concentration of 126 CFU/100 mL, consistent with the effluent concentration guidelines in the VAPDES permit (#VA0063177). For model application scenarios in which WWTP wet weather flow upgrades are proposed, effluent discharge concentrations were estimated based on the methods described in Section 5.

Table 3-7: Summary of fecal coliform and *E.coli* CSO EMCs				
CSO Districts	**CSO Drainage Areas**			
	Outfall Serial No.	**Outfall Location**	**Fecal Coliforms (#/100 mL)**	***E.coli* (#/100 mL)**
South Side James River Park	018	42nd Street	986,775	318,000
	017	Reedy Creek	986,775	318,000
	016	Woodland Heights	986,775	318,000
	015	Canoe Run	986,775	318,000
	040	CSO-1 OUT/SSJRP	986,775	318,000
North Side James River Park	011	Park Hydro	437,343	150,000
	010	Gambles Hill	437,343	150,000
	009	Seventh Street	437,343	150,000
	(008)[a]	(Sixth Street)[a]	437,343	150,000
	007	Byrd Street	437,343	150,000
	(036)[b]	(Virginia Street)[b]	437,343	150,000
Manchester Area (WWTP Area)	014	Stockton Street	86,266[d]	34,000
	013	Maury Street	86,266[d]	34,000
	021	Gordon Avenue	86,266[d]	34,000
Gillies Creek	005	Peach Street	612,230	205,000
	002	Orleans Street	612,230	205,000
	004	Bloody Run	612,230	205,000
	003	Nicholson Street	612,230	205,000
	(023)[c]	(Old Fulton Street Bridge)[c]	612,230	205,000
	024	White and Varina Streets	612,230	205,000
	025	Briel Street and Gilles Creek	612,230	205,000
	026	1250 feet east of Government Road	612,230	205,000
	(027)[c]	(Williamsburg Road and Gillies Creek)[c]	612,230	205,000
	028	800' North of Nicholson Street	612,230	205,000
	035	25th and Dock Streets	612,230	205,000
	039	550 feet Downstream from Government Road	612,230	205,000
Shockoe Creek	006	Shockoe Creek	315,369[d]	111,000
	034	19th and Dock Street	315,369[d]	111,000
Remote Locations	020	McCloy Street	647,000	215,000
	019	Hampton Street	647,000	215,000
	033	Shields Lake	647,000	215,000
	012	Hilton Street	647,000	215,000
	031	Oakwood Cemetery	647,000	215,000

4 Model Calibration

Model calibration is the process of adjusting model parameters and assumptions within defensible ranges to achieve reasonable agreement between modeled and observed conditions. Model parameters and assumptions are set to the extent possible based on site specific data. However, in some cases, calibration is necessary because site specific data are either limited or unavailable. The calibration process fine-tunes these parameters, within reasonable bounds, to improve model calculations.

4.1 Calibration Data

The calibration process relies heavily on site-specific data to guide the tuning of model inputs. Site specific data support identification of important spatial patterns or time trends in environmental conditions. These patterns often lend insights into the processes or sources most strongly influencing environmental conditions. In this way, the model calibration process involves interpreting site data to understand and bring the model into agreement with important conditions. Site data vary in their capacity to support such an interpretation depending largely on their quantity and locations. The following sections describe the site specific data available for calibration of the modeling framework and also describe the interpretation of these data.

4.1.1 Watershed Model

4.1.1.a Hydrology

The hydrology calibration for the watershed model relied on data from Falling Creek (USGS #02038000), which was the only continuous flow and water depth gage within the modeled area (

Figure 2-2). Daily average flow data was available from 1955-1994. It was assumed that calibrated parameters related to in-channel roughness, overbank roughness, and impervious area would be similar between Falling Creek and the remainder of the watershed. This assumption seems reasonable based on a comparison of key watershed characteristics that influence runoff, including impervious area, slope, and soil infiltration, in Falling Creek versus the other model subcatchments. This comparison is shown in the table below.

Table 4-1: Median value of key runoff parameters in Falling Creek compared to the rest of the model subcatchments

Key Runoff Parameter	Median Value in Model Subcatchments	Median Value in the Falling Creek Subcatchment
% impervious area	26%	22%
% slope	5%	7%
Min infiltration	2.5	2.7
Max infiltration	0.161	0.178

4.1.1.b Water quality

The selected water quality calibration period was calendar years 2011 through 2013. This time period had the greatest quantity of sampling data available and the greatest range of *E.coli* results, including high values that would be indicative of wet weather source impacts. Seven stations on five different tributaries were chosen to evaluate the water quality calibration (Table 4-2). Station selection was based on the quantity of available data during the calibration period, the proximity of the station to the mouth of the stream, distribution of stations in the model extent, and the size of the tributary. Stations near stream mouths were selected because they more accurately reflect the total *E.coli* load delivered to the James River for each tributary. Stations representing a varied spatial distribution and a variety of sizes were selected to evaluate the robustness of the calibrated parameters.

Table 4-2: Water quality monitoring stations used for watershed model calibration

Tributary	Station ID	*E.coli* Data (#)
Falling Creek	399/400	30
Cornelius Creek	1310	15
Powhite Creek	1100	12
Upham Brook	4	14
Upham Brook	2	7
Reedy Creek	1235/RC1	6

Similar to the hydrology calibration, the water quality calibration was limited by the available data. Because of the data limitations, the water quality calibration was viewed not so much as a definitive calibration, but as a reasonable estimate of tributary loads and their timing so that calibration of the James River receiving water quality model could move forward. If necessary, the watershed model calibration would be revisited if the results from the receiving water quality model indicated it was necessary. The final calibration of the watershed model would be considered complete once the water quality calibration of the James River model was complete. After initial tuning of the watershed model water quality parameters, tributary *E.coli* loads were passed forward to the James River receiving water model. The effect of these tributary loads on James River water quality was assessed through calibration of the James River model which is further described in 4.4.

Water quality data in the tributaries were limited in their capacity to describe wet weather conditions. Most of the data collected appeared to be sampled during dry weather periods, a time when *E.coli* concentrations are expected to be low. Additionally, for almost all stations, samples were collected once per day, and therefore do not capture the temporal variability of bacteria (also known as the "pollutograph") that is expected during a rainfall event.

4.1.2 CSS Model

The CSS model was calibrated by Greeley and Hansen in 2015 during the initial model development as described in the CSS model documentation of the Waste Water Collection System Master Plan (Greeley and Hansen, 2015). The calibration was done using monitoring data from 16 flow meters, 7 rain gauges, and one river level sensor near outfall CSO 06 (Figure 2-3). The monitoring period lasted 11 months, from July 2012 to June 2013. Several issues related to the metering were identified in the report, and not all data collected was suitable to be used for model calibration. Ten (10) wet weather events were selected from the monitoring period to perform the wet weather calibration.

4.1.3 Receiving Water Quality Model

The hydrodynamic calibration period for the James River receiving water quality model was calendar years 2011 through 2013. This is the same period used for the water quality calibration, and includes a wide range of James River flow conditions. Data from two USGS stations supported the hydrodynamic model calibration: one in the riverine reach (Station 02037500 at Huguenot Bridge) and one in the estuarine reach (Station 02037705 at the City Locks). Data from the riverine USGS station quantify the change in stream depth and velocity with river flow. Data from the estuarine USGS station quantify the amplitude and phasing of tidal water levels.

The water quality calibration period for the James River receiving water model was calendar years 2011 through 2013. As shown in Figure 4-1, this period contains nearly the greatest density of sampling data in the James River. It also represents a typical range of flow and precipitation conditions. While calendar year 2010 had the highest sample count, several of the samples resulted in non-detected *E.coli* concentrations so they were less informative for the model calibration.

Data from the six locations with the greatest quantity of samples with detectable *E.coli* concentrations guided the calibration. Three of these locations occur in the riverine reach and three occur in the estuarine reach. One station (#753) is upstream of all Richmond sources, two are near downtown Richmond and are influenced by CSOs (#641 and #840), and the remaining three are downstream of CSOs and beyond Richmond (#576, #574, and #572). These stations are shown in Figure 2-4.

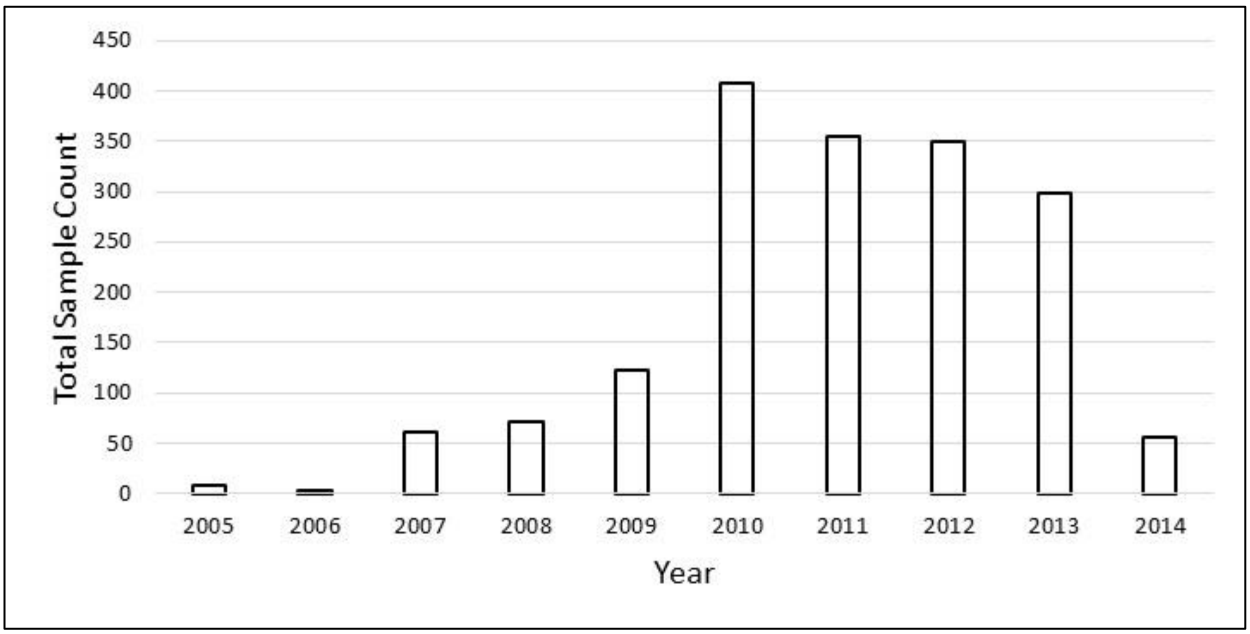


Figure 4-1: James River E.coli Water Quality Sample Count by Year

The calibration data were analyzed to identify patterns in water quality along the James River that would guide model calibration. Three significant observations were made. First, dry weather *E.coli* concentrations increase significantly moving from the upstream most station at Huguenot Bridge (station

753) to the downtown area (station 840).

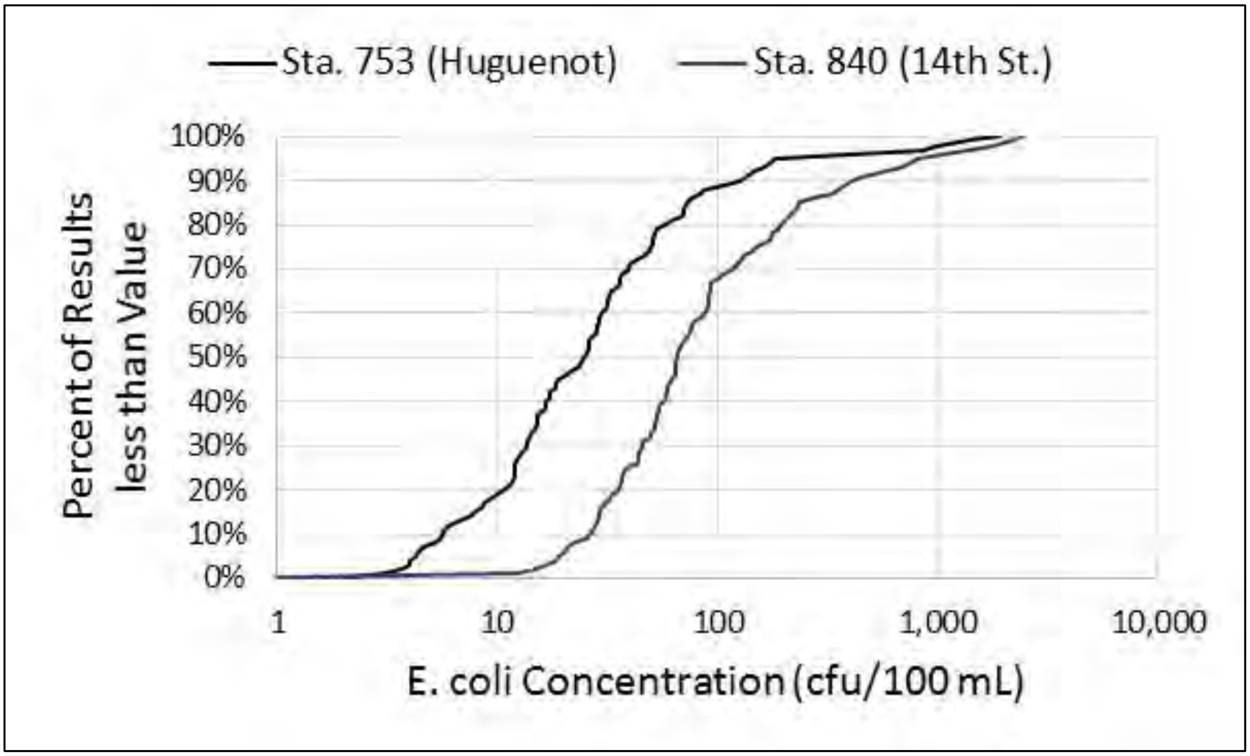


Figure 4-2 compares cumulative frequency distributions (CFDs) at the upstream station and a station near downtown. Median (50th percentile) *E.coli* concentrations increase from 25 to 66 CFU/100 mL, indicating a significant persistent source of *E.coli* to the river between these locations.

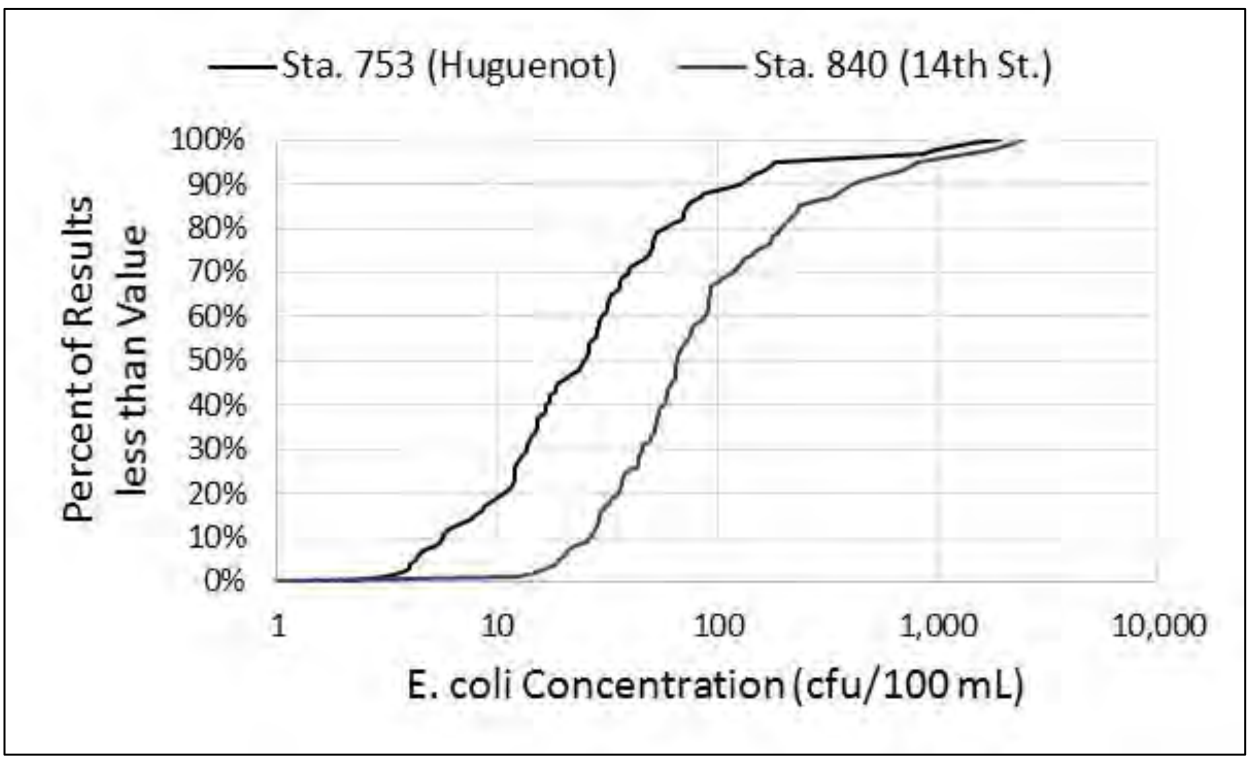


Figure 4-2: Increase in *E.coli* Concentrations from Huguenot Bridge to 14th St. Bridge

Second, *E.coli* concentrations are similar among station 840 on the south side of Mayo Island at 14th Street and stations 576, 574, and 572 which occur farther downstream in the estuarine reach.

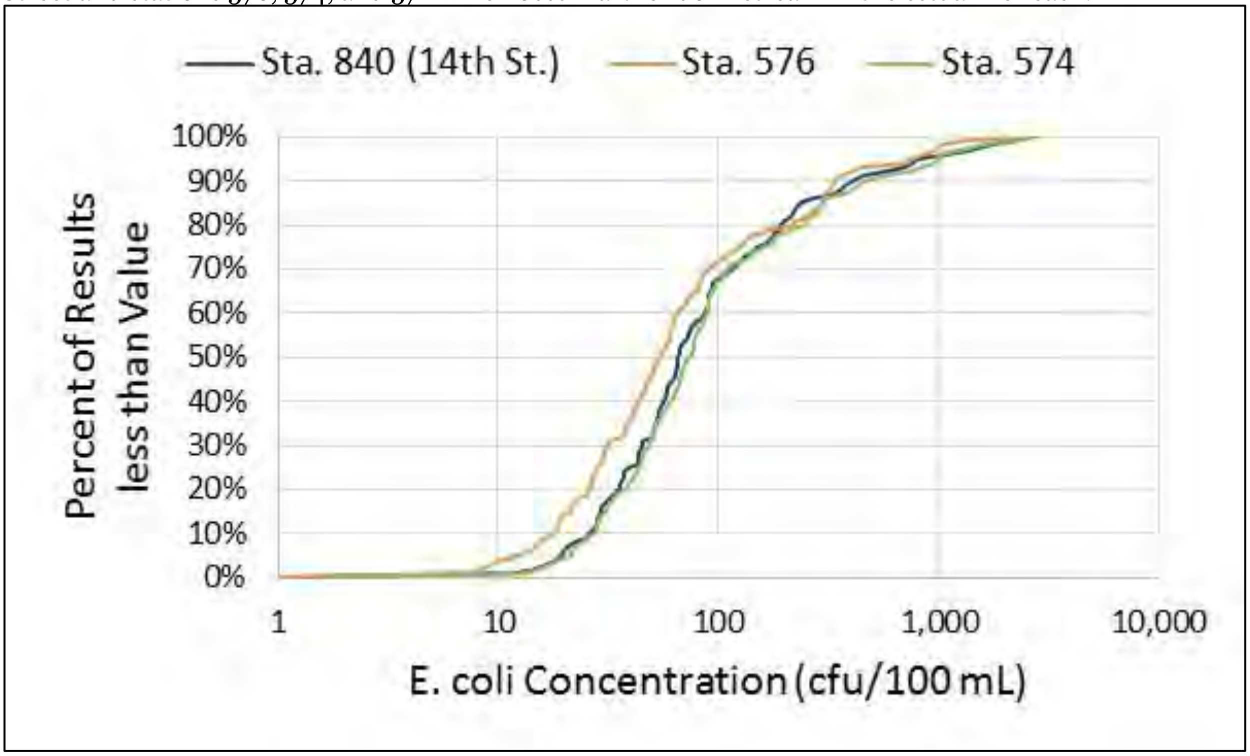


Figure 4-3 compares the cumulative frequency distributions (CFDs) among these stations. Similarities in the *E.coli* concentrations among these stations indicate that, most of the time, additional pollutant loads downstream of station 840 and on the north side of Mayo Island are small relative to the upstream *E.coli* load. Similarity in *E.coli* concentrations at these three locations also indicates that in-stream losses of bacteria are minor between stations 840, 576, and 574. Median (50th percentile) E.coli concentrations at stations 840, 576, and 574 are 66, 74, and 55 CFU/100 mL respectively.

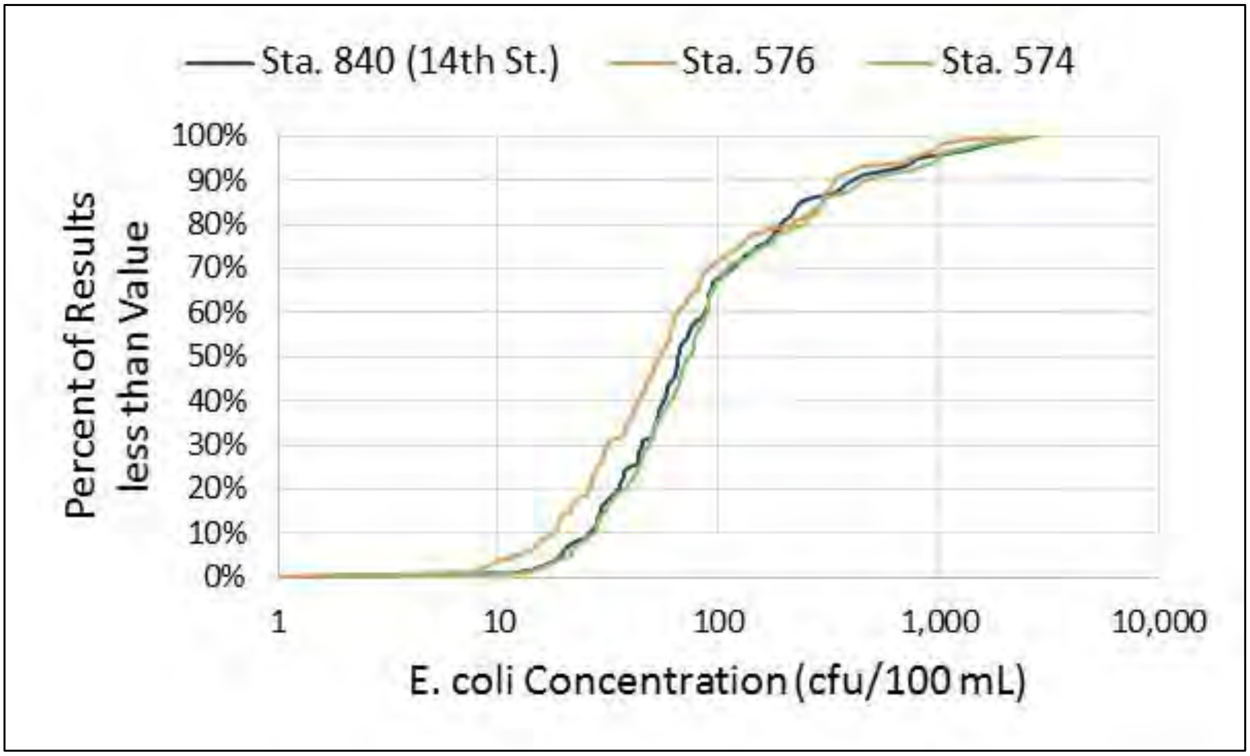


Figure 4-3: Similarity in *E.coli* Concentrations among Stations 840, 576, and 574

Third, *E.coli* concentrations at station 641 are significantly higher than at stations 840, 576, 574, and 572 and are assumed to be unrepresentative of ambient conditions on the north side of the island. If these data were representative of the total flow north of the island, then *E.coli* concentrations at downstream stations would be higher than data at station 841 on the south side of the island. Given the similarity in concentrations between stations 841, 576, and 574, it is assumed that samples at station 640 are not representative of the broader river flow north of the island. Samples at this location were taken within a protected embayment that receives discharge from CSO 06 (Shockoe Retention Basin discharge). The protected embayment may have flow properties different from the main section of James River (e.g. sheltered location, stagnant water, little flushing from the James River, direct CSO discharge) that may relate to the unrepresentatively high *E.coli* concentrations observed there.

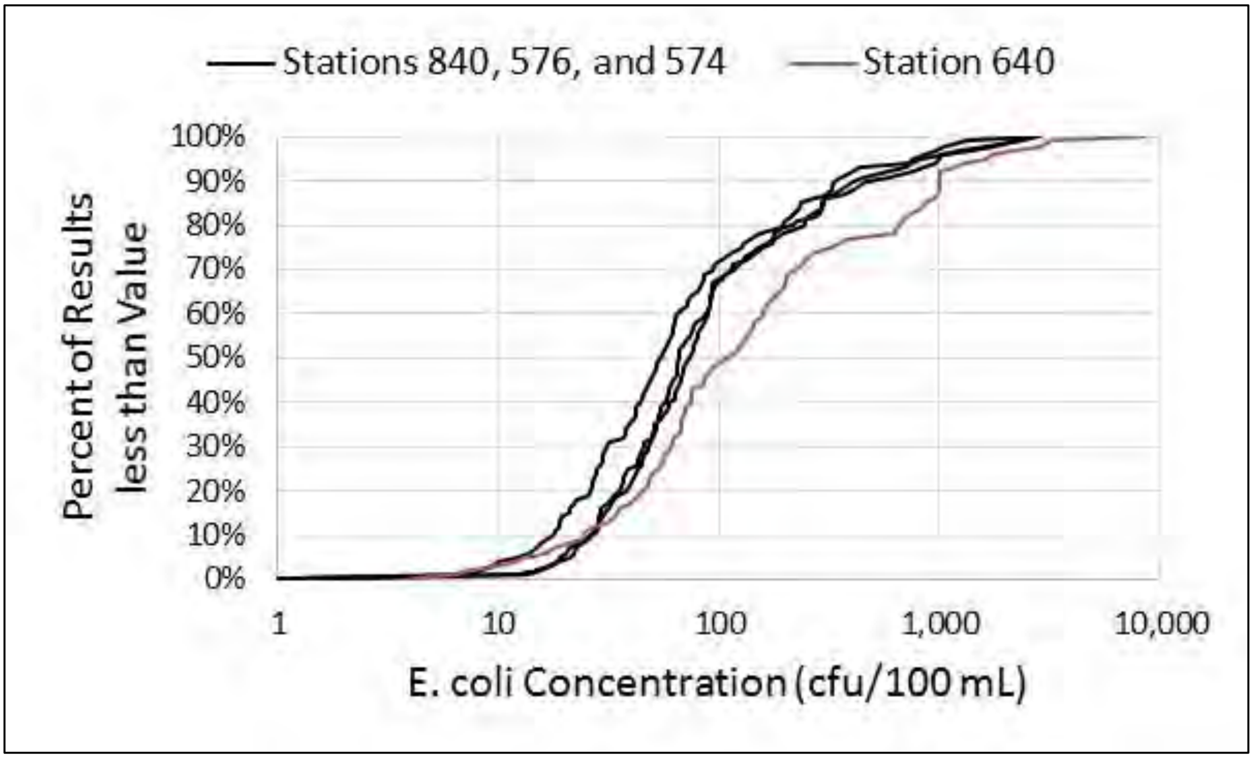


Figure **4-4** illustrates differences between *E.coli* concentrations at station 640 and the surrounding stations.

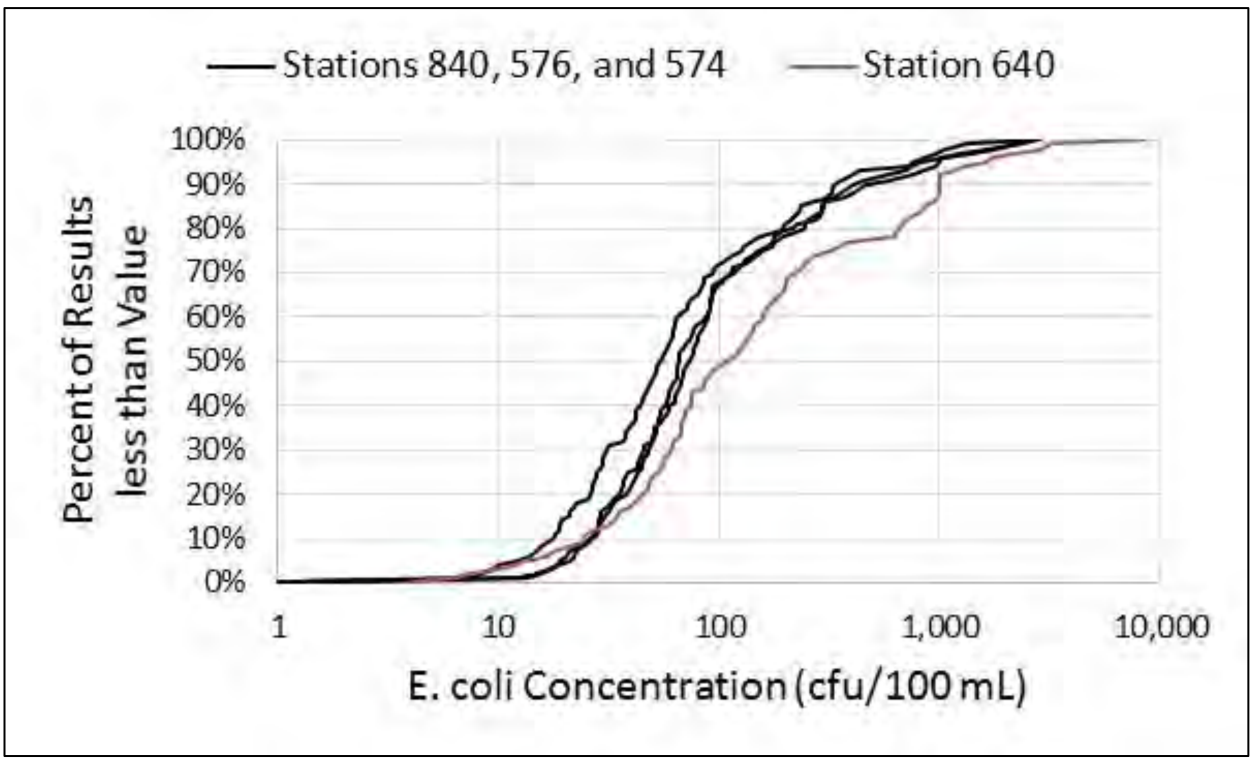


Figure 4-4: Differences in *E.coli* Concentrations between station 640 and other surrounding stations

These observations from the data represent the understanding of water quality patterns that guided James River water quality model calibration decisions, which are further described in the sections below.

4.2 Model Evaluation and Performance Criteria

Model evaluation and performance criteria are principles and standards for evaluating the success of a model calibration. In some cases, statistical evaluations of model output are useful in that they can be related to industry standards. In other cases, reliable statistical standards are unavailable and model calibration is guided primarily by visual evaluation of graphics comparing model and data. Considerations that guided the model calibration process are described for each model below.

4.2.1 Watershed Model

The evaluation of the hydrology calibration involved statistical and visual comparisons between the modeled flows at the outlet of the upstream portion of the Falling Creek watershed and observed flows at the Falling Creek USGS gage. Annual and cumulative modeled flow volume were evaluated. Comparisons were also made between model results and gaged flows for 18 individual storm events. For each event, model results were qualitatively and statistically evaluated based on the shape of the hydrograph, total event volume, and event peak flows.

The evaluation of the water quality calibration relied upon graphical summaries of model results. These summaries included boxplots, cumulative frequency distributions, and one-to-one plots of model results versus observed data. The primary calibration parameters were pollutant build-up and wash-off, baseflow concentration of *E.coli*, and in-stream *E.coli* decay rate. Due to the lack of available water quality data, the final calibration of the watershed model was completed as part of the water quality calibration for the James River EFDC model.

4.2.2 CSS Model

The performance evaluation of the original Wet Weather Combined Sewer (WWCS) model was conducted by Greeley and Hansen and included visual comparisons of flow hydrographs for individual wet weather events at the metering locations as well as 1:1 plots for comparisons of wet weather event flow volume and peak flows. The model evaluation is described in the Collection System Hydraulic model report of the Wastewater Collection System Master Plan by GH (Greeley and Hansen, 2012).

Brown and Caldwell evaluated the adjusted Clean Water Plan version of the CSS model (described in Section 3.2) against available flow observations as well as the underlying WWCS model by GH and the comparison described in detail in the IP Model Development documentation (Brown and Caldwell, 2016). This includes flow comparisons for individual wet weather events at meter locations (against observations) as well as volumetric comparisons at CSO locations on an event and annual basis against the WWCS model.

4.2.3 Receiving Water Quality Model

Evaluation of the hydrodynamic model performance relied on graphical summaries of model output. In the riverine reach, modeled depths and velocities were plotted against modeled discharge and compared against observed depths and velocities plotted against observed discharge. These relationships of depth and velocity versus discharge are strongly influenced by the hydraulic characteristics of the James River including bed slope, width, and channel roughness. In the estuarine reach, the model was evaluated using two other graphic types: time series and one-to-one plots. These tools were used to assess the phasing and amplitude of the modeled tides and the effect of river flows on water levels in the estuarine reach.

Evaluation of the water quality model performance also relied on graphical summaries of model output, including time series plots and cumulative frequency distributions (CFDs). Emphasis was placed on evaluating the model's consistency with elevated *E.coli* concentrations which would most significantly influence compliance with water quality standards.

4.3 Hydrology and Hydrodynamics Calibration Results

Hydrology and hydrodynamics describe the quantities and rates of water moving through a system. In the James River water quality modeling framework, this includes movement of storm runoff from the watershed into and through tributaries and storm water sewers, movement of water and wastewater into and through the combined sewer system and through the wastewater treatment plant and combined sewer overflows, and movement of water into and through the James River. Calibration of hydrology and hydrodynamics is important in that it strongly influences the concentrations and persistence of pollutants in an environmental system.

4.3.1 Watershed Model

The purpose of the hydrology calibration was to: 1) reasonably approximate the volume and timing of observed flows in Falling Creek and 2) develop hydrologic parameters that could be used for all subcatchments and stream channels in the watershed model extent. In the absence of robust site-specific data, it was assumed that all subcatchments and stream channels in the model would have similar hydrologic properties. This assumption was considered reasonable because median values are similar for subcatchment parameters, such as impervious area, percent slope, and soil properties between the gaged portion of the Falling Creek watershed and the other watersheds included in the model extent. The model was run for calendar years 1985 to 1994, and modeled cumulative flows and storm event hydrographs were compared to observed flows at the USGS gage. Subcatchment percent impervious area and stream channel roughness values were adjusted to bring the modeled results into alignment with observed values.

On a cumulative basis, the model results reasonably match observed flows for all years until spring of 1993 and spring of 1994 (Figure 4-5).

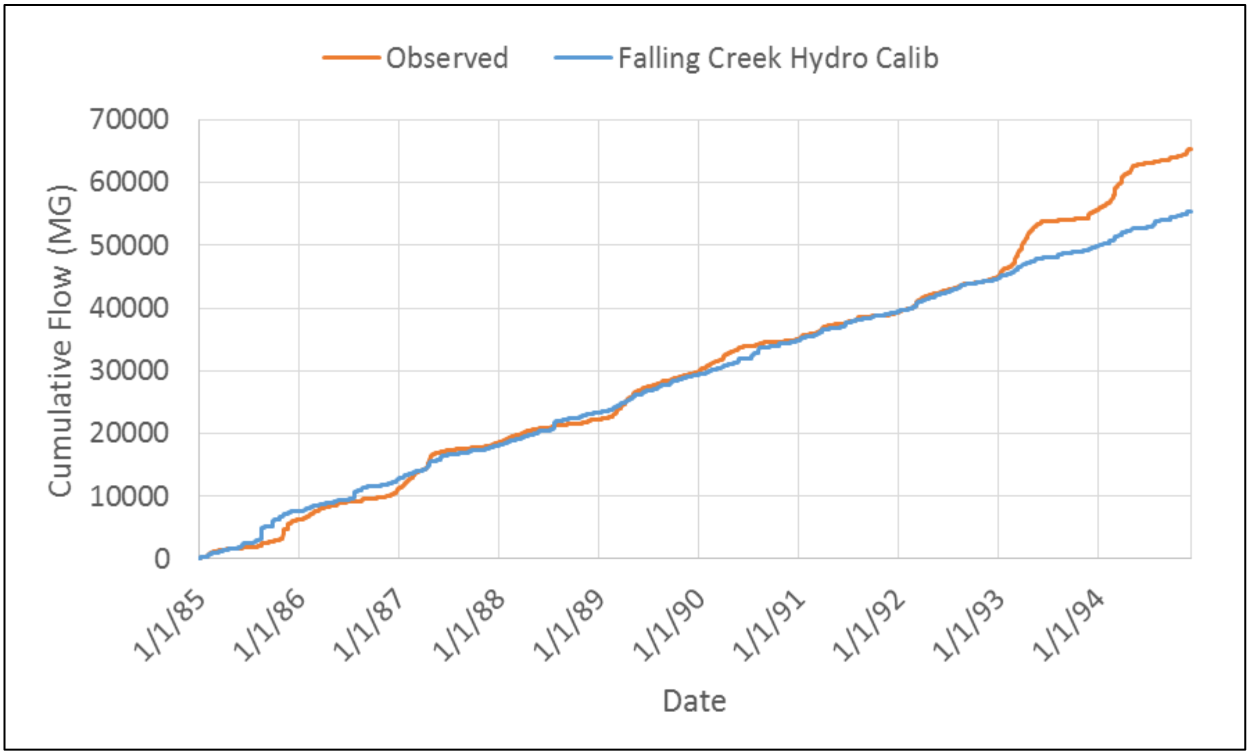


Figure 4-5: Observed and Modeled Cumulative Flow Volume at the Falling Creek Gage

For the period 1985 to 1994, the model underpredicted observed flows by approximately 15%. However, when the flows from 1993 and 1994 were excluded, the difference in cumulative volume between modeled and observed flows decreased to -0.5% (Table 4-3). The cause for the 1993 and 1994 increases in observed flows are unknown, but similar increases were observed in four other USGS gages in the region: Totopotomoy Creek near Studley, VA (USGS 01673550); James River near Richmond, VA (USGS 02037500); Appomattox River at Mattoax, VA (USGS 02040000); and Chickahominy River near Providence Forge, VA (USGS 02042500), indicating that this is not merely an instrumental problem at a single gage (Figure 4-6). Variations could be attributable to differences in rainfall in the Falling Creek watershed and at the Richmond Airport, which are approximately 11.7 miles apart as the crow flies.

Table 4-3: Observed and Modeled Annual Flow Volumes at the Falling Creek Gage

Year	Observed Total Annual Flow (MG)	Modeled Total Annual Flow (MG)	Percent Difference Between Modeled and Observed
1994	9,614	5,584	-41.9%
1993	10,740	5,181	-51.8%
1992	5,678	5,209	-8.3%
1991	4,214	4,609	9.4%
1990	5,253	5,521	5.1%
1989	7,566	6,110	-19.2%
1988	3,677	5,143	39.9%
1987	7,435	5,417	-27.1%
1986	4,875	5,066	3.9%

Table 4-3: Observed and Modeled Annual Flow Volumes at the Falling Creek Gage			
Year	**Observed Total Annual Flow (MG)**	**Modeled Total Annual Flow (MG)**	**Percent Difference Between Modeled and Observed**
1985	6,262	7,639	22.0%
OVERALL	**65,313**	**55,477**	**-15.1%**
OVERALL (excl. '93-'94)	**44,959**	**44,712**	**-0.5%**

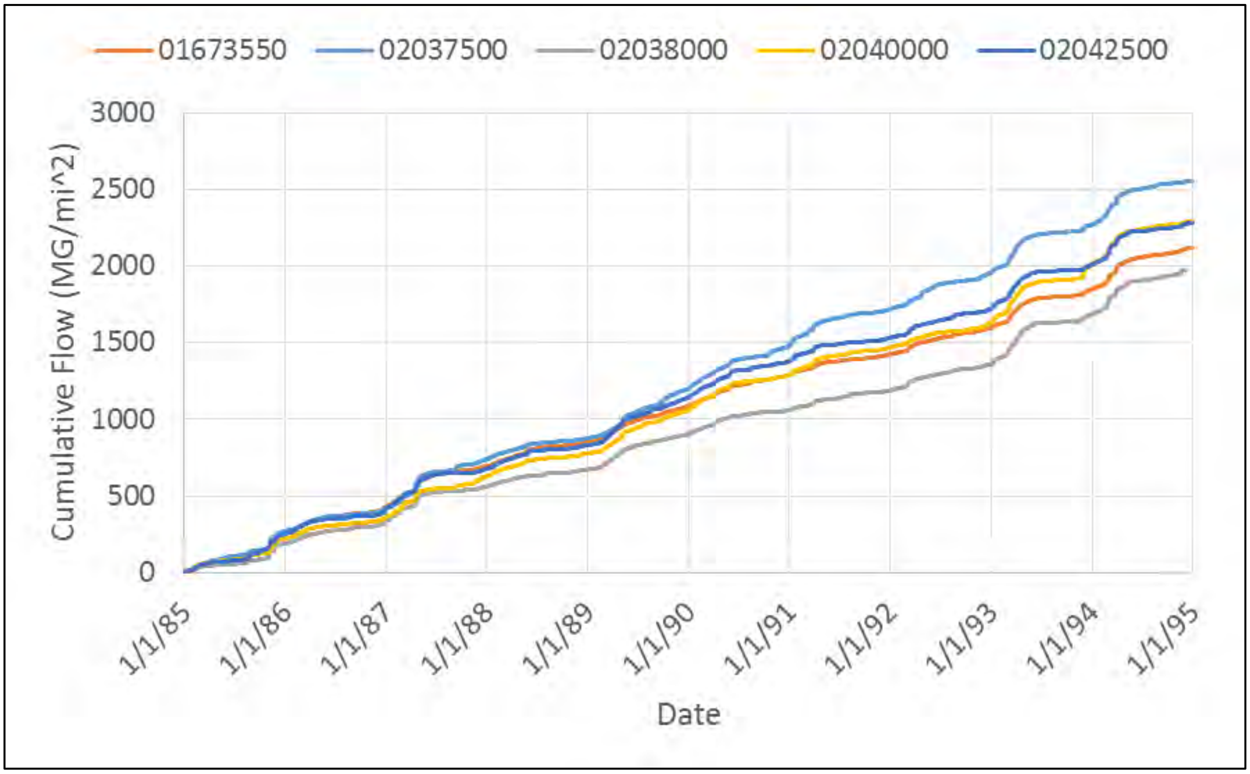


Figure 4-6: Area Normalized Cumulative Flow Volume for USGS Gages in the Richmond Region

On an event basis, model results tend to over predict event volumes and peak flows (Figure 4-7 and Figure 4-8), but the general shape of the hydrographs tend to match (Figure 4-9). The model currently only uses precipitation from one gage at Richmond International Airport (RIA). Variations on an event basis could be attributable to differences in rainfall in the Falling Creek watershed and at the Richmond Airport, which are approximately 11.7 miles apart as the crow flies.

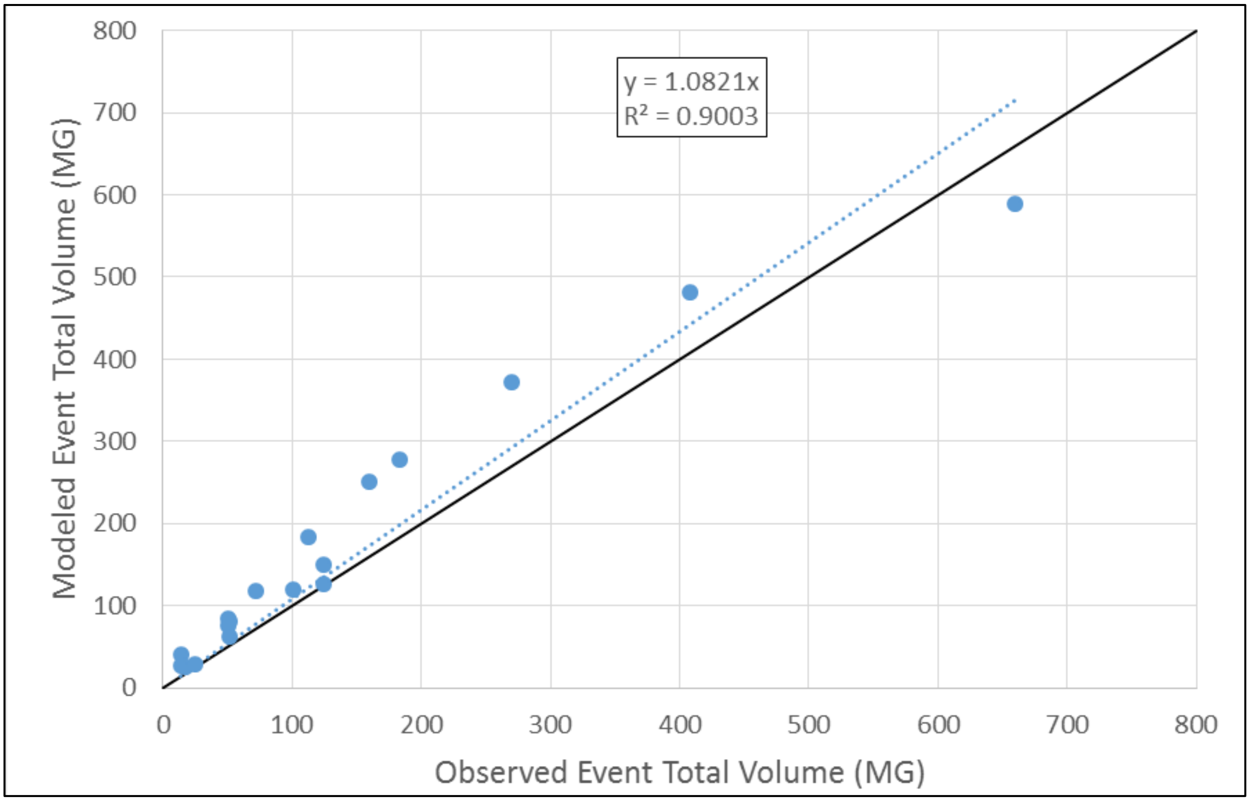


Figure 4-7: Modeled vs Observed Event Volume

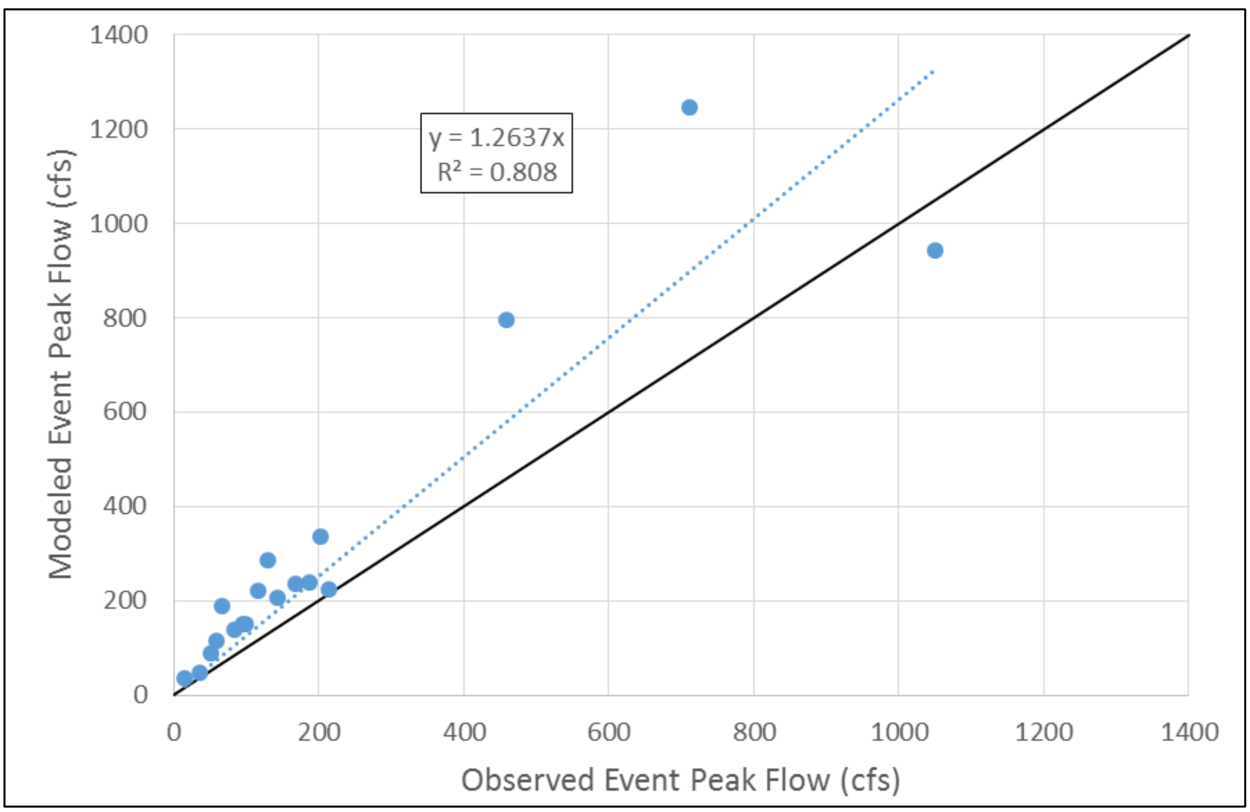


Figure 4-8: Modeled vs. Observed Event Peak Flow Rate

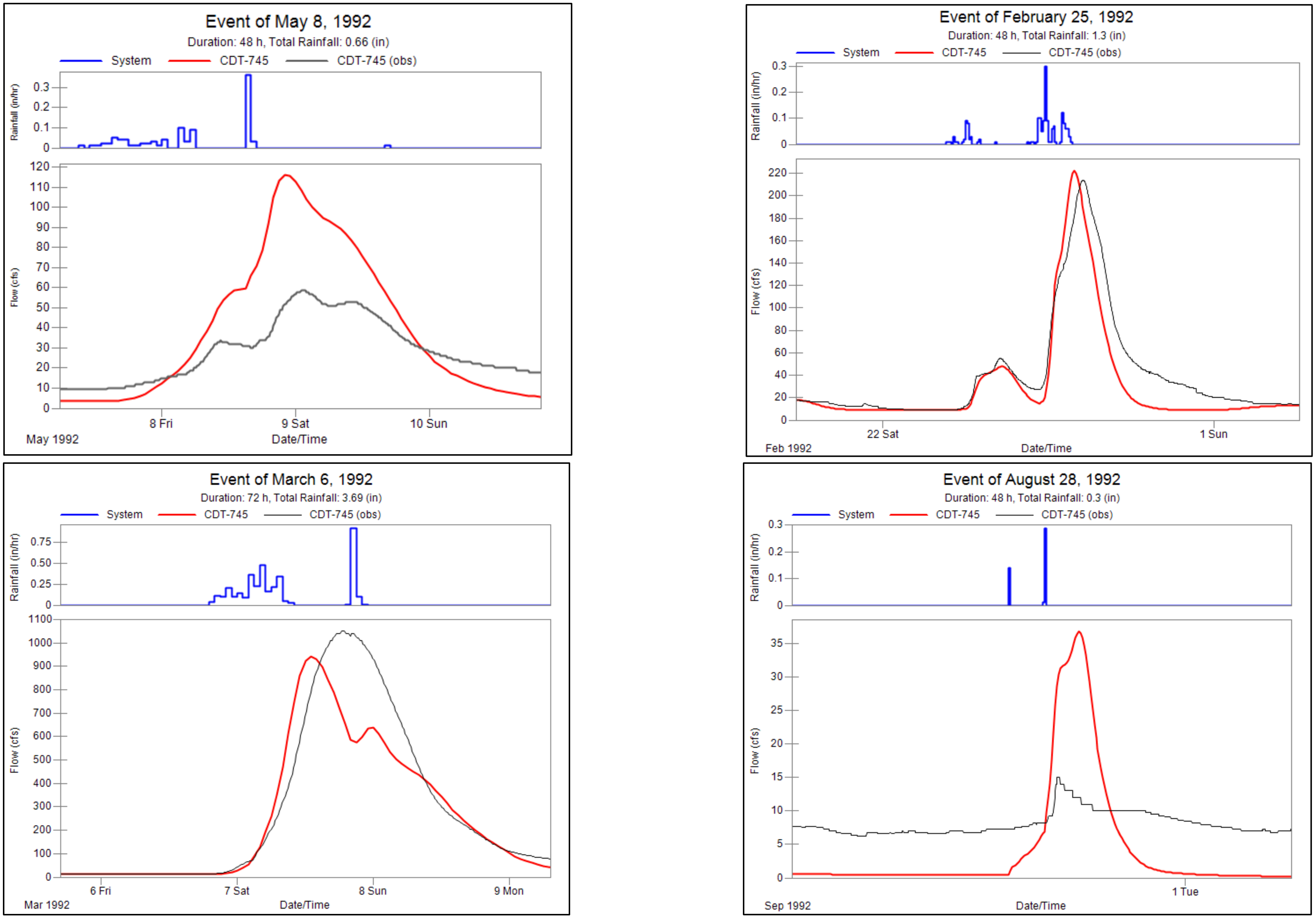


Figure 4-9: Modeled vs Observed hydrographs for four events at Falling Creek Gage

Three calibration parameters were used to adjust cumulative volumes, event volumes, and event peak flows: percent impervious area, Manning's N for in-channel roughness, and Manning's N for overbank roughness. Adjustments to modeled cumulative volume were made by adjusting the percent impervious area. Adjustments to event peak flows and the timing of peak flows were made by adjusting in-channel and overbank Manning's values. Manning's N for in-channel roughness was varied between 0.035 and 0.05 for a main channel that was assumed to be clean, winding and have some pools and shoals. Manning's N for overbank roughness was varied between 0.04 and 0.08 for overbanks that were assumed to have light brush and trees (Chow, 1959).

Impervious area is not typically a calibrated parameter, but initial model runs underestimated observed cumulative flows (dotted green line in Figure 4-10). To determine the cause of the underestimated flows, NLCD impervious cover data were compared to a planimetric impervious layer provided by the City of Richmond. The analysis revealed that the NLCD impervious layer underestimated the median percent impervious area, especially in less urban areas. To correct the underestimation of impervious area a linear regression was used to adjust the NLCD impervious area upwards for consistency with the planimetric data (dotted blue line in figure below). Finally, because the amount of directly connected impervious area is not known, the percent impervious area for each subcatchment was adjusted downward to account for impervious areas that are not directly connected to a waterway (solid blue line in figure below). Results from each run are summarized in Figure 4-10.

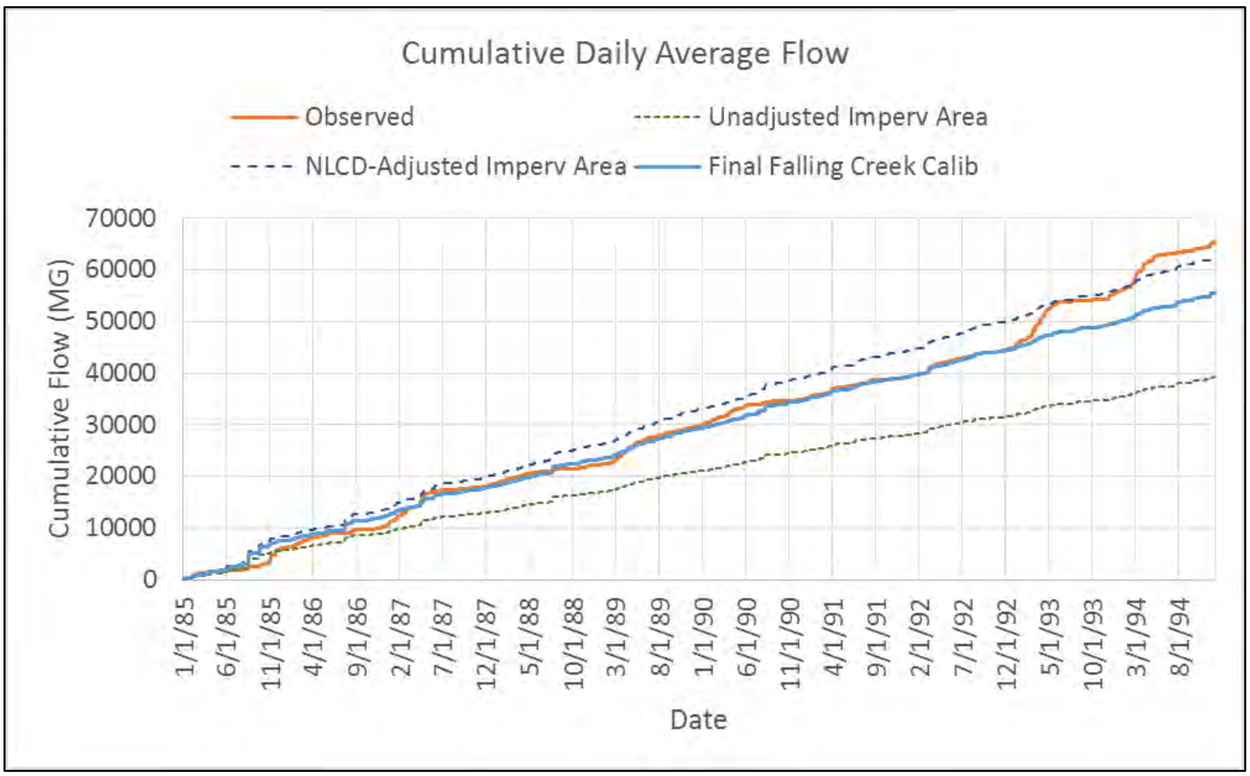


Figure 4-10: Model calibration results (impervious area)

4.3.2 CSS Model

The CSS calibration of the original Wet Weather Combined Sewer (WWCS) model focused both on achieving the appropriate volume and peak flows within the sewer system and on characterizing the discharge at the combined sewer outfalls, specifically at CSO 06 (Shockoe Retention Basin). While calibration within the sewer system was deemed acceptable and representative of conditions at that time, calibration at the Shockoe Retention Basin was more difficult to achieve due to the complex hydraulic situation in this area as well as to the manual overflow operations that occur at this location (Greeley and Hansen, 2015).

The original WWCS model was modified and adapted so that it could be used in hindcast mode for a long-term continuous period, and in order to operate the model for evaluating CSS alternatives. After the modifications, the performance of the resulting CSS IP model was checked against monitoring data as well as against the results from the underlying original WWCS model. A discussion of the results is included in the CSS model review memorandum (Brown and Caldwell, 2016). Overall, the CSS IP model predicts lower overall CSS volume discharges and events compared to the results documented in the 2002 LTCP re-evaluation report, as well as compared to the CSS Annual Reports. These differences can be attributed to two main reasons:

- Numerous changes to the CSS model were performed since the 2002 LTCP re-evaluation, and the CSS model was re-calibrated on a few different occasion. This results in the CSO discharge volumes and number of CSO events to be different from those reported in the 2002 LTCP re-evaluation. These differences are deemed justified based on the additional monitoring data that was used to conduct the re-calibration, and on the CSS model revisions, including operational and physical changes to the combined sewer system and waste water treatment plant system that were implemented since the 2002 Long Term Control Plan Re-Evaluation.
- The CSS IP model uses standard operating rules to model the CSO operations at the Shockoe Retention Basin, causing the CSO discharges modeled at this location to be different from those reported in the CSS Annual Report, where the CSO discharges are calculated by using the real-time operator logs and which are interweaved with the results from the CSS model.

4.3.3 Receiving Water Quality Model

The purpose of the hydrodynamic model calibration was to adjust model parameters within defensible ranges to achieve reasonable agreement between modeled and observed water levels and velocities. The model was run for calendar years 2011 through 2013, and the modeled relationships between river discharge and water level, as well as river discharge and velocity were compared to the observed relationships in the riverine reach. Modeled roughness heights, which represent both grain roughness associated with substrate and larger scale bed forms, were adjusted within bounds consistent with Manning's N roughness values cited in the FEMA Flood Insurance Study (FEMA, 2014). These adjustments were made to bring the modeled water levels and velocities in closer agreement with the observed data.

Figure 4-11 and Figure 4-12 illustrate the riverine model calibration and show sensitivity of the model results to varying roughness height inputs. The calibrated bed roughness heights varied from 5 to 50 millimeters corresponding to Mannings N values from 0.03 to 0.045. Roughness heights were halved in the sensitivity test named "Lower Roughness Test," and they were doubled in the sensitivity test named "Higher Roughness Test." Increases in bed roughness caused increases in modeled water surface elevations and decreases in current velocities. The calibrated roughness inputs provided a balance of accurately simulating both water surface elevations and current velocities.

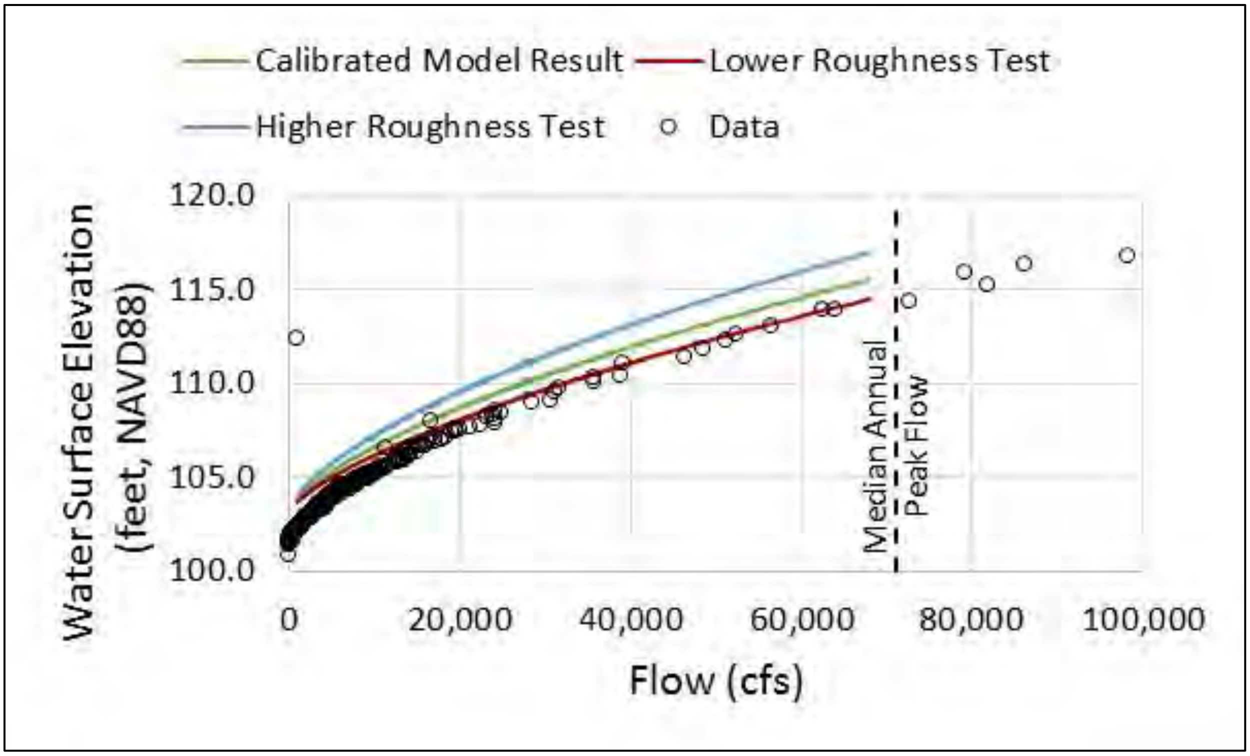


Figure 4-11: Comparison of Modeled and Observed Water Levels at upstream USGS gage

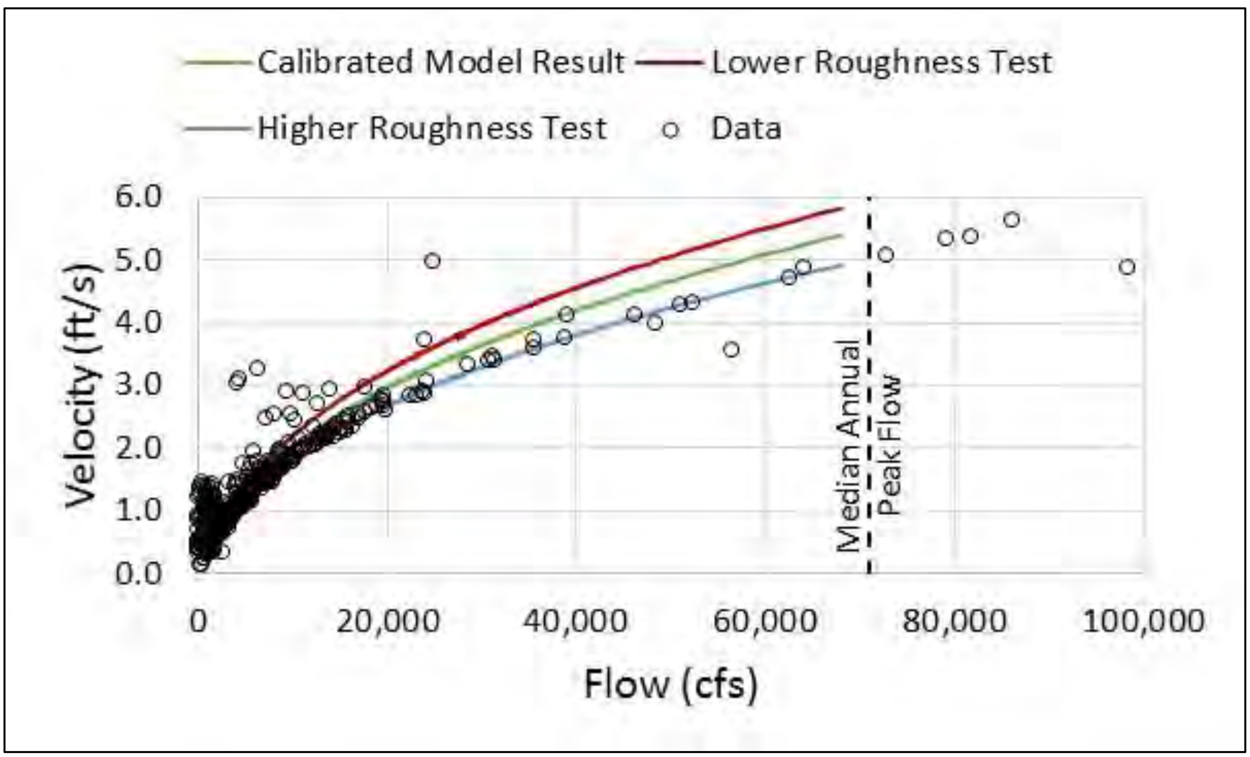


Figure 4-12: Comparison of Modeled and Observed Velocities at upstream USGS gage

Calibration to USGS water level data in the estuarine reach was achieved by adjusting the water level at the boundary to account for the effect of river flow on water levels. Water levels at the boundary were reduced relative to the gaged water levels to account for changes in water level between the gage and the model boundary. The data were adjusted according to the expression:

$$Z_{boundary} = Z_{Gage} - C * Q^n$$

Where:

- $Z_{boundary}$ is the estimated water level at the downstream boundary in feet
- Z_{gage} is the observed water surface elevation at the USGS gage (#02037705) in feet,
- C and n are constants which were determined via calibration to be 4.4e-7 and 1.5; and,
- Q is the James River flow rate in cubic feet per second

The data were also shifted by approximately three minutes backward in time to account for propagation of the tides from the model boundary to the gage location.

Figure 4-13 and Figure 4-14 illustrate the estuarine model calibration and Figure 4-15 shows how the model performed in the absence of this flow-based water level adjustment at the downstream boundary. Without this flow-based adjustment to water levels, modeled water levels are biased four feet high relative to the data during the highest flow conditions.

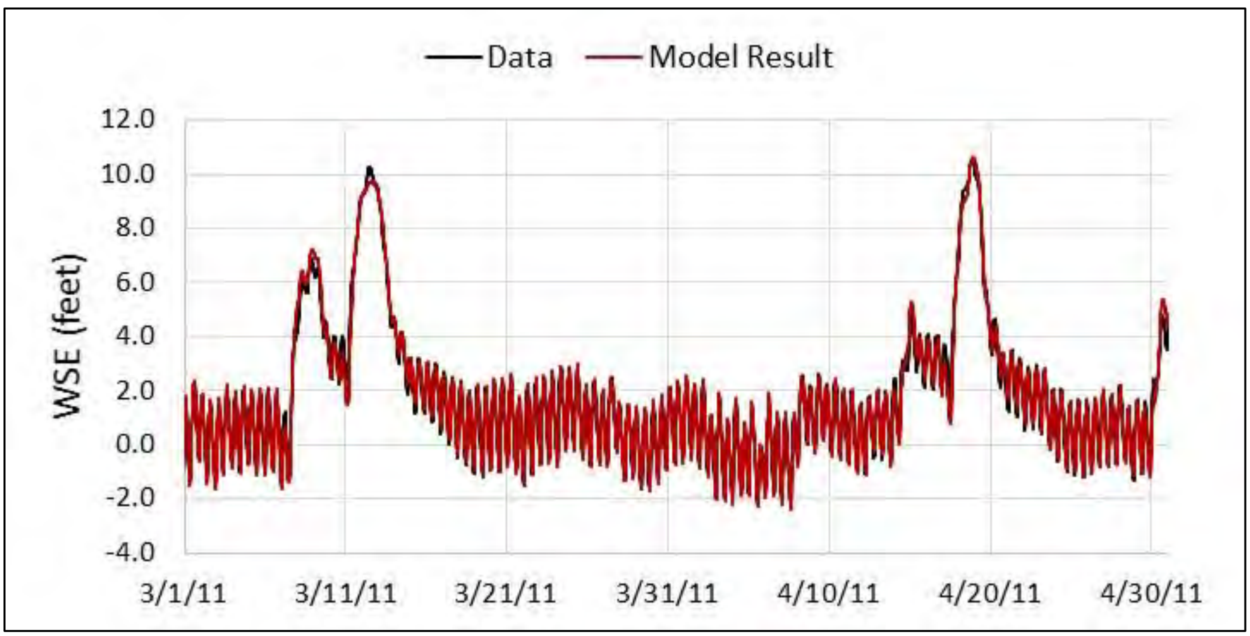


Figure 4-13: Time Series Comparison of Modeled and Observed Water Levels at downstream USGS gage

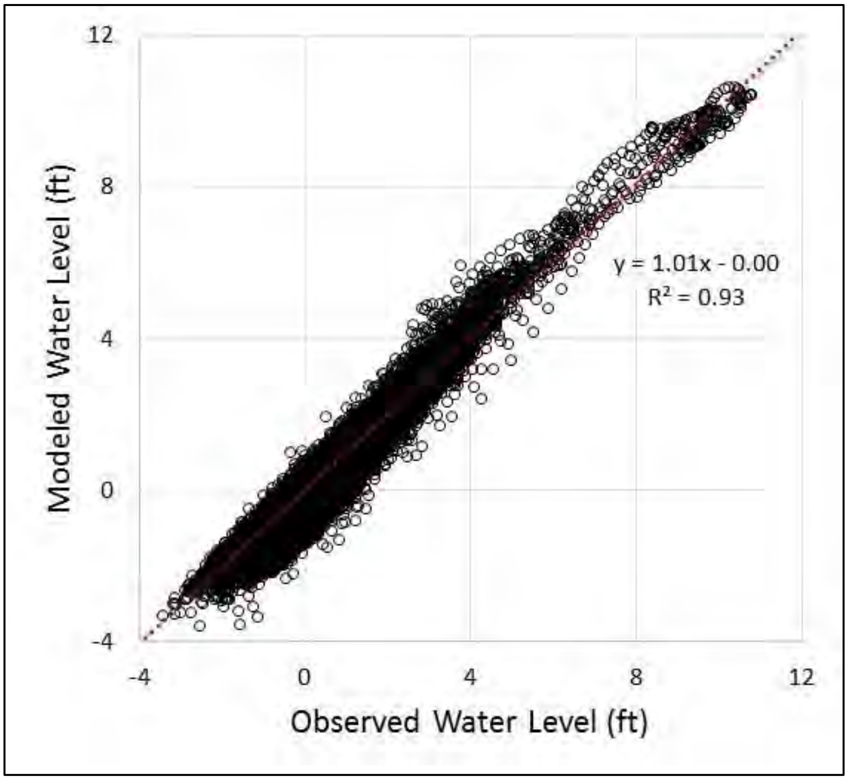


Figure 4-14: One-to-one Comparison of Modeled and Observed Water Levels at downstream USGS gage

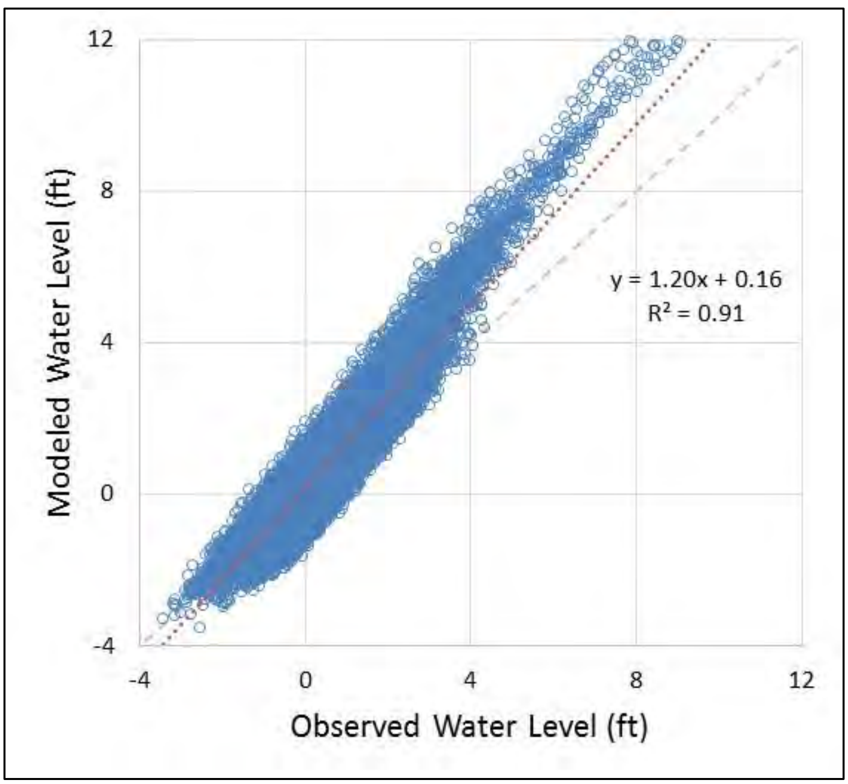


Figure 4-15: One-to-one Comparison of Modeled and Observed Water Levels at downstream USGS gage without calibration of water levels at the boundary

4.4 Water Quality Calibration Results

Calibration of water quality conditions involved adjusting inputs that influence the quantity, timing, and locations of *E.coli* delivered to the receiving waters and adjusting inputs that influence the survival of *E.coli* in the streams. *E.coli* sources in the water quality modeling framework include *E.coli* washoff from the watershed, persistent background sources of *E.coli* (e.g.: wildlife), *E.coli* in combined sewer overflows and treatment plant effluent, and *E.coli* originating from upstream locations in the James River watershed.

4.4.1 Watershed Model

The main objectives of the watershed water quality calibration were to estimate *E.coli* loading to the receiving water quality model and the approximate timing of these loads. To evaluate the first objective, the distribution of modeled *E.coli* concentrations was compared to observed data using boxplots. To evaluate the second objective, model results were compared to observed data using one-to-one plots, where the observed data is compared to the modeled data for a given model time step.

Data from the Falling Creek location were primarily used to calibrate the watershed model for two reasons: First, Falling Creek stations 399/400 have the greatest quantity of observed data. Second, since Falling Creek is the only tributary in the watershed model with a USGS flow gage, the modeled flows are likely to be the most accurately represented. Therefore, accurately modeling observed concentrations in Falling Creek would result in the best estimation of *E.coli* loads delivered to the receiving water quality model. Since there is a limited amount of data available in the tributaries, the initial calibration was considered complete and satisfactory once the modeled results from Falling Creek and the majority of the other five tributaries matched observed values within reason.

The model was run for the calendar years 2011 to 2013 and modeled *E.coli* concentrations were compared to observed results for six tributaries. Figure 4-16 and Figure 4-17 illustrate the watershed model water quality calibration. Model results at Falling Creek reasonably approximate the median observed concentration and the distribution of observed values. Modeled median values for four out of the other five tributaries also appear to be reasonable, with the modeled medians within one order of magnitude of the observed medians. Maximum modeled *E.coli* concentrations are generally greater than the observed data, which is assumed to be due to the lack of wet weather data collected in the tributaries. One-to-one plots were evaluated in light of the fact that in-stream *E.coli* concentrations can vary greatly in time and space (USEPA, 2010). To account for the natural variability that can occur when sampling *E.coli*, two additional sets of lines were added to the 1-to-1 plot: the first set of dashed lines represent a two-times (2x) confidence interval representing the variability in monitoring data results associated with field-collection efforts. The second set of dotted lines represents a ten-time (10x) confidence interval which represents the possible variability in monitoring data results associated with both the field collection efforts and the laboratory methods. The majority of points on the one-to-one plots fall within the 10x confidence interval for all stations.

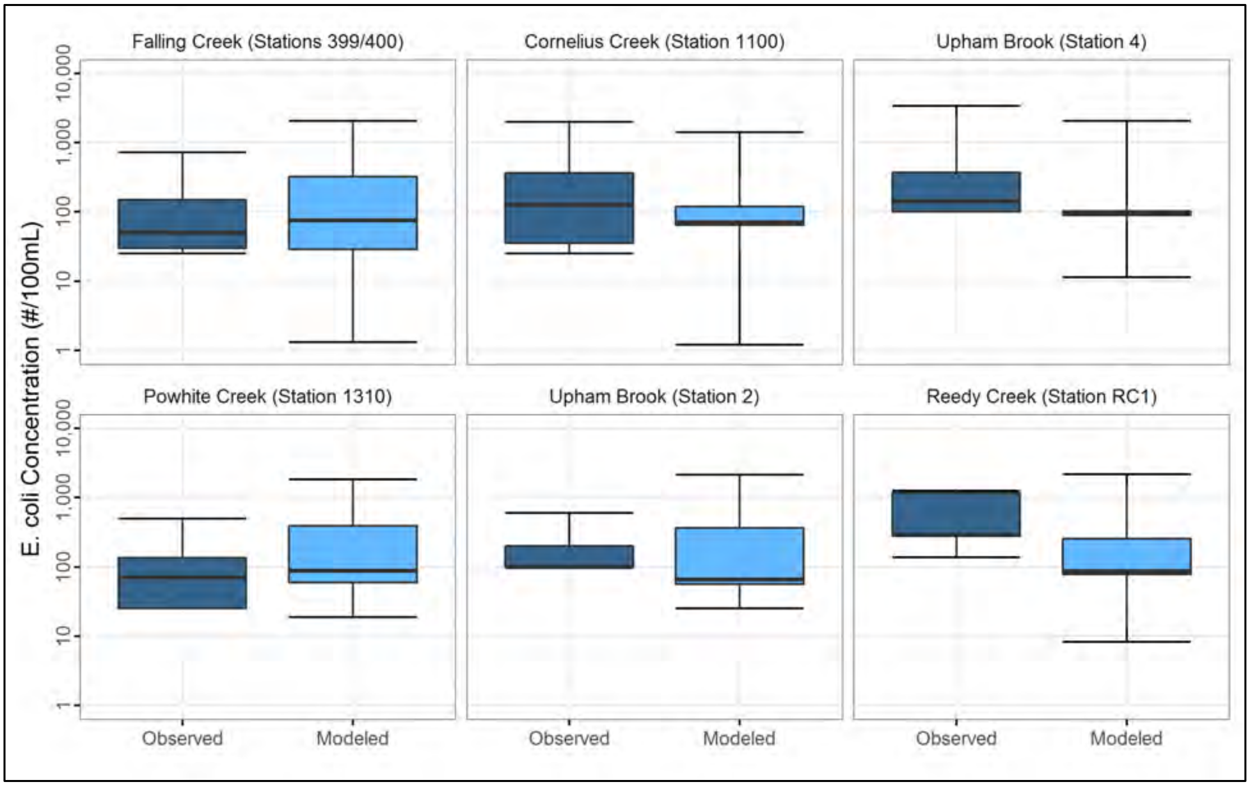


Figure 4-16: Boxplots of Modeled vs. Observed E.coli Concentrations in Select Richmond Tributaries

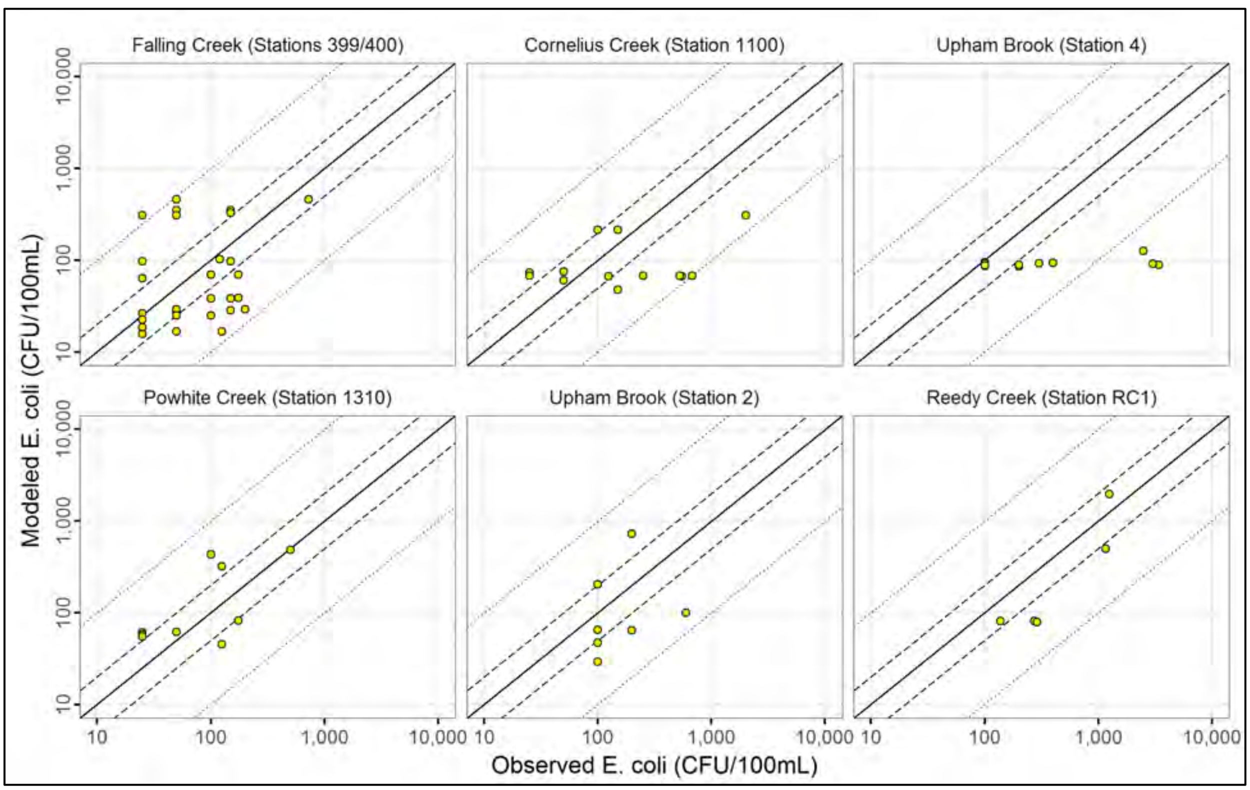


Figure 4-17: One-to-One Plots of Modeled vs Observed E.coli Concentrations in Select Richmond Tributaries

Calibration of the watershed model to better represent the *E.coli* concentrations was achieved by adjusting the values of four main parameters: pollutant build-up rate, pollutant wash-off rate, baseflow *E.coli* concentration, and in-stream decay rate. Pollutant build-up and wash-off had the greatest influence on wet weather in-stream concentrations, while baseflow *E.coli* concentration had the greatest influence on dry weather concentrations. Of the six stations evaluated, *E.coli* decay rate was found to have the greatest influence on Falling Creek, the largest tributary in the model extent. The impact of in-stream decay rate for the other five stations was nominal because travel times in these tributaries was generally shorter.

4.4.2 CSS Model

Explicit water quality calibration of the CSS model was not conducted. Rather, the CSO discharges were assigned bacteria concentrations based on monitoring results conducted for the development of the original LTCP. Additionally, the WWTP discharges were assigned bacteria concentrations based on the current bacteria water quality standards. Section 3.3 and 5.2 discusses the pollutant concentrations assigned to the various CSS outfalls and the WWTP discharge streams in more detail.

4.4.3 Receiving Water Quality Model

The primary objectives of the James River water quality model calibration were to: 1) evaluate the reasonableness of modeled *E.coli* loadings by source type and 2) evaluate the completeness of modeled *E.coli* sources. These objectives were achieved by evaluating consistency between modeled and observed *E.coli* concentrations and identifying and resolving any significant biases. The water quality model calibration is controlled in large part by estimates of *E.coli* concentrations from upstream of the study area and by estimates of *E.coli* loads from the watershed model and CSO model. Because of this, the water quality model calibration is a consistency check between the load estimates and sampling data in the James River.

The model was run for calendar years 2011 through 2013 and modeled *E.coli* concentrations were compared to observed concentrations at six stations. Figure 4-18 and Figure 4-19 illustrate the James River water quality model calibration. Median modeled *E.coli* concentrations are within 15% of median observed *E.coli* concentrations except at Station 641 where, as described in Section 4.1.3, the sampling data are anomalously high and not suitable for model calibration. Maximum modeled *E.coli* concentrations are all higher than observed *E.coli* concentrations. This is because model results are computed for every hour of the three year period, while samples were only taken occasionally, making it unlikely that the samples would capture the highest *E.coli* concentrations that actually occur in the river.

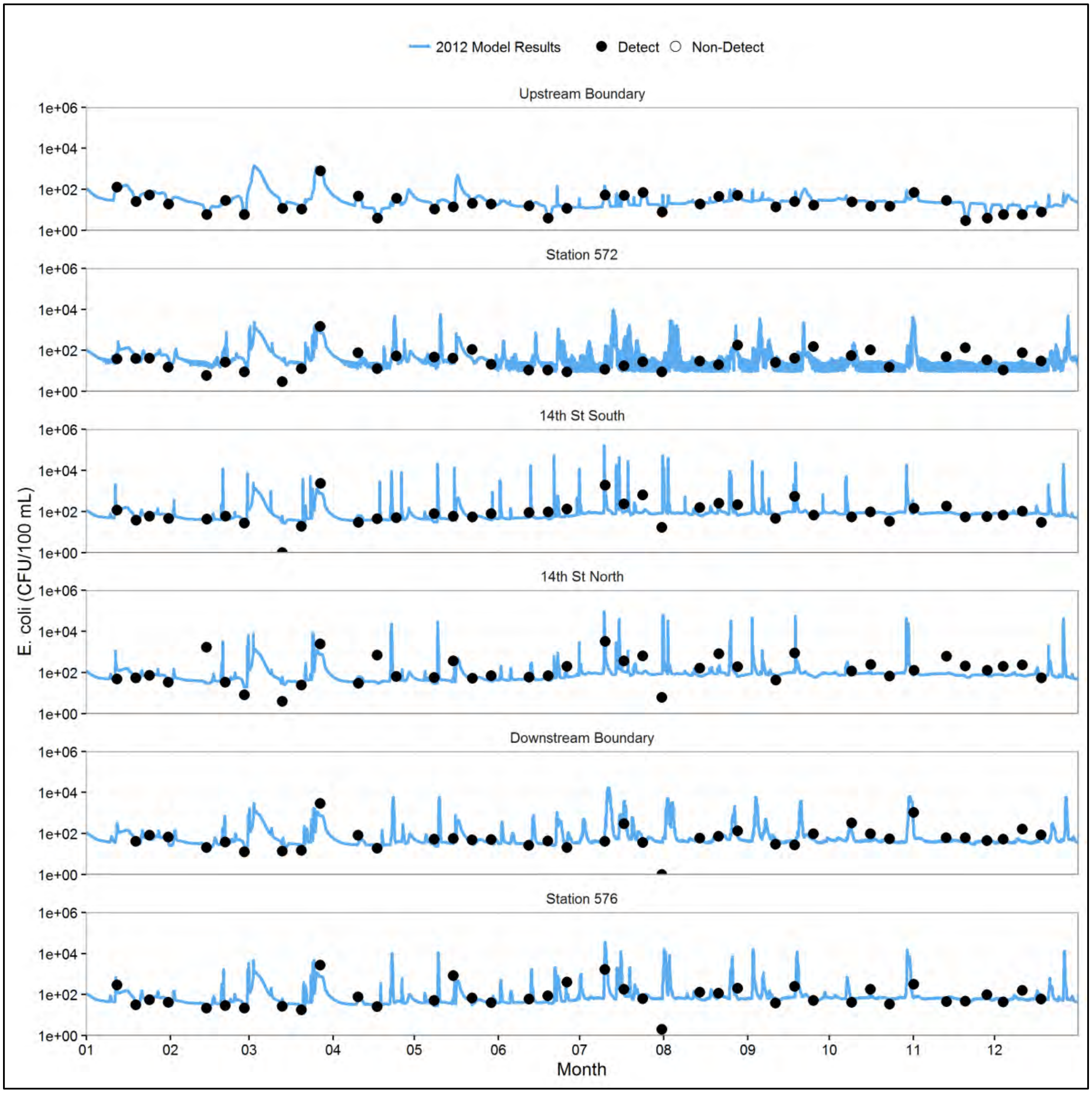


Figure 4-18: Time Series Comparison of Modeled and Observed *E.coli*

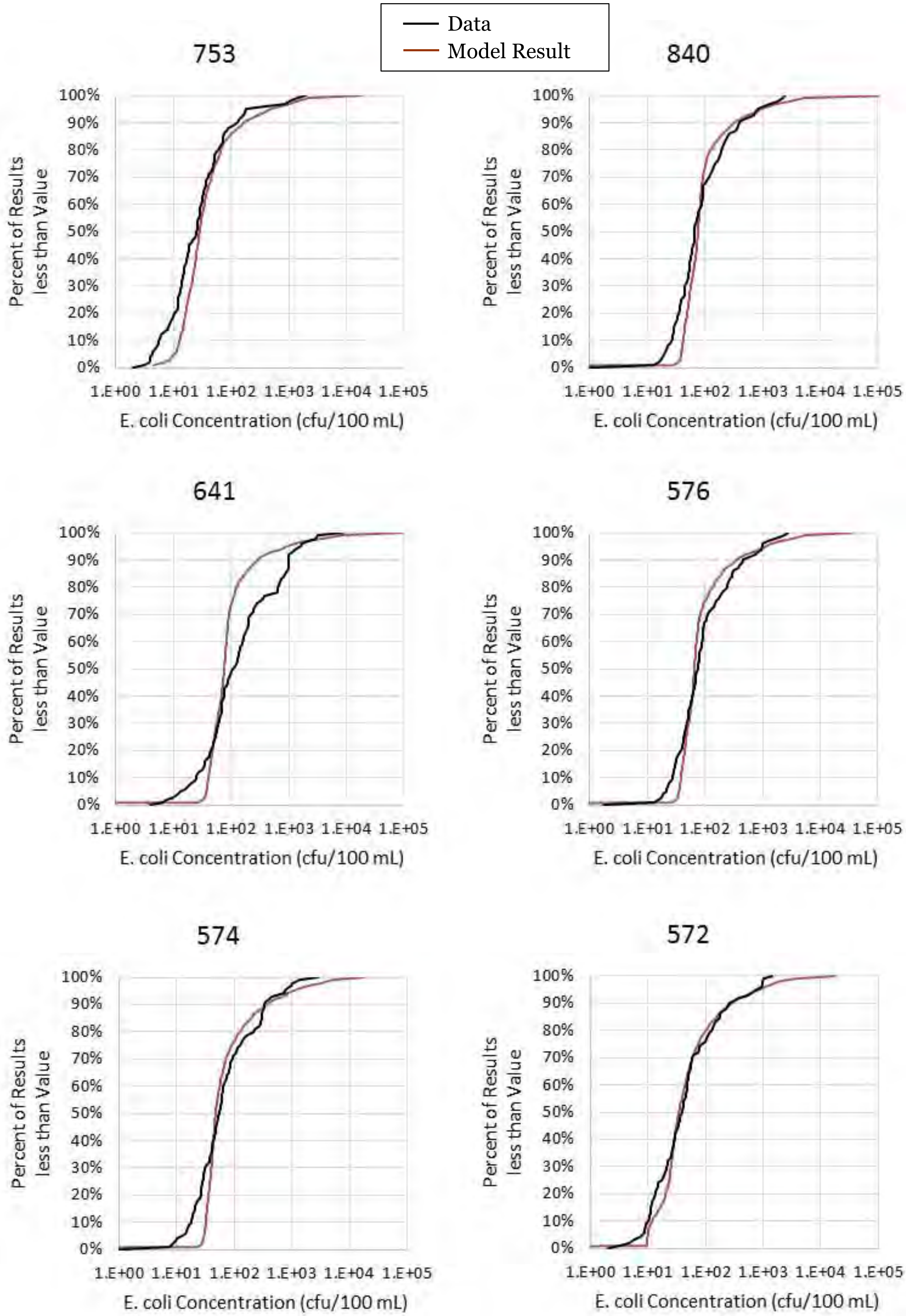


Figure 4-19: Cumulative Frequency Distribution Comparisons of Modeled and Observed *E.coli*

Calibration of the water quality model required the introduction of a significant unknown source between the Huguenot Bridge and the 14th Street Bridge (Figure 4-20). It is assumed that this source represents bacteria contributions from common background sources such as wildlife and failing septic systems. This source was introduced to the model at a constant rate of 3.2E+12 CFU/day just downstream of the Poney Pasture Park. This assumed loading rate is of the same order of magnitude as the loading rate estimated for failing septic systems and wildlife in the James River Richmond Bacteria TMDL (MapTech, 2010). Increases to instream *E.coli* concentrations due to the background source are generally between 30 and 40 CFU/100 mL. The decision to input this load near the park is not meant to indicate that the source(s) necessarily originates there. Additional sampling data would be required to identify the spatial distribution of this source(s) between the Huguenot Bridge and the 14th Street Bridge.

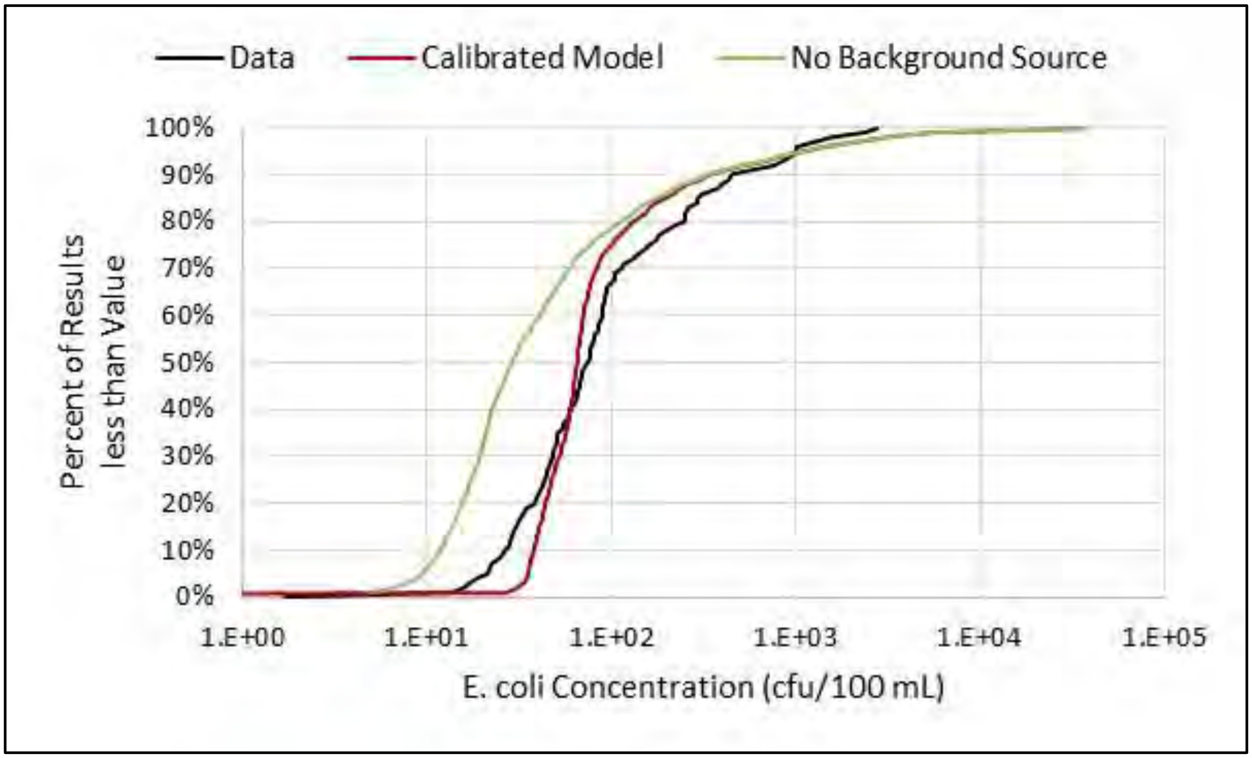
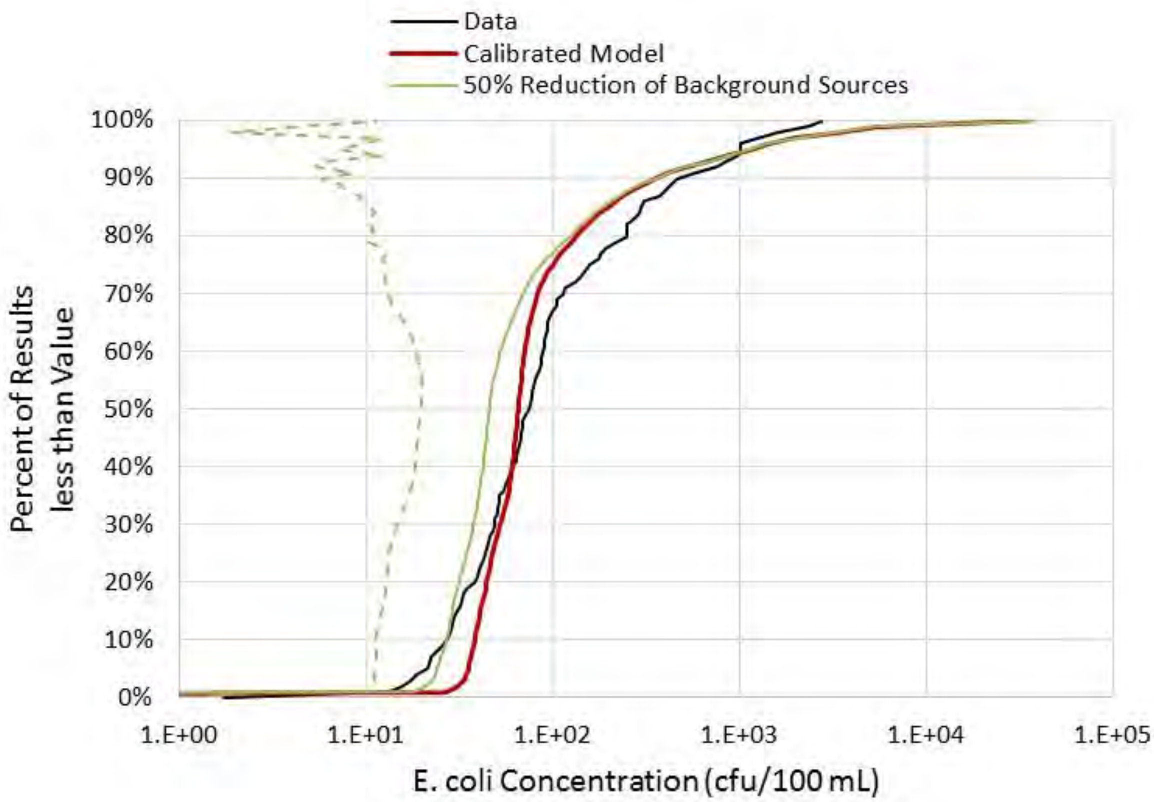


Figure 4-20: Sensitivity of Model Calibration to the Background Source

Figure 4-21 and Figure 4-22 illustrate sensitivity of the model results to adjustments of all major *E.coli* loading assumptions. In each plot, the source type of interest was reduced by 50% to evaluate its influence on modeled *E.coli* concentrations. Model results at the downstream city limit are shown. In these figures, the green dashed line represents the difference between the calibrated model result and the source reduction sensitivity test result. Reductions in persistent sources such as the James River upstream of Richmond and the background source always have some influence on *E.coli* concentrations. However, wet weather sources only reduce *E.coli* concentrations when precipitation has occurred. As a result, CSOs, for instance, only reduce concentrations thirty-five percent of the time (i.e. for the 65th to 100th percentile on the plots).



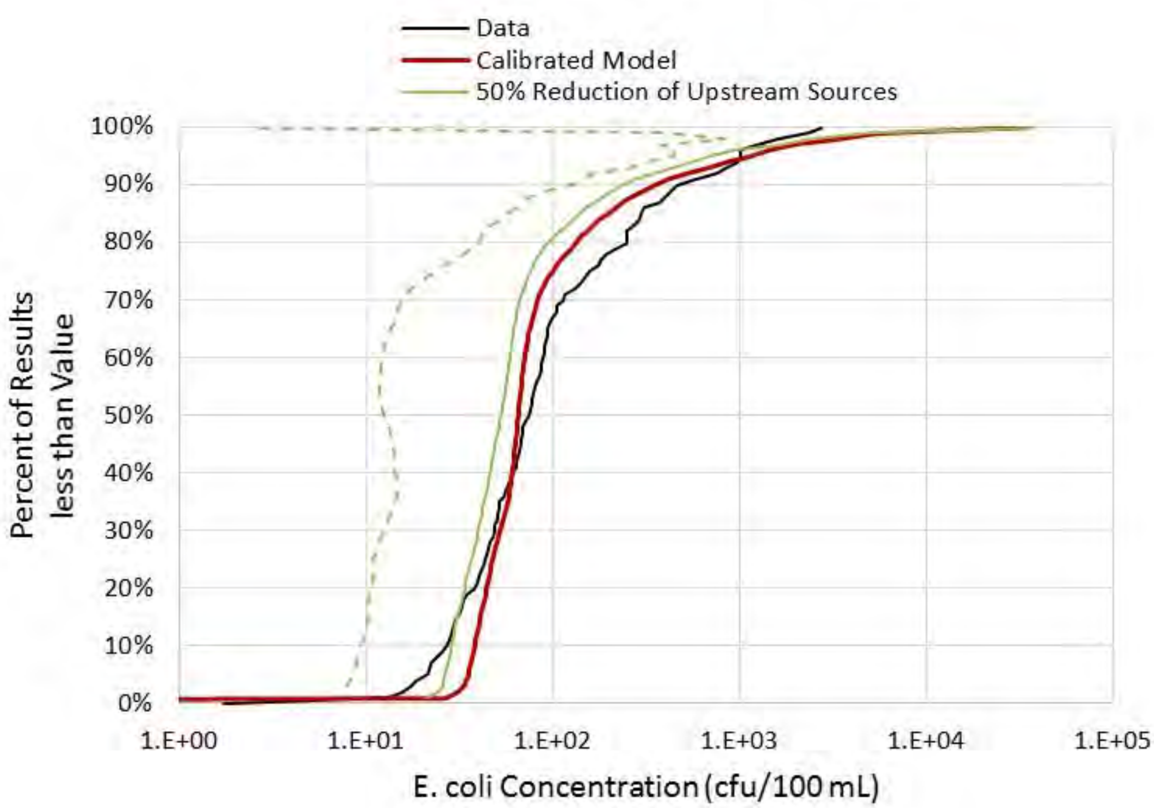


Figure 4-21: Sensitivity of Model Results to 50% Reduction of Persistent Sources

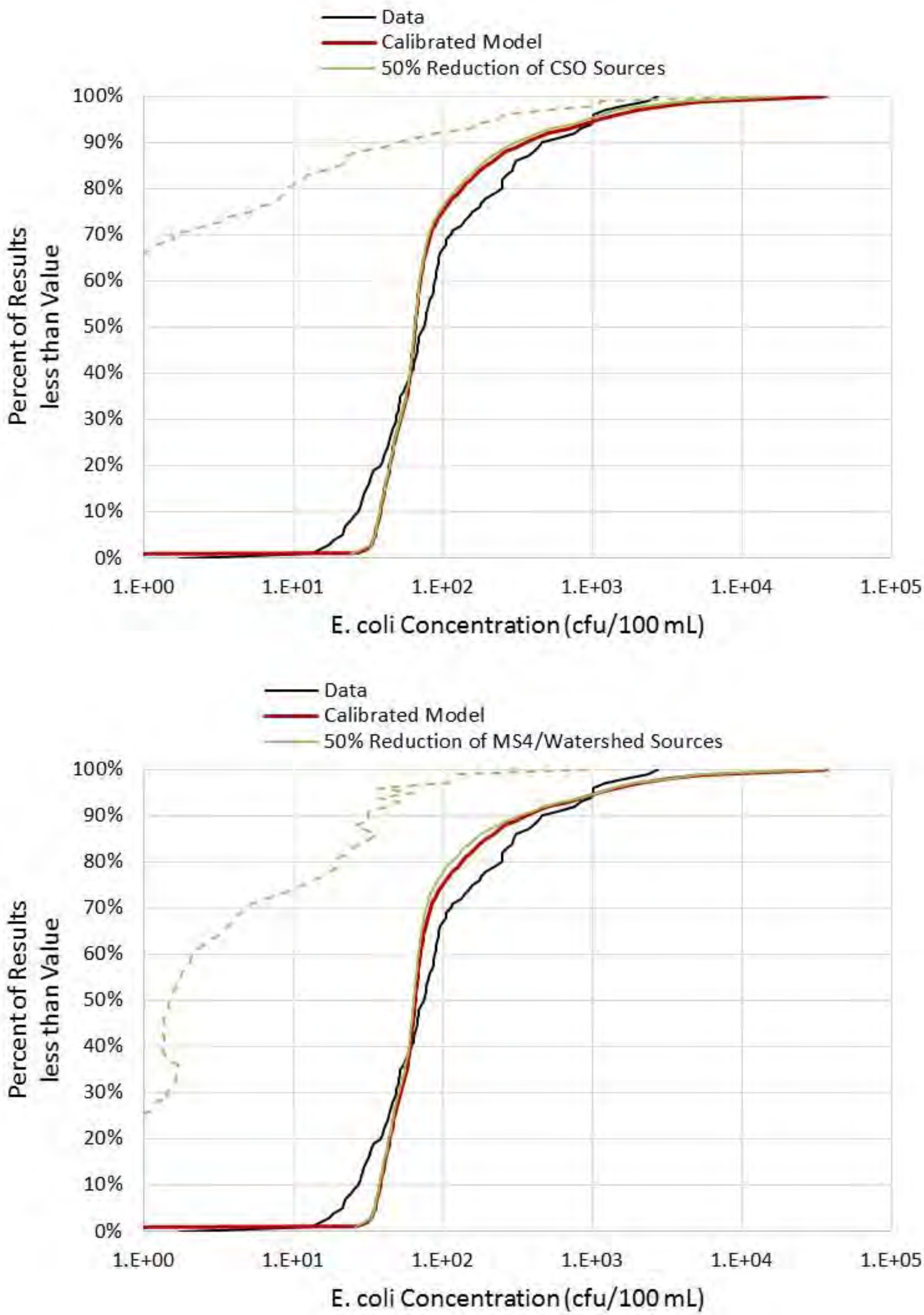


Figure 4-22: Sensitivity of Model Results to 50% Reduction of Wet Weather Sources

5 Model Application and Results

5.1 Overview

To date, the model has been applied to evaluate the following:

- Current conditions: Best representation of current conditions, and includes all the Phase I and Phase II CSO improvements from the LTCP.
- Baseline Conditions: represents the current condition, plus all the currently funded Phase III collection system improvement projects from the LTCP.
- Green Infrastructure in the MS4 Area Strategy: represents the baseline conditions, plus the implementation of 104 acres of green infrastructure on city-owned area in the MS4.
- Green Infrastructure in CSO Area Strategy: represents the baseline conditions, plus the implementation of 18 acres of green infrastructure on city-owned area in the CSS area.
- CSS Infrastructure Improvements Strategy: represents the baseline conditions, plus all the remaining unfunded Phase III collection system improvement projects from the LTCP.

The sequencing of the modeling applications is shown in the figure below.

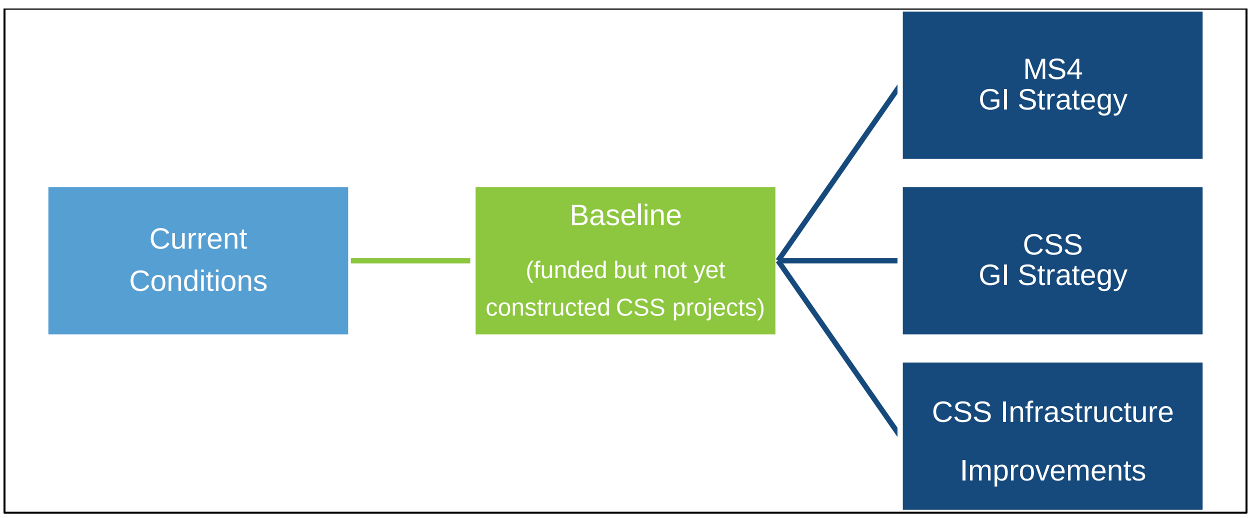


Figure 5-1: Sequencing of Model Applications

These conditions and strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges, expressed as Billion CFU
- Overall average percent improvement in monthly geomean water quality standard compliance at the downstream city limit
- Reduction in number of CSO events

- Reduction in CSO volume (Million gallons)

These four metrics are used in the Strategy Calculator, a spreadsheet tool that is used to evaluate and score the different management strategies across a wide range of goals and objectives (LimnoTech, 2017).

The model is further used to evaluate water quality benefits relative to the monthly geometric mean standard and the statistical threshold value (STV) standard, on a monthly basis. The geometric mean standard states that the monthly geometric mean *E.coli* concentration must fall below 126 cfu/100 mL to be in compliance. The VDEQ statistical threshold value standard states that no more than 10% of *E.coli* concentrations in a month may exceed 235 cfu/100 mL to be in compliance.

5.2 Methodology for Model Application and for Evaluating Model Results

The three-year period of 2011 through 2013 was selected as the application period because it represents a continuous time period that includes typical wet, dry, and average precipitation conditions, with corresponding responses in James River flow conditions. This is shown in Figure 5-2.

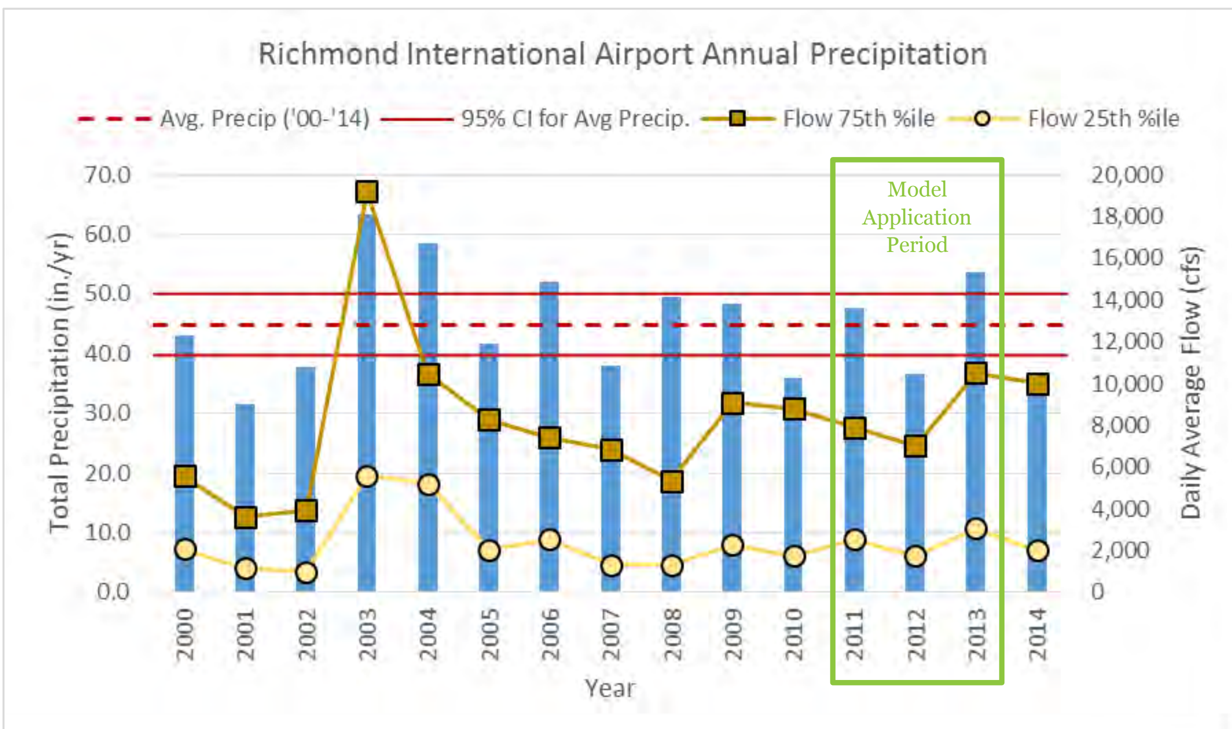


Figure 5-2: Precipitation and Daily Average Flow at Richmond International Airport

The following process was followed when applying the water quality model components to evaluate the various strategies:

1. Simulate any improvements to the combined sewer system or treatment plan with the CSS model;
2. Relay model results from potential CSS improvements in the Gillies or Almond Creek tributaries to the watershed model;
3. Simulate any MS4 strategies or CSS improvements in the Gillies or Almond Creek improvements with the watershed model;

4. Simulate the impact of improvements in the James River by relaying CSS model results (i.e. time series of overflow discharge and bacteria load) and watershed model results (i.e. time series of tributary flows and bacteria loads) to the James River Receiving Water Quality Model.
5. Summarize the results of the model runs using the metrics described in the previous section.

After running the water quality modeling framework through the process described above, water quality compliance was evaluated at the downstream boundary of the city, Richmond's National Pollutant Discharge Elimination System (NPDES) compliance point. *E.coli* concentrations at this point were compared to the monthly geometric mean of 126 CFU/100 mL and the STV of <10% of all samples exceeding 235 CFU/100mL. For each month that violated the water quality standard, a detailed component analysis was completed. The component analysis tracks the relative contribution of each *E.coli* source (upstream, CSOs, watershed/MS4, background, and WWTP) to the modeled concentration in the James River. This type of analysis is useful to evaluate which sources of bacteria have the greatest impact on water quality conditions in the James River for a given point in time or location in the river.

Additionally, model results were summarized to determine the overall bacteria load reduction, CSO volume reduction, reduction in number of CSO overflow events, and to evaluate the percent improvement towards monthly geomean water quality standard compliance at the downstream city limit. The "percent improvement towards monthly geometric mean compliance", also dubbed "percent improvement" for convenience, ranges from 0% to 100%, with 0% corresponding to the existing state of compliance and 100% corresponding to full compliance with the monthly geomean water quality standard. The "percent improvement" is computed as follows:

$$I_p = \frac{\sum_1^n V_{n,scenario} - \sum_1^n V_{n,current}}{\sum_1^n V_{n,current}}$$

Where:

- "I_p" is Percent Improvement,
- "V" is the compliance metric value for a given month, (e.g. the geometric mean value for December 2011),
- "n" is an index for the month, and
- the subscripts "scenario" and "current" correspond to a scenario of interest and the current condition, respectively.

Graphically, each summation term in this equation is the total bar height above the water quality standard as shown in Figure 5-3. If, under a particular scenario, the total bar height above the standard is small compared to the current conditions, then the "percent improvement" will be nearly 100% and the system will be near full compliance. If the total bar height under a particular scenario is similar to that of the current condition, then the "percent improvement" will be nearly 0%.

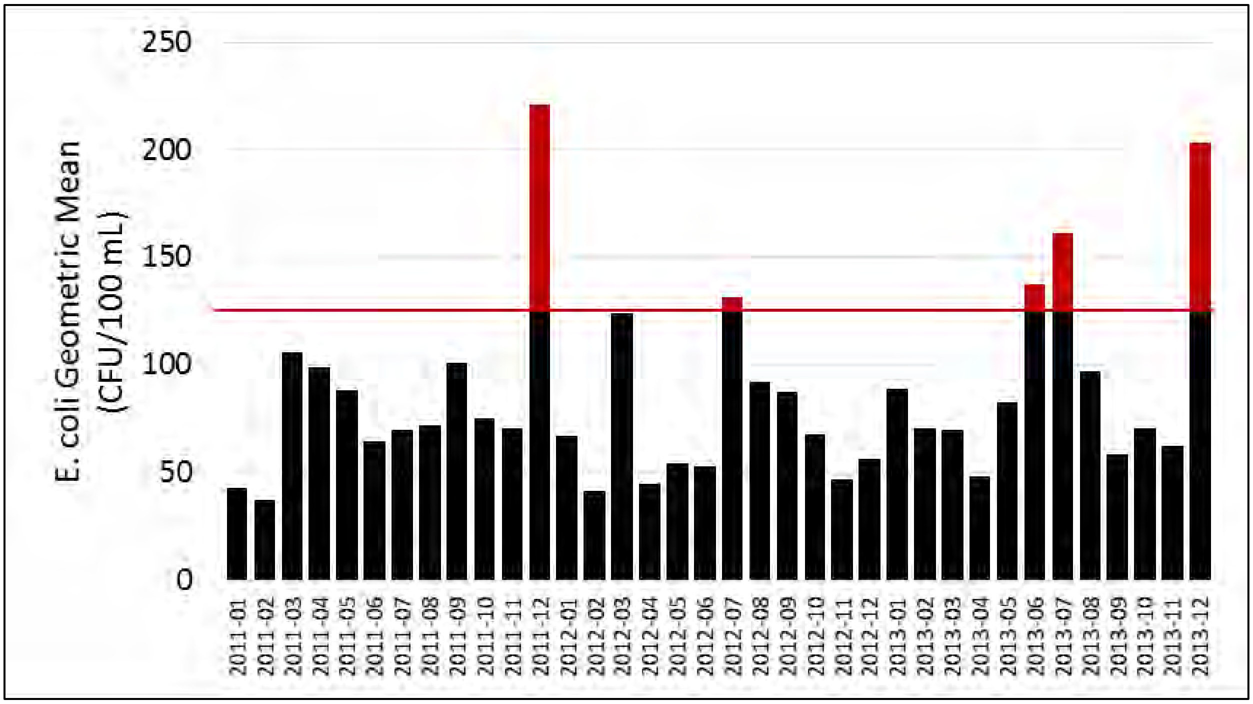


Figure 5-3: Graphical Depiction of the "Percent Improvement" Metric

5.3 Overview of Model Scenarios

Each strategy that was evaluated by the water quality model required unique changes to the model inputs, as further described in the sections below.

5.3.1 Current Conditions

Because the model calibration period and model application period are the same, no further changes were implemented to assess the current conditions.

5.3.2 Baseline Conditions

The baseline conditions represents the current conditions plus the addition of all the currently funded Phase III collection system improvement projects from the LTCP. These projects include the sewer separation of CSO 028A and CSO 028E, replacement of the CSO 04 regulator, and increasing the wet weather treatment capacity of the treatment plant to 140 MGD. These three projects were modeled in the CSS model, and results were passed down to the watershed model and the receiving water quality model. Because these projects are already funded and included in the City's planning documents, this condition was considered to be the baseline condition against which other additional strategies would be compared for the purpose of evaluating the metrics used in the Strategy Calculator.

Additional discussion of the projects included in the baseline conditions is presented in Section 5.3.5

5.3.3 Green Infrastructure in the MS4 Area Strategy

The "green infrastructure in the MS4 area" strategy proposed to implement green infrastructure to treat 104 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation (DPR), in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. The acreage of green infrastructure was determined by identifying the total area of land that is owned by either DPU or DPR, using ArcGIS. Additional information such as topography and soil type was then superimposed over the DPU and DPR properties. Through this visual analysis, it was determined that roughly 50% of the DPU/DPR land would likely not be conducive to the implementation of green infrastructure without significant engineered modifications such as land leveling or soil amendments. Therefore the total available land for this strategy was reduced by half. The remaining area was summarized by subwatershed so that it could be simulated in the watershed model.

All area available for green infrastructure implementation within a subwatershed was modeled as one representative green infrastructure practice since the specific types of green infrastructure are unknown at this planning stage. The generic practices were modeled using SWMM storage nodes with an assumed effective depth of 1.5 feet and sized in area to capture a 1.2 inch storm (90th percentile storm on an average annual basis). The modeled generic green infrastructure practices account for evaporation and bottom infiltration into the native soil. It was assumed that all green infrastructure is being drained within 48 hours to provide storage volume for back-to-back rainfall events. This was simulated by using an appropriately sized orifice to simulate practice underdrains. Potential flows exceeding the green-infrastructure capacity in the model were handled by a weir simulating practice overflow or flow rejection. Water quality routines were applied to the water volumes stored in the practices.

5.3.4 Green Infrastructure in the CSS Area Strategy

The "green infrastructure in the CSS area" strategy proposed to implement green infrastructure to treat 18 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation, in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. The acreage of green infrastructure included in this strategy was determined through the same process as described in the previous section. Additionally, green infrastructure in the CSS model was simulated in the same way as is done in the MS4 area, as described in the previous section.

5.3.5 CSS Infrastructure Improvements Strategy

The "*CSS Infrastructure Improvements*" strategy[2] includes ten projects that are included in the Phase III collection system upgrades described in the LTCP (Greeley and Hansen, 2002):

1. CSO 14 regulator upgrade
2. CSO 028A & 028E sewer separation
3. CSO 04 & CSO 05 regulator replacement
4. Lower Gillies sewer conveyance
5. WWTP wet weather treatment to 140 MGD
6. WWTP wet weather treatment to 300 MGD
7. CSO 21 replacement
8. CSO 21 additional 2 MG storage
9. Shockoe Retention Basin (SRB) expansion
10. SRB disinfection

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[2] Alternative LTCP projects are currently being evaluated by Brown and Caldwell but results are not yet available to be included as of March 2017.

Of those ten projects, #1-#3 and #5 are included in the Baseline Conditions, since these projects are currently funded by the City of Richmond. Implementation of all ten projects represents the obligations under the LTCP, and is commonly referred to as the "*full LTCP*" scenario.

The unfunded projects were modeled in isolation to determine individual impact on CSO volume discharge, bacteria load reduction, and impact on the receiving water quality. These CSS "scenarios" are summarized in Table 5-1 and Table 5-2.

Table 5-1: Description of CSS Projects Evaluated by the Water Quality Model

CSS Scenario	CSS Project Name	CSS Project Description
Current	Current Conditions	Current sewer conditions, including all LTCP Phase I and Phase II projects.
14-3	Baseline Conditions	Includes the currently funded projects: -- CSO 04, 014, and 05 regulator upgrades -- CSO 028A & 028E disconnection -- WWTP wet weather treatment up to 140 MGD
14-2	Gillies Conveyance	Lower Gillies Wet Weather Conveyance Interceptor to convey more flow to the WWTP
15-4	300 MGD Wet Weather Treatment	WWTP wet weather treatment up to 300 MGD
15-5	CSO 21 Replacement	Replacement of the CSO 21 regulator and additional 2MG storage
18-4	SRB Expansion	Shockoe retention basin (SRB) expansion to 15MG
18-5	SRB Expansion and Disinfection	SRB Expansion to 15MG and chlorine disinfection of the SRB discharge at CSO 06
19-3A	Full LTCP	All 10 Phase III projects, Full Long-term Control Plan (LTCP) achieved.

Table 5-2: CSS Water Quality Model Matrix

CSS Project	CSS Scenario					
	Baseline (14-3)	14-2	15-4	15-5	18-4	18-5	Full LTCP (19-3A)
CSO 14 regulator upgrade	X	X	X	X	X	X	X
CSO 028A & 028E separation	X	X	X	X	X	X	X
CSO 04 & CSO 05 replacement	X	X	X	X	X	X	X
Lower Gillies Conveyance		X					X
WWTP wet weather treatment to 140 MGD	X	X		X	X	X	
WWTP wet weather treatment to 300 MGD			X				X
CSO 21 replacement and additional 2MG storage				X			X
SRB expansion					X	X	X
SRB disinfection						X	X

In addition to making changes to the CSS model elements and configuration to represent the individual CSS improvements, the E.coli concentrations associated with the WWTP were also modified depending on the CSS project. Under current conditions, the WWTP treats inflows up to 75 MGD, with no supplemental treatment during wet weather flows. Several CSS scenarios simulate wet weather treatment up to 140 MGD, and yet others simulate wet weather treatment up to 300 MGD. The WWTP treatment scheme for each scenario is summarized in Table 5-3.

Table 5-3: WWTP Treatment for Each CSS Scenario

CSS Scenario	Full Treatment (MGD)	Primary Treatment (MGD)	Preliminary Treatment (MGD)	Total Treatment (MGD)
Current	75	--	--	75
14-3	75	65	--	140
14-2	75	65	--	140
15-4	85	55	160	300
15-5	75	65	--	140
18-4	85	55	--	140
18-5	85	55	160	140
19-3A	85	55	160	300

E.coli concentrations associated with each treatment pathway were estimated based on previous modeling, and a flow-weighted average *E.coli* concentration was calculated to estimate the total *E.coli* contribution from the WWTP. All influent to the WWTP was assumed to have an *E.coli* concentration of 235,000 CFU/100mL. It was assumed that influent receiving full treatment would result in an effluent concentration of 126 CFU/100 mL, consistent with the effluent concentration guidelines in the VAPDES permit (#VA0063177). Effluent concentrations from primary and preliminary treatment facilities were calculated according to the following formula:

$$Effluent\ E.coli\ concentration = \frac{influent\ concentration}{reduction\ factor}$$

The effluent reduction factors for primary and preliminary treatment were calculated using formulas that were developed as part of ongoing modeling efforts by Greeley and Hansen (Greeley and Hansen, personal communication, 11/15/2016).). The primary treatment reduction factor is governed by the following equation:

$$Log\ reduction\ factor = 0.76 * \ 10^{2.57904-1.2563*\log(Q)}$$

Where: Q is the inflow in MGD

The preliminary treatment reduction is governed by the following equation:

$$Log\ reduction\ factor = 0.76 * \ 10^{2.77053-1.2563*\log(Q)}$$

Where: Q is the inflow in MGD

For both treatment pathways, the reduction factor is large when flows are small due to increased contact time with the UV disinfection system. Therefore, a treatment floor of 126 cfu/100 mL was set because it was assumed that the treatment capacity of the primary and preliminary pathways could not exceed full treatment.

Post-processing was also required to simulate disinfection at SRB. All influent to SRB was assumed to have an *E.coli* concentration of 111,000 CFU/100 mL, consistent with *E.coli* EMC for CSO 06. The effluent reduction factor for SRB was calculated using a formula that was developed as part of ongoing modeling efforts by Greeley and Hansen (Greeley and Hansen, personal communication, 11/15/2016.)

$$Log\ reduction\ factor = 11.8102 - 3.1211 * \log(Q)$$

Where: Q is the flow rate in MGD

Similar to the WWTP alternative treatment pathways, the SRB reduction factor is large when flows are small due to increased contact time with the chlorine disinfection system. Therefore, a treatment floor of 126 cfu/100 mL was set because it was assumed that the SRB treatment capacity could not exceed full treatment at the WWTP.

5.4 Results

The James River water quality model was configured to compute *E.coli* concentrations at an hourly interval for the three year typical period. These results were compared against the monthly water quality standards and summarized at key locations of interest along the river. Additionally, results were also summarized to show the overall bacteria load reduction, CSO volume reduction, and reduction in number of CSO events.

5.4.1 Current Conditions

Figure 5-4 show the modeled monthly geomean concentrations and the percent exceedance of the STV standards at the downstream boundary of the city. For each month that violated the water quality standard, a detailed component analysis was completed. The component analysis tracks the relative contribution of each *E.coli* source (upstream, CSOs, watershed/MS4, background, and WWTP) to the modeled concentration in the James River. This type of analysis is useful to evaluate which sources of bacteria have the greatest impact on water quality conditions in the James River for a given point in time or location in the river.

Under current conditions, the geometric mean water quality standard is violated at the downstream city limit (the compliance evaluation point) for 4 months of the 36 month typical period. Significant contributors to non-compliance are upstream sources, the background sources, and CSOs. Non-compliance tends to occur when James River flows and upstream James River concentrations are high or when James River flows are low and significant precipitation events cause combined sewer discharges.

The statistical threshold value standard is more frequently violated, with 16 of 36 months exceeding the standard at the downstream City limit. Significant contributors to non-compliance of the STV standards are mainly CSOs and upstream sources, and to a lesser extent, the MS4/Watershed source. The CSOs are a more frequent and greater contributor to water quality violations using the STV standard than using the monthly geometric mean standard.

These results illustrate that:

- The James River is in violation of both the geometric mean and the statistical threshold value water quality standards for some months out of the three year simulation period.
- The primary cause of a water quality standard violation can sometimes be linked to Richmond combined sewer overflows, while at other times it is due to upstream sources. Background and MS4/Watershed sources play a smaller overall role in the bacteria water quality violations. The WWTP does not contribute significantly to bacteria water quality violations.

Figure 5-5 illustrates the E.coli monthly geometric mean in the James River, from a few miles upstream of the city limits to a few miles past the downstream city limits. During some months, for example in April 2012 (orange line), the James River is compliant upstream of the city and local *E.coli* sources are small enough that the James River is also compliant downstream of the city. During other months, like in June of 2013 (blue line), the James River is compliant upstream of the city but because of the contributions from background, watershed, and CSO sources, the James River exceeds the water quality standards at the downstream city limit. Finally during some months, like December 2011 (dark green line), the river is non-compliant with the water quality standards upstream of the city and remains non-compliant downstream of the city.

Table 5-4 shows the E.coli load, CSO volume, and number of CSO events under the existing conditions.

Table 5-4: Existing Condition: E.coli Load, CSO Volume, and Number CSO Events

Metric	Value
Average yearly E.coli load (billion cfu)	9,651,987
Average annual number of CSO events	53
Average yearly CSO volume discharged (million gallons)	1,670

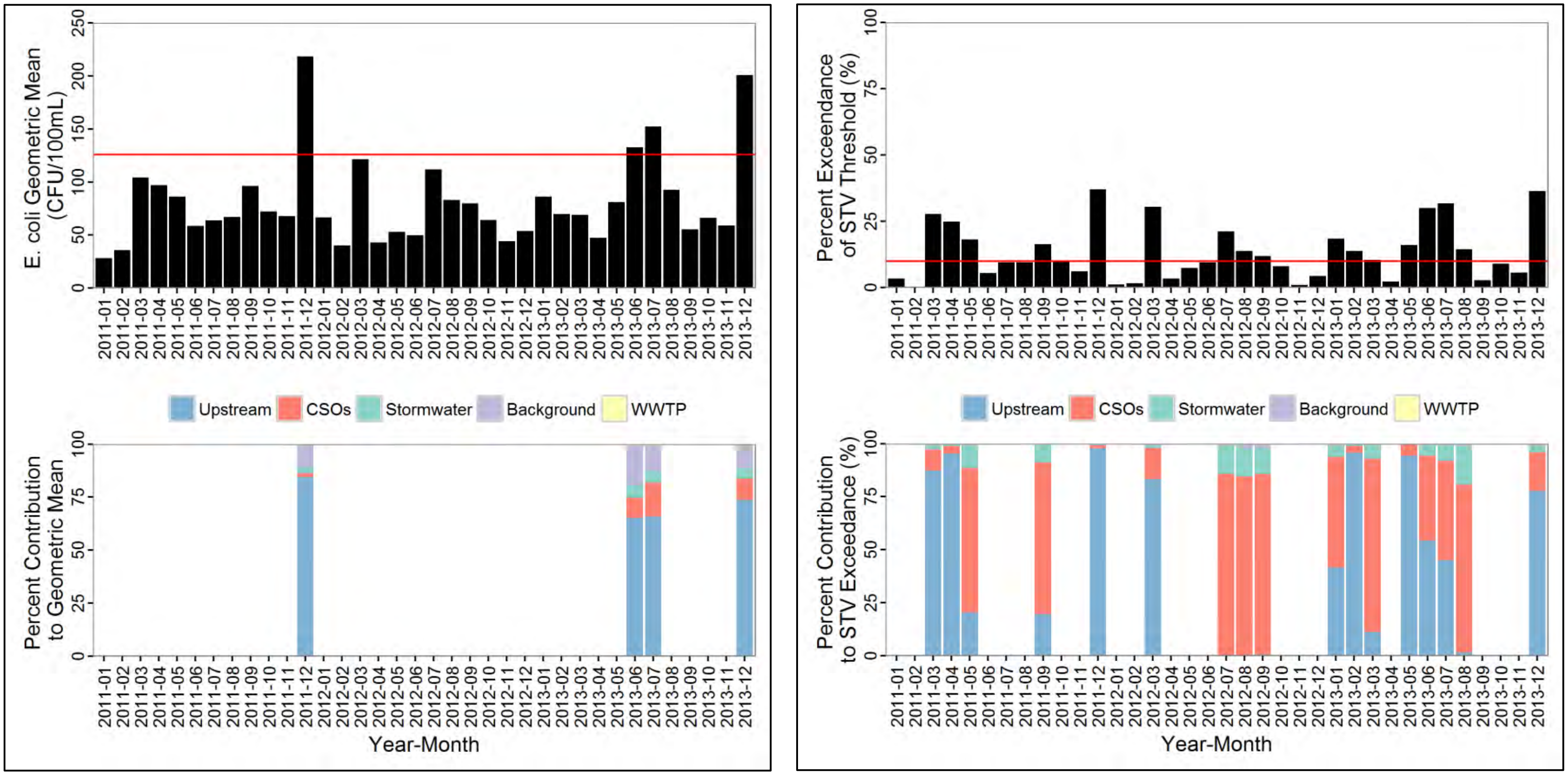


Figure 5-4: Existing Condition: Monthly Geometric Mean and STV Standard Model Results

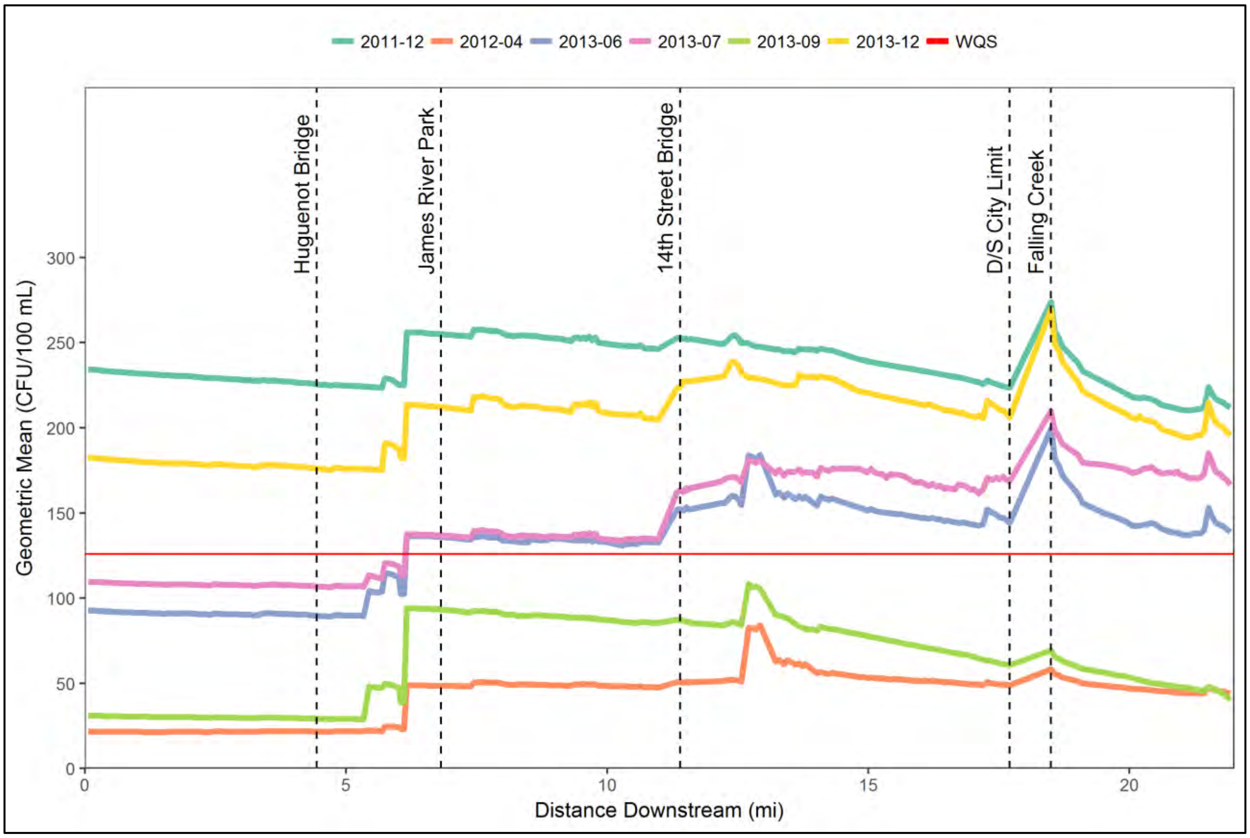


Figure 5-5: Lateral and temporal variability in E.coli concentration in the James River

5.4.2 Baseline Conditions

Figure 5-6 shows the modeled monthly geomean concentrations and the percent exceedance of the STV standards at the downstream boundary of the city for the baseline condition. For each month that violated the water quality standard, a detailed component analysis was completed. Similar to current conditions, under baseline conditions, the geometric mean water quality standard is violated at the downstream city limit (the compliance evaluation point) for 4 months of the 36 month typical period. Significant contributors to non-compliance are upstream sources, the "background" or "unknown" source, and CSOs. Non-compliance tends to occur when James River flows and upstream James River concentrations are high or when James River flows are low and significant precipitation events cause combined sewer discharges.

The statistical threshold value standard is more frequently violated, with 16 of 36 months exceeding the standard at the downstream City limit. Significant contributors to non-compliance of the STV standards are mainly CSOs and upstream sources, and to a lesser extent, the MS4/Watershed source. Though the baseline projects significantly reduce CSOs, these projects alone are not sufficient to bring the James River into compliance with water quality standards.

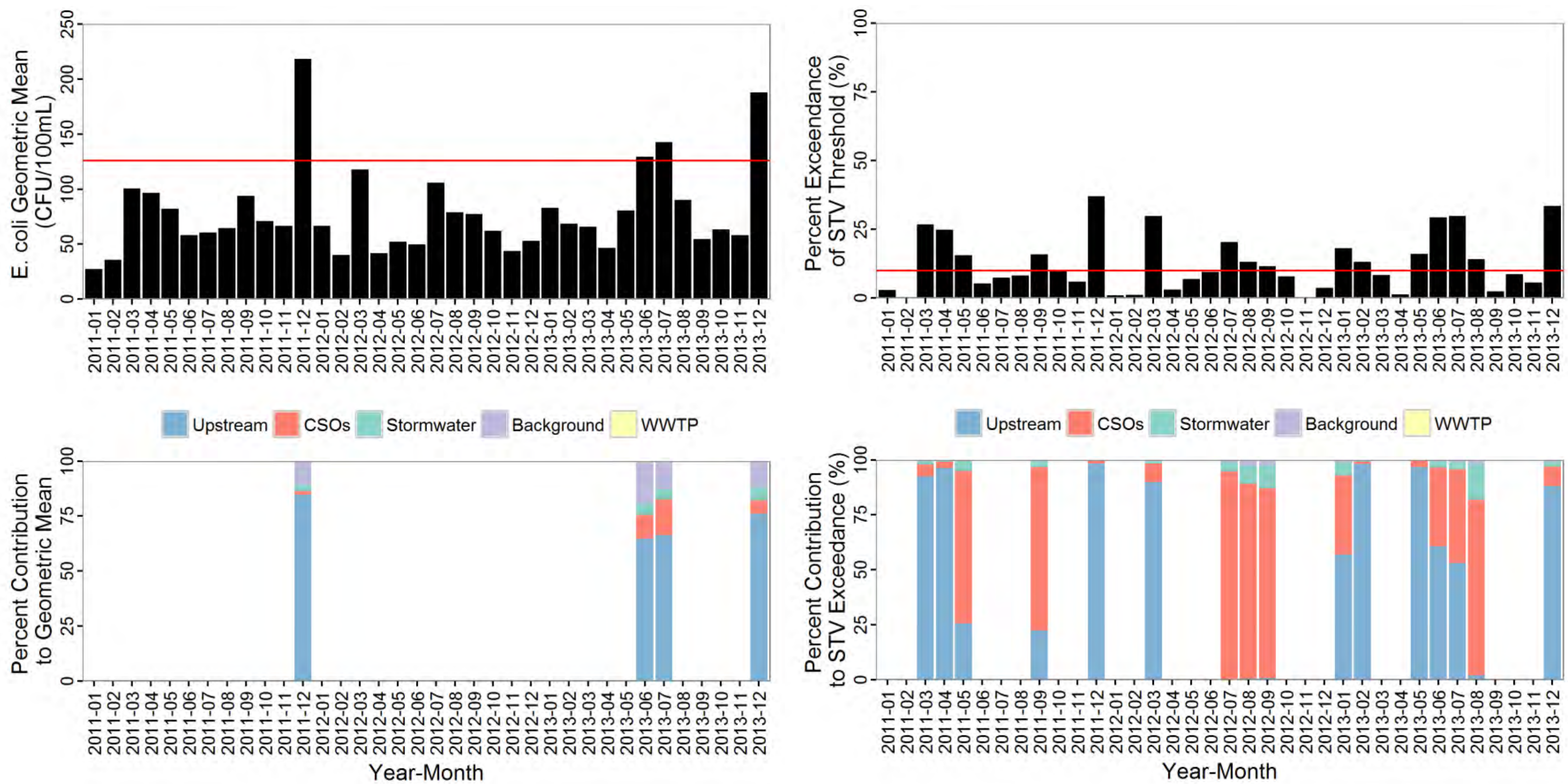


Figure 5-6: Baseline Condition: Monthly Geometric Mean and STV Standard Model Results

Table 5-5 shows the E.coli load, CSO volume, and number of CSO events under the existing conditions. The baseline conditions represent the improvements due to the implementation of several CSO improvement projects. Compared to the existing conditions, these projects collectively reduce the E.coli loads by approximately 18%, reduce the number of overflows by 2 events, and reduce the yearly CSO volume discharged by approximately 29%.

Table 5-5: Baseline Condition: E.coli Load, CSO Volume, and Number CSO Events	
Metric	**Value**
Average yearly E.coli load (billion cfu)	7,958,183
Average annual number of CSO events	51
Average yearly CSO volume discharged (million gallons)	1,190
Percent improvement compared to current conditions (%)	12.8

5.4.3 Green Infrastructure in the MS4 Area Strategy

The "*green infrastructure in the MS4 area*" strategy proposed to implement green infrastructure to treat 104 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation, in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. Table 5-6 shows the E.coli load, CSO volume, and number of CSO events under the "Green Infrastructure in the MS4 Area" strategy. This strategy reduces the E.coli load entering the James River only slightly compared to the baseline conditions (<0.6% reduction). This strategy only targets Richmond's MS4 area, so the number of CSO events and the yearly CSO volume are not affected compared to the baseline scenario.

Table 5-6: Green Infrastructure in MS4 Strategy: E.coli Load, CSO Volume, and Number CSO Events	
Metric	**Value**
Average yearly E.coli load (billion cfu)	7,954,132
Average annual number of CSO events	51
Average yearly CSO volume discharged (million gallons)	1,190
Percent improvement compared to current conditions (%)	13.0

5.4.4 Green Infrastructure in the CSS Area Strategy

The "*green infrastructure in the CSS area*" strategy proposed to implement green infrastructure to treat 18 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation, in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. Table 5-7 shows the E.coli load, CSO volume, and number of CSO events under the "Green Infrastructure in the CSS Area" strategy. This strategy reduces the E.coli load entering the James River only slightly compared to the baseline conditions (<0.6% reduction). This strategy specifically targets the CSS area. The area of GI implementation (18 acres) is not significant enough to reduce the number of CSO events, but it does reduce the annual CSO volume discharged slightly compared to the baseline scenario.

Table 5-7: Green Infrastructure in CSS Strategy: E.coli Load, CSO Volume, and Number CSO Events	
Metric	**Value**
Average yearly E.coli load (billion cfu)	7,905,833
Average annual number of CSO events	51
Average yearly CSO volume discharged (million gallons)	1,180
Percent improvement compared to current conditions (%)	12.9

5.4.5 CSS Infrastructure Improvement Strategy

Table 5-6 shows the E.coli load, CSO volume, and number of CSO events under the "CSS Infrastructure Improvement" strategy. This strategy includes numerous projects intended to reduce the number of CSO events and CSO volume discharged.

Table 5-8: CSS Infrastructure Improvement Strategy: E.coli Load, CSO Volume, and Number CSO Events			
Metric	**Value**	**Reduction Compared to Baseline Conditions**	**Reduction Compared to Existing Conditions**
Average yearly E.coli load (billion cfu)	4,407,072	45%	54%
Average annual number of CSO events	50	2%	5%
Average yearly CSO volume discharged (million gallons)	228	81%	86%
Percent improvement compared to current conditions (%)	21.3%	-	-

Figure 5-7 illustrates water quality compliance at the downstream City limit for the CSS Infrastructure Improvement strategy. Under this strategy, the geometric mean water quality standard is violated at the downstream city limit (the compliance evaluation point) for 3 months of the 36 month typical period. Non-compliance occurs because the upstream sources contribute significant flow and high bacteria loads.

The statistical threshold value standard is more frequently violated, with 16 of 36 months exceeding the standard at the downstream City limit. Significant contributors to non-compliance of the STV standards are mainly CSOs and upstream sources, and to a much lesser extent, the MS4/Watershed source. The CSOs continue to contribute to non-compliance under the STV standards, especially during the summer months. The CSOs are a more frequent and greater contributor to water quality violations using the STV standard than using the monthly geometric mean standard.

These results illustrate that:

- Controlling City of Richmond bacteria sources alone would not achieve compliance with water quality standards.
- Reducing combined sewer overflows via the CSS Infrastructure Improvement strategies would significantly reduce the average yearly CSO volume discharged (81% reduction compared to the baseline conditions). It would also improve compliance with water quality standards, especially during times when upstream sources are not significantly contributing to water quality violations.

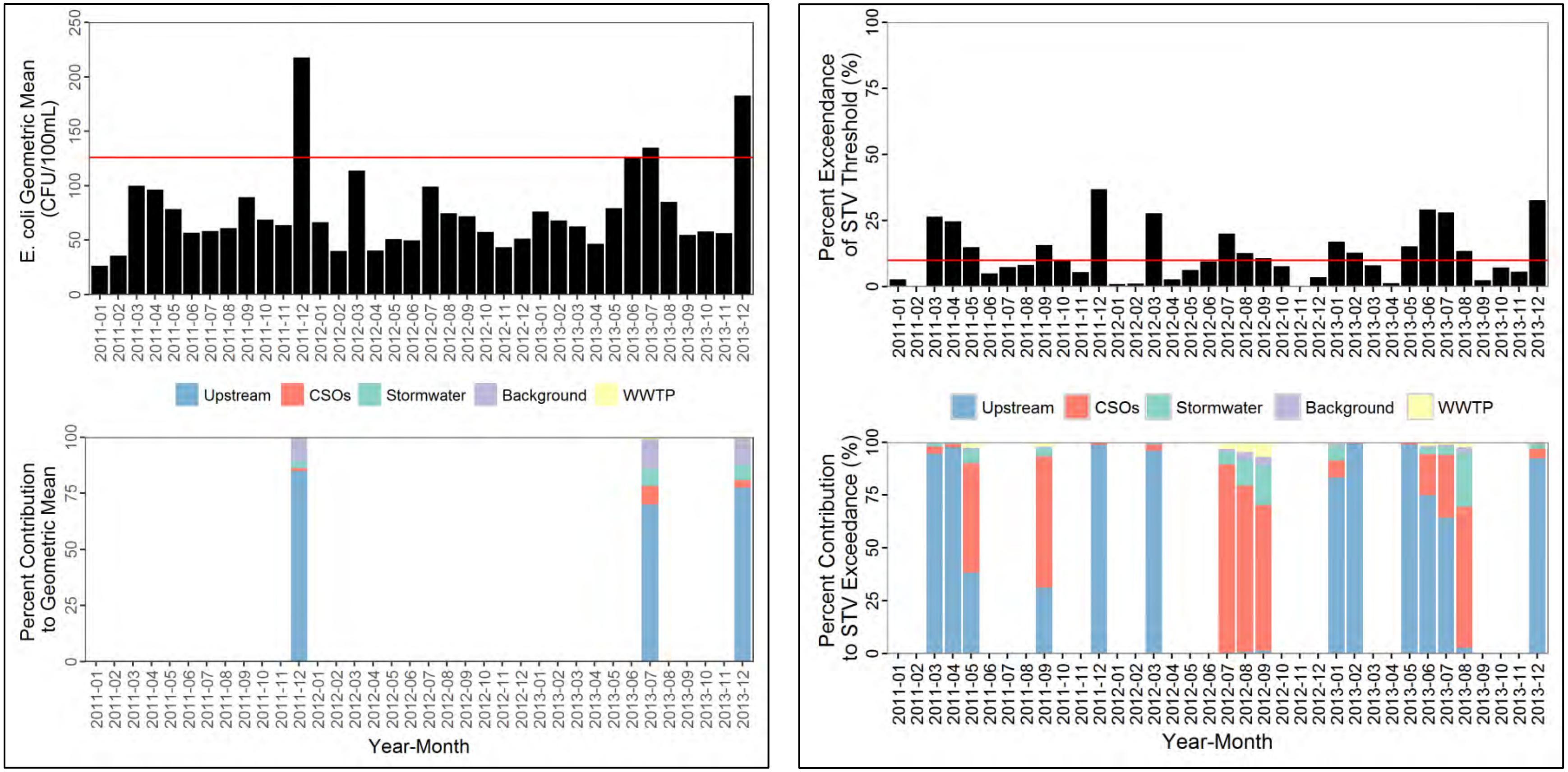


Figure 5-7: CSS Improvement Infrastructure Strategy: Monthly Geometric Mean and STV Standard Model Results

5.4.5.a CSS Infrastructure Improvement Strategy with Upstream Load Reductions

The James River Bacteria TMDL (MapTech, 2010) details the *E.coli* load reductions that would be necessary to achieve water quality compliance upstream of the City. These reductions, which were based on an independent analysis of water quality, were generally greater than 50%. Based on this information, the Water Quality model was applied for the CSS Infrastructure Strategy, whereby upstream load reductions were incrementally reduced until the downstream water quality criteria would be achieved under the monthly geomean standard. If all other sources remain the same, and with the CSS Infrastructure improvements in place, upstream sources would need to be reduced by 50% in order to meet the monthly geomean standard. These results are shown in

Figure 5-8.

5.4.5.b Evaluating Individual CSS Infrastructure Improvement Projects

The CSS Infrastructure Improvement Strategy consists of several different projects as outlined in the LTCP, and shown in Table 5-1 and Table 5-2. Each project was evaluated in isolation to determine individual project impact on bacteria load reduction and on the percent improvement towards meeting the monthly E.coli geometric mean water quality standard. Figure 5-9 summarizes the *E.coli* load reductions and Table 5-9 shows the “percent improvement” for each project scenario. Even though the individual scenarios can achieve significant E.coli load reductions (22%-67% reductions), the “percent improvement” shows smaller gains that vary between 13% and 21%. This is because E.coli loads from the CSS system make up only a fraction of the total *E.coli* load in the James River.

5.4.5.c Evaluating Alternative CSS Improvement Projects

It is anticipated that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost. These alternatives will be evaluated against the existing LTCP projects, and results will be presented as they become available.

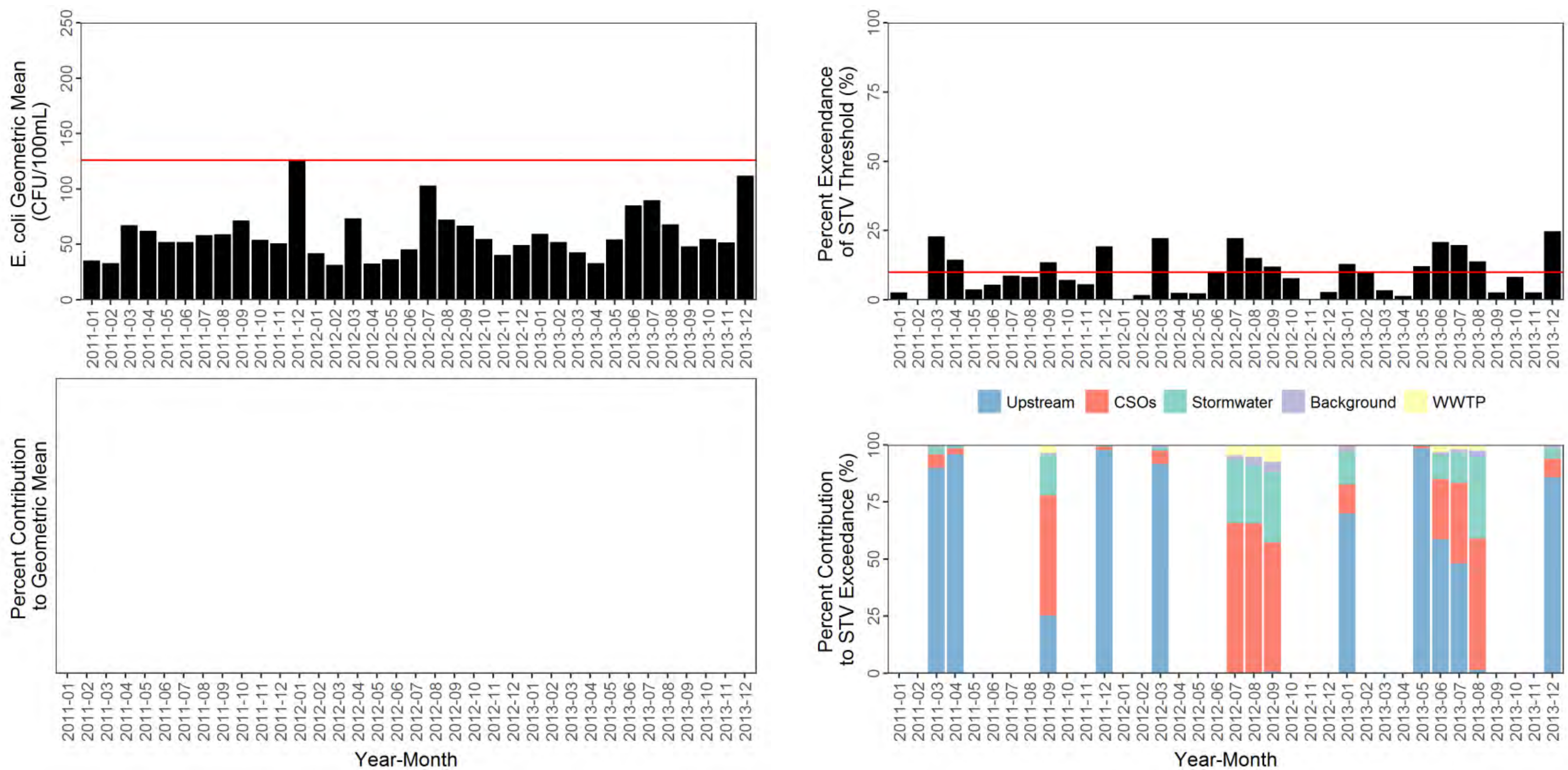


Figure 5-8: Modeled Water Quality Concentration with CSS Improvement Infrastructure Strategy and a 50 Percent Reduction in Upstream Loads

Figure 5-9: E.coli Load Reduction for Each CSS Infrastructure Improvement Project

Table 5-9: Percent Improvement Over Current Conditions for each CSS Infrastructure Improvement Project

CSS Scenario	Project	3-year Aggregate CSO Event Reduction (#)	3-year Aggregate CSO Volume Reduction (MG)	3-year Aggregate Exceedance of Geomean Standard (CFU/100ml)	Percent Improvement Over Current Conditions
Current	Current Conditions	--	--	200	--
14-3	Baseline Conditions	5	1,439	174	12.8%
14-2	Gillies Conveyance	5	1,468	174	13.2%
15-4	300 MGD Wet Weather Treatment	5	2,488	167	16.6%
15-5	CSO 21 Replacement	6	1,634	175	12.5%
18-4	SRB Expansion	1	1,950	168	16.1%
18-5	SRB Expansion and Disinfection	5	3,993	158	21.0%
19-3A	CSS Infrastructure Improvement Strategy (Full LTCP)	8	4,325	157	21.3%

5.4.6 Summary of Results for the Strategy Calculator

The strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges, expressed as Billion CFU
- Percent improvement in monthly geomean water quality standard compliance at the downstream city limit
- Reduction in number of CSO events
- Reduction in CSO volume (Million gallons)

These four metrics are used in the Strategy Calculator, a spreadsheet tool that is used to evaluate and score the different management strategies across a wide range of goals and objectives (LimnoTech, 2017). The results for the Strategy Calculator are summarized in Table 5-10.

Table 5-10: Strategy metric results used in the Strategy Calculator

Metric	GI in MS4	GI in CSS	CSS Infrastructure
Average yearly E.coli load reduction compared to the baseline (billion cfu)	4,051	52,350	3,551,112
Average reduction in annual number of CSO events compared to the baseline conditions	0	0	1
Average reduction in annual CSO volume discharged compared to the baseline conditions (million gallons)	0	9	962
Percent improvement compared to baseline conditions (%)	0.1	0.1	10

6 References

American Society of Civil Engineers (ASCE). 1992. Design & Construction of Urban Stormwater Management Systems, New York, NY.

Brown and Caldwell. 2016. Draft Technical Memorandum: CSO Model Review and Advancement Strategy: Model Review. May 10, 2016.

Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Federal Emergency Management Agency (FEMA). 2014. Flood Insurance Study: City of Richmond, Virginia. Revised July 16, 2014.

Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steuck, M., & Tyler, D. 2002. The National Elevation Dataset. Photogrammetric engineering and remote sensing, 68(1), 5-32.

Greeley and Hansen. 2002. Combined Sewer Overflow (CSO) Study; Long-Term CSO Control Plan Re-Evaluation. January, 2002.

Greeley and Hansen. 2012-2014:

- Broad Rock Creek Watershed Plan. Final Report. November 2012.
- Cherokee Lake Watershed Plan. Final Report, November 2012.
- Falling Creek Watershed Plan. Final Report, February 2014.
- Gillies Creek Watershed Plan. Final Report, November 2012.
- Goodes Creek Watershed Plan. Final Report, November 2012.
- Grindall Creek Watershed Plan. Final Report, November 2012.
- Jordan’s Branch Watershed Plan. Final Report, November 2012.
- Manchester Watershed Plan. Final Report, November 2012.
- Pocosham Creek Watershed Plan. Final Report, February 2014.
- Reedy Creek Watershed Plan. Final Report, November 2012.
- Riverfront Watershed Plan. Final Report, January 2014.
- Willow Oaks Watershed Plan. Final Report, January 2014.

Greeley and Hansen. 2015. Wastewater Collection System Master Plan: Collection System Hydraulic Model. November 2015.

James, W., Rossman, L. A., & James, W. R. C. 2010. User's guide to SWMM 5: [based on original USEPA SWMM documentation]. CHI.

Lawson, 2003. HSPF Model Calibration and Verification for Bacteria TMDLS: Guidance Memo No. 03-2012. Commonwealth of Virginia. Department of Environmental Quality. Water Division.

LimnoTech. 2008. Richmond CSO and James River receiving water model – Model description & Modeling procedure.

LimnoTech, 2017. Calculator Webinar, January 2017. Accessible through: http://www.rvah2o.org/file-upload-form/ or through https://player.vimeo.com/video/199872947

MapTech, 2010. Bacterial Total Maximum Daily Load Development for the James River and Tributaries – City of Richmond. November 2010. McCuen, R. et al. 1996. Hydrology, FHWA-SA-96-067, Federal Highway Administration, Washington, DC

Risley, J. C., Stonewall, A., & Haluska, T. L. 2008. Estimating flow-duration and low-flow frequency statistics for unregulated streams in Oregon (No. FHWA-OR-RD-09-03). US Department of the Interior, US Geological Survey.

USACE, 2013. Richmond Deepwater Terminal to Hopewell After Dredging. Survey of September 2011 to January 2012. James River, Virginia. 1/23/2013.

USACE, 1979-1980. National Dam Safety Program. Norfolk District Corps of Engineers. Reports available through the Defense Technical Information Center: http://www.dtic.mil/dtic/

USEPA, 2010. Sampling and Consideration of Variability (Temporal and Spatial) For Monitoring of Recreational Waters (EPA Publication No. EPA-823-R-10-005).

USGS, 2017. Load Estimator (LOADEST): A Program for Estimating Constituent Loads in Streams and River. Website accessed 2/13/2017. Page last modified: 12/12/2016.

7 Glossary

CSO: Combined sewer overflow

CSS: Combined sewer system

CWA: Clean Water Act

DCIA: Directly connected impervious area

DEM: Digital elevation model

EFDC: Environmental Fluid Dynamic Code

EMC: Event mean concentration

HSG: Hydrologic soil group

LiDAR: Light detection and ranging

MRLC: Multi-Resolution Land Characteristics

MS4: Municipal separate storm sewer system

NCDC: National Climatic Data Center

NLCD: National Land Cover Database

NRCS: National Resources Conservation Service

NOAA: National Oceanic and Atmospheric Administration

NRCS: National Resources Conservation Service

RIA: Richmond International Airport

SSO: Sanitary sewer overflow

SSURGO: Soil Survey Geographic database

SWMM: Storm Water Management Model

USGS: United States Geological Survey

Appendix 2. Strategy Fact Sheets

STRATEGY: RIPARIAN AREAS

Replace or restore 10 acres of riparian buffers according to state guidance. This may include:

- Implementing in the MS4 and / or the CSS areas of the City
- Replacing grassed buffers and impervious surfaces with a forested buffer
- Evaluating opportunities for inclusion of access points to waterbody for recreational activities

Riparian areas within urban environments often face numerous pressures from encroachment to increased pollutant impacts. The Riparian Area strategy includes the identification of areas within a 100 foot riparian buffer that have been compromised by insufficient vegetation to perform its function. This can stem from factors such as the removal of trees, lack of an understory, or presence of impervious surfaces.

A GIS analysis of the City's streams and the land cover surrounding these streams identified locations where these stream buffer deficiencies exist. The intent of the Riparian Area strategy is to replace or restore these deficient buffers. Several assumptions were made in association with this strategy including:

- Removal of two acres of impervious surfaces
- Restoration of eight acres of grassed areas to forest buffer
- Planting 125 trees per acre

Additionally, because one objective is to facilitate recreational access to the streams, this strategy will also incorporate four access points within these 10 acres of restored riparian area (1 access point per 1,000 feet of buffers replaced/restored).

This strategy also makes the assumption that there will be an investigation of the possibility to increase the width of riparian buffers within the City to 200 feet. If determined feasible, riparian buffers will be expanded upon where possible.

While this strategy is not traditionally considered "green infrastructure," it was characterized as such for the scoring of the strategies due to elements of the strategy, such as removal of impervious surfaces and tree planting.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Riparian Area strategy was included in **TIER 1** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
√	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
√	Riparian buffers restored/increased
√	Habitat protected or restored
√	Habitat connected by green corridor
√	Impervious surface reduced or treated
√	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
√	Stream access points added
√	Streams buffers added
	Conservation easements added
	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	19
Average yearly TP load reduction (lbs/yr)	4
Average yearly TSS load reduction (lbs/yr)	1,081
Average yearly E.coli load reduction (billion cfu/yr)	83

Cost Effectiveness	
Cost per pound TN removed	$58,902
Cost per pound TP removed	$292,553
Cost per pound TSS removed	$1,017
Cost per billion cfu E.coli removed	$13,190

STRATEGY: GREEN INFRASTRUCTURE IN THE MS4

Install or retrofit green infrastructure (GI) draining 104 acres of city-owned impervious surfaces (50% of all city-owned impervious area) through efforts such as:

- Installing GI on DPU property, specifically targeting city-owned vacant properties for stormwater management
- Installing a mix of GI, including bioengineered tree boxes (like Filtera-type practices)
- Installing GI on Parks department property (e.g.: playgrounds, parks, cemetery roadways, vacant properties, etc.)
- Retrofitting four DPU stormwater BMPs (e.g., dry ponds to more efficient BMPs); draining at least 6 acres of impervious surface

This green infrastructure (GI) strategy is intended to represent a general mix of practices typically included in GI implementation efforts. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the GI types included, area treated, and load reductions efficiencies, and other benefits provided by the GI practices. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

The mix of GI types included and shown below is based on some of the more common GI types that are routinely implemented in the region. The practices assumed for this strategy are not meant to be exclusive or all-encompassing; other practices such as constructed wetlands, impervious surface disconnection, or nutrient management, could also be included under this strategy. The "final" list of GI practices will be determined though the Framework Planning process, as the City and stakeholders move closer to evaluating projects for implementation (see Chapter 7 of the City's Integrated Water Resources Management Plan for additional discussion on Framework Planning).

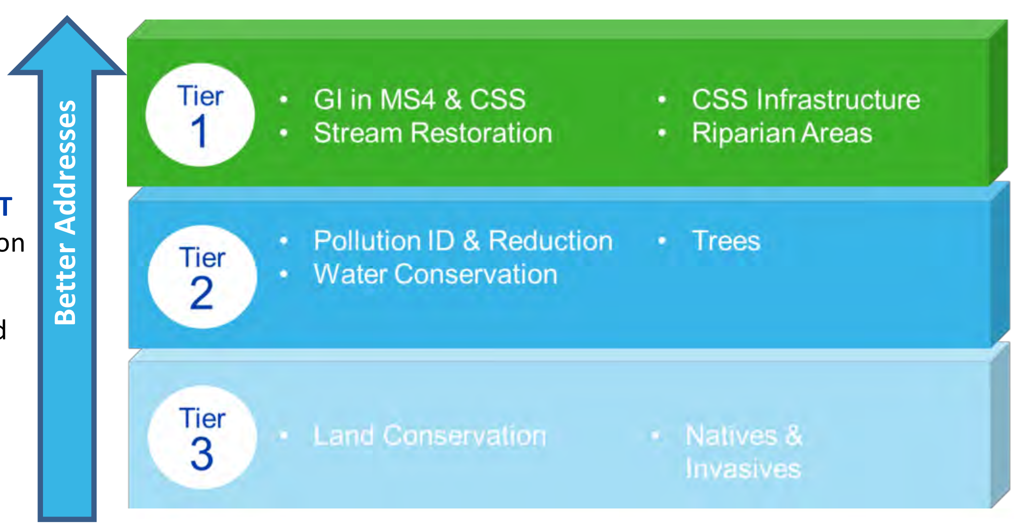
The Mix of GI and Associated Acres Assumed for GI in the MS4

Green Infrastructure Practice	Area Treated (acres)
Engineered tree boxes	17
Stormwater pond retrofit (dry pond to wet pond)	6
Green roofs	1
Rainbarrels	16
Permeable pavement - A/B soils, underdrain	10
Permeable pavement - C/D soils, underdrain	10
Bioretention/raingardens - A/B soils, underdrain	21
Bioretention/raingardens - C/D soils, underdrain	23
Total Area Treated by Green Infrastructure in the MS4 area	**104**

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, GI in the MS4 was included in **TIER 1** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
√	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
√	Habitat protected or restored
	Habitat connected by green corridor
√	Impervious surface reduced or treated
√	Trees planted
	Potable water consumption reduced
√	Rain or storm water used for irrigation
√	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs)	414
Average yearly TP load reduction (lbs)	90
Average yearly TSS load reduction (lbs)	42,397
Average yearly E.coli load reduction (billion cfu)	3,531

Cost Effectiveness	
Cost per pound TN removed	$30,181
Cost per pound TP removed	$138,687
Cost per pound TSS removed	$295
Cost per billion cfu E.coli removed	$3,540

STRATEGY: GREEN INFRASTRUCTURE IN THE COMBINED SEWER SYSTEM (CSS)

Install or retrofit green infrastructure (GI) draining 18 acres of city-owned impervious surfaces through efforts such as:

- Installing GI on DPU property, specifically targeting city-owned vacant properties for stormwater management
- Installing a mix of GI, including bioengineered tree boxes (like Filtera-type practices)
- Installing GI on Parks department property (e.g.: playgrounds, parks, cemetery roadways, vacant properties, etc.)

This green infrastructure (GI) strategy is intended to represent a general mix of practices typically included in GI implementation efforts. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the GI types included, area treated, and load reductions efficiencies, and other benefits provided by the GI practices. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

The Mix of GI and Associated Acres Assumed for GI in the CSS

Green Infrastructure Practice	Area Treated (acres)
Engineered tree boxes	2.9
Green roofs	0.2
Rainbarrels	2.7
Permeable pavement - A/B soils, underdrain	1.8
Permeable pavement - C/D soils, underdrain	1.8
Bioretention/raingardens - A/B soils, underdrain	4.1
Bioretention/raingardens - C/D soils, underdrain	4.5
Total Area Treated by Green Infrastructure in the MS4 area	**18**

The mix of GI types included and shown here is based on some of the more common GI types that are routinely implemented in the region. The practices assumed for this strategy are not meant to be exclusive or all-encompassing; other practices such as constructed wetlands, impervious surface disconnection, or nutrient management, could also be included under this strategy. The "final" list of GI practices will be determined though the Framework Planning process, as the City and stakeholders move closer to evaluating projects for implementation (see Chapter 7 of the City's Integrated Water Resources Management Plan for additional discussion on Framework Planning).

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, GI in the CSS was included in **TIER 1** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
√	Bacteria reduction
	Reduction in no. of CSO events
√	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
√	Habitat protected or restored
	Habitat connected by green corridor
√	Impervious surface reduced or treated
√	Trees planted
	Potable water consumption reduced
√	Rain or storm water used for irrigation
√	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
√	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs)	74
Average yearly TP load reduction (lbs)	16
Average yearly TSS load reduction (lbs)	7,393
Average yearly E.coli load reduction (billion cfu)	40,642

Cost Effectiveness	
Cost per pound TN removed	$45,270
Cost per pound TP removed	$209,375
Cost per pound TSS removed	$453
Cost per billion cfu E.coli removed	$82

STRATEGY: STREAM RESTORATION

This strategy includes the rehabilitation of 2,500 linear feet of stream, including activities such as removal of concrete channels and repair of incised banks. These streams can be located within the MS4 or the CSS areas of the City. This strategy also includes the evaluation of opportunities for inclusion of access points to a waterbody for recreational activities.

The 2,500 linear feet selected for this Stream Restoration Strategy was based upon a similar expanse included within the City's Chesapeake Bay TMDL Action Plan. Several assumptions were made in the development of this strategy including the following:

- The EPA CBP-approved pollutant reduction for this practice considers the ecoregion within which the stream restoration takes place. Because Richmond is split approximately in half between the Coastal Plain and the Piedmont ecoregions, it was assumed that 50% of the stream rehabilitation efforts would occur in each.
- Stream restoration projects will include a riparian buffer of 100 feet, but, where possible, the buffer will be increased to 200 feet.
- The average width of the streams restored was assumed to be 50 feet.
- This 100-foot buffer along the 2,500 linear feet of stream restoration results in almost 6 acres of riparian buffer restored or increased.
    - This is separate from what is included in the Riparian Area Strategy.
- Trees would be planted at a density of 125 trees per acre with over 700 trees planted.
    - This is separate from what is included in the Tree Strategy.
- Because improving waterfront access for recreation is an objective for the IWRM Plan, an access point for residents was assumed to be included for every 1,000 feet of stream restored. Two access points are therefore assumed for this 2,500 linear feet of stream restoration.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Stream Rehabilitation strategy was included in **TIER 1** of priorities for implementation.

METRICS

The table below shows the metrics that are addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC		METRIC		METRIC
√	TN reduction	√	Riparian buffers restored/increased	√	Area treated by GI
√	TP reduction	√	Habitat protected or restored	√	Streams restored
√	TSS reduction	√	Habitat connected by green corridor		Stormwater volume reduction
	Bacteria reduction		Impervious surface reduced or treated	√	Stream access points added
	Reduction in number of CSO events	√	Trees planted		Stream buffers added
	Reduction in CSO volume		Potable water consumption reduced		Conservation easements added
	PCB, metals, and toxics reduction		Rain or storm water used for irrigation		Trash reduction
	Amount of water conserved		Percent increase in WQS compliance at James River compliance point		

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	188
Average yearly TP load reduction (lbs/yr)	170
Average yearly TSS load reduction (lbs/yr)	75,013
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$15,467
Cost per pound TP removed	$17,059
Cost per pound TSS removed	$39
Cost per billion cfu E.coli removed	--

STRATEGY: TREE PLANTING

Increase natural land cover by focusing on tree planting, including:

- Increasing tree canopy on City property by 5%
- Protecting existing tree canopy by following maintenance addressed in the Tree Planting Master Plan

The tree planting strategy is intended to protect as well as increase the amount of tree canopy that covers Richmond. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the number and density of trees planted, area treated, load reduction efficiencies, and other benefits provided by tree planting. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM. For example, it was assumed that 2,000 trees per year would be planted at a density of 125 trees/acre and that a single tree could reduce up to 466 gallons of storm water per year.

In addition to reducing target pollutant loads and stormwater volume, increasing the tree canopy also provides additional benefits to the public and to wildlife. As part of the tree planting strategy, trees planted in 50% of targeted areas are intended to increase or protect existing habitat, and 25% of the areas targeted for tree planting will be part of green corridors.

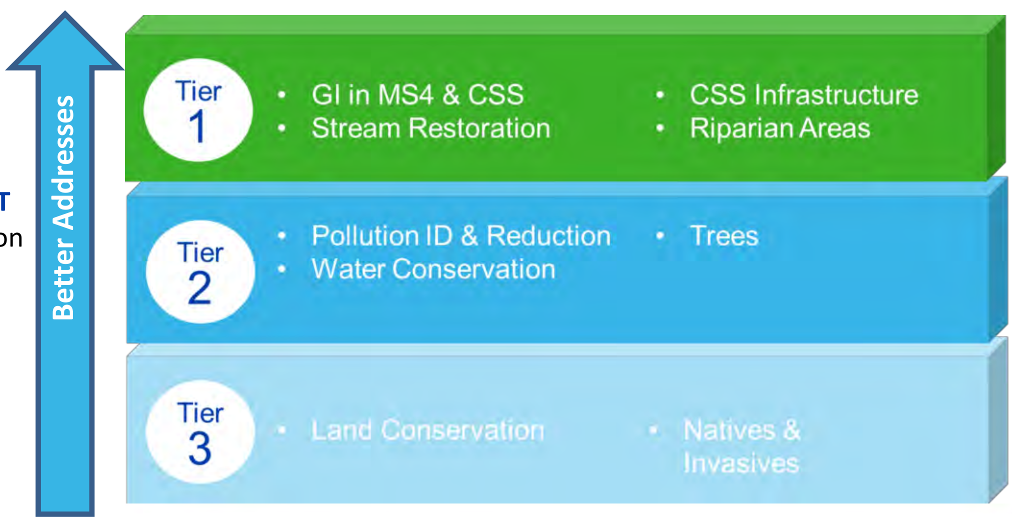
Acres Assumed for Tree Planting in the MS4

Tree Planting Practice	Area (acres)
Total area targeted for tree planting	80
Effective tree canopy area	33
Tree canopy area over impervious area	7
Tree canopy area over pervious areas	26
Habitat protected/restored	17
Habitat protected by green corridor	8

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Tree Planting strategy was included in **TIER 2** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
√	Habitat protected or restored
√	Habitat connected by green corridor
√	Impervious surface reduced or treated
√	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	30
Average yearly TP load reduction (lbs/yr)	4
Average yearly TSS load reduction (lbs/yr)	447
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$72,158
Cost per pound TP removed	$520,833
Cost per pound TSS removed	$4,925
Cost per billion cfu E.coli removed	--

STRATEGY: NATIVE PLANT RESTORATION/INVASIVE PLANT REMOVAL

Increase the number and variety of native plants in the City of Richmond by:

- Using 80% native plants in new landscaping at public facilities by 2023
- Removing 5% of invasive plant species on DPU and park properties and replace with native species

The native plant restoration/invasive plant removal strategy focuses on populating new landscaping projects with plant species native to Richmond, actively removing invasive plant species and replacing them with native, and promoting public awareness of invasive plants. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the area treated, load reductions efficiencies, and other benefits provided by the native plant restoration/invasive plant removal. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

There are two main components of the native restoration/invasive removal. The first component focuses on native plant restoration and invasive plant removal on City property. The native plant restoration/invasive plant removal strategy will also take several other factors into account such as biodiversity and the suitability of a species for a given location. Plantings of native species will focus on a wide variety of plants that are commonly found in the Coastal Plain/Piedmont region. In areas of the city that are not expected to receive supplemental watering, only drought-tolerant, native species will be considered. The second component of this strategy will be to develop a "do not plant" list of invasive species to raise awareness of problem species and to help guide local gardeners.

Strategy Elements	
20	Acres of native planting and/or invasive removal
2,000	Trees planted

While this Strategy does not offer significant reductions in target pollutants, they do provide a number of other benefits for the public, the city, and local wildlife, including: increased recreational space, plant biodiversity that will support a wider range of wildlife, and decreased watering costs associated with maintaining appropriately placed native plant species.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Native Plant Restoration/Invasive Plant Removal strategy was included in **TIER 3** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
	TN reduction
	TP reduction
	TSS reduction
	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
√	Habitat protected or restored
√	Habitat connected by green corridor
	Impervious surface reduced or treated
√	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
	Area treated by GI
	Streams restored
	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness for various strategies is evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) only. Because this strategy doesn't result in reduction of these pollutants, cost effectiveness could not be calculated.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	--
Average yearly TP load reduction (lbs/yr)	--
Average yearly TSS load reduction (lbs/yr)	--
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	--
Cost per pound TP removed	--
Cost per pound TSS removed	--
Cost per billion cfu E.coli removed	--

STRATEGY: WATER CONSERVATION

Reduce water consumption by 10% (from 2009-2014 baseline) through efforts such as:

- Installing water efficient fixtures as a policy by 2023 in all new public facility construction
- Implementing incentive programs that provide retrofits for low income households
- Encouraging water conservation on City properties
- Installing conservation landscaping on city-owned properties

This water conservation strategy is intended to represent a general mix of practices typically included in water conservation implementation efforts. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the conservation measures included, gallons of water conserved, load reductions efficiencies, and other benefits provided by the conservation practices. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

The mix of conservation activities included and shown here is based on incorporation of common water conservation practices, such as rain barrels and encouraging water conservation by City staff. An incentive program is also planned that will include retrofits of low flush toilets and other fixtures. The "final" list of water conservation practices will be determined though the Framework Planning process, as the City and stakeholders move closer to evaluating projects for implementation (see Chapter 7 of the City's Integrated Water Resources Management Plan for additional discussion on Framework Planning).

The Mix of Conservation Practices and Associated Gallons Conserved Assumed for Water Conservation

Water Conservation Practice	Water Conserved (million gallons)
1,000 New rain barrels	0.52
Conservation incentives	250
Improvements in the water distribution system	250
Total Water Conserved by Water Conservation Practices (over five years)	**500.52**

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Water Conservation strategy was included in **TIER 2** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the Water Conservation strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
	PCB, metals, and toxics reduction
√	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
	Habitat protected or restored
	Habitat connected by green corridor
√	Impervious surface reduced or treated
	Trees planted
√	Potable water consumption reduced
√	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	11
Average yearly TP load reduction (lbs/yr)	1
Average yearly TSS load reduction (lbs/yr)	422
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$24,092
Cost per pound TP removed	$195,744
Cost per pound TSS removed	$639
Cost per billion cfu E.coli removed	--

STRATEGY: LAND CONSERVATION

Place an additional 10 acres of city-owned land under conservation easement. When selecting acreage to include in the easement consideration will be given to the following factors:

- Prioritizing the conservation of land that creates connected green corridors
- Evaluating opportunities for inclusion of access points to waterbodies for recreational activities

The land conservation strategy focuses on placing an additional 10 acres of City-owned land under conservation easement. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to implementation. It was assumed that 50% of the land included in the conservation easement would create connected green corridors. Green corridors are areas of open space that connect fragmented green spaces together allowing for the improved movement of people and wildlife.

While the land conservation strategy does not offer significant reductions in target pollutants, they do provide a number of other benefits for both local wildlife and the public, including: habitat protection, habitat restoration, increased recreational space, and an increased number of access points to waterbodies within the City.

Land Conservation Benefits
Conservation/restoration of habitat
Improved connectivity between habitats
Increased public open space
Increased mobility for wildlife
Increased access to recreational opportunities

Because there are no regulatory requirements driving land conservation in the City, this strategy also helps the City address the IWRM Plan objective to exceed regulatory requirements, when possible.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Each is discussed on the following page.

Overall, the Land Conservation strategy was included in **TIER 3** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC		METRIC		METRIC
	TN reduction		Riparian buffers restored/increased		Area treated by GI
	TP reduction	√	Habitat protected or restored		Streams restored
	TSS reduction	√	Habitat connected by green corridor		Stormwater volume reduction
	Bacteria reduction		Impervious surface reduced or treated	√	Stream access points added
	Reduction in no. of CSO events		Trees planted		Streams buffers added
	Reduction in CSO volume		Potable water consumption reduced	√	Conservation easements added
	PCB, metals, and toxics reduction		Rain or storm water used for irrigation		Trash reduction
	Amount of water conserved		Percent increase in WQS compliance at James River compliance point		

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness for various strategies is evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) only. Because this strategy doesn't result in reduction of these pollutants, cost effectiveness could not be calculated.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	--
Average yearly TP load reduction (lbs/yr)	--
Average yearly TSS load reduction (lbs/yr)	--
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	--
Cost per pound TP removed	--
Cost per pound TSS removed	--
Cost per billion cfu E.coli removed	--

STRATEGY: POLLUTANT IDENTIFICATION AND REDUCTION

Reduce the contribution of pollutants to the municipal separate stormwater sewer system (MS4) area by:

- Conducting at least one special study per year in hot spot areas to identify illicit discharges/connections
- Collecting data associated with non-structural BMPs to facilitate quantification of pollutant reduction

The first part of this strategy involves identifying and eliminating illicit discharges within the MS4 area. Illicit discharges are sources of pollutants collected to storm drains that contribute contaminants to the system during periods of dry weather. This strategy will find and eliminate illicit discharges by conducting at least one special study each year in an area that has been deemed a “hot spot” for pollutant loading. By targeting “hot spots” the city can effectively and efficiently target relatively large sources of pollutants by eliminating the source of the discharge or by implementing a best management practice (BMP) to reduce the pollutant loading. Over five years, at least 3 of these studies will be used to meet pollutant reductions required by the Chesapeake Bay TMDL.

The second part of this strategy involves data collection for non-structural best management practices (BMPs). Currently, the assumptions associated with implementing non-structural BMPs such as catch basin clean outs and street sweeping are based on region-specific literature reviews. Because there is not an approved or commonly used methodology in place to account for pollutant reductions associated with pet waste removoal, this practice was not accounted for quantitatively in the strategy calculator. By collecting site-specific data on pollution reduction practices, the City will be able to refine the pollutant removal rates associated with these projects and to better quantify their impact on the James River. As additional data and research substantiate the quantification of additional pollutant removal practices, these will also be taken into consideration.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Pollutant Identification and Reduction strategy was included in **TIER 2** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
	Habitat protected or restored
	Habitat connected by green corridor
	Impervious surface reduced or treated
	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
	Area treated by GI
	Streams restored
	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
√	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	448
Average yearly TP load reduction (lbs/yr)	162
Average yearly TSS load reduction (lbs/yr)	57,893
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$36,597
Cost per pound TP removed	$100,882
Cost per pound TSS removed	$284
Cost per billion cfu E.coli removed	--

STRATEGY: IMPLEMENT CSS INFRASTRUCTURE PROJECTS

Implement projects outlined in Richmond's combined sewer overflow long-term control plan (CSO LTCP), including:

- Installing wet weather interceptor in Lower Gillies Creek to convey more flow to the WWTP
- Increasing wet weather treatment to 300 MGD at the WWTP
- Expanding Shockoe Retention Basin by 15 MG to capture more combined sewer overflow
- Adding disinfection at the Shockoe outfall to reduce bacteria in combined sewer overflow
- Expanding secondary treatment at the WWTP to 85 MGD

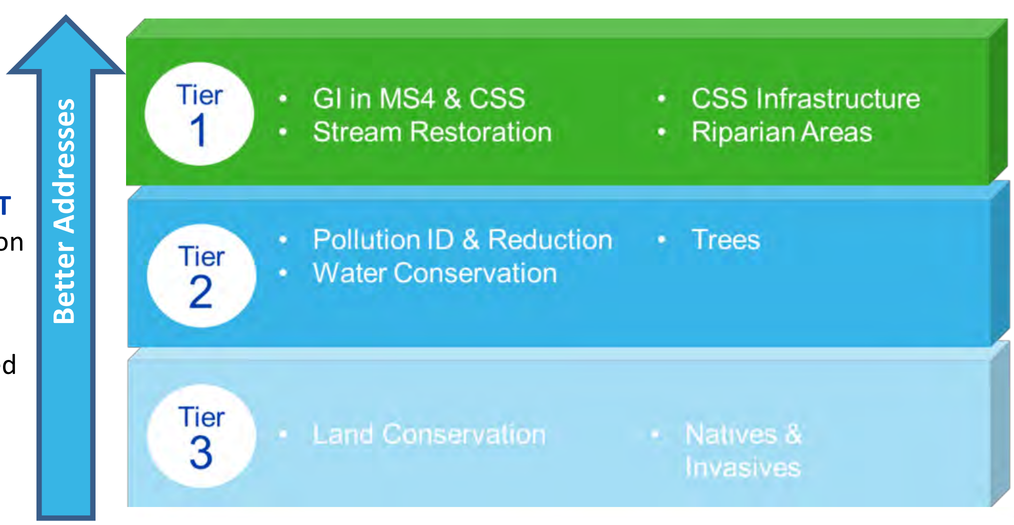
Implementation of Richmond's combined sewer overflow long-term control plan (CSO LTCP) is required under a consent order from the State Water Control Board. The consent order was issued in 2005 and includes an implementation schedule and a description of LTCP projects that will be implemented. Projects that are part of this strategy are aimed at decreasing the volume of CSOs by rerouting flows from the combined sewer outfalls to the Richmond waste water treatment plan (WWTP) and Shockoe retention basin (SRB), where those flows can then receive some level of treatment before being released into the James River. Increasing the treatment capacity of the WWTP and SRB, will result in smaller pollutant loads entering the James River, thereby improving water quality.

Strategy Elements
Expanding wet weather treatment at the waste water treatment plant
Improving wet weather conveyance in Lower Gillies Creek to the waste water treatment plant
Expanding the Shockoe Retention Basin and disinfecting combined sewer overflows at SRB
Expanding secondary treatment at the waste water treatment plant

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Implement CSS Infrastructure Strategy was included in **TIER 1** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
√	Bacteria reduction
√	Reduction in no. of CSO events
√	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
	Habitat protected or restored
	Habitat connected by green corridor
	Impervious surface reduced or treated
	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
√	Percent increase in WQS compliance at James River compliance point

	METRIC
	Area treated by GI
	Streams restored
	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
√	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	7,066
Average yearly TP load reduction (lbs/yr)	903
Average yearly TSS load reduction (lbs/yr)	116,843
Average yearly E.coli load reduction (billion cfu/yr)	3,551,112

Cost Effectiveness	
Cost per pound TN removed	$55,507
Cost per pound TP removed	$434,293
Cost per pound TSS removed	$3,357
Cost per billion cfu E.coli removed	$110

SUPPORTING ACTIONS TO MAIN STRATEGIES

While strategies have been defined as "activities, actions, or items that will help meet goals and objectives" of the Integrated Water Resources Management (IWRM) Plan, a number of additional actions have been identified to support or facilitate the implementation of these strategies. These supporting actions to the main strategies include efforts that may broaden the main strategy, additional specificity on how a strategy could be implemented, or identify additional resources and data needs to fully implement the main strategy. These supporting actions are not necessarily quantifiable in and of themselves and may be components of multiple main strategies. They may also involve efforts on non-City property and rely on resources that are outside the DPU's authority.

The development of strategies that meet the goals and objectives of the IWRM Plan resulted in a number of supporting actions related to:

- Partnerships
- Maintenance
- Monitoring, assessment & planning
- Incentives & credits
- Regulations, ordinances & codes
- Outreach

A summary of each of the supporting actions is discussed below and specific examples of these actions are included in the following tables.

The following table identifies which of these supporting actions are included in each strategy. For instance, the Riparian Area, Green Infrastructure (GI) in the municipal separate storm sewer system (MS4), and Tree Strategies address each of the six supporting actions. Alternatively the Pollution Identification (ID), Combined Sewer System (CSS) Infrastructure, and Land Conservation Strategies address only two supporting actions.

	Riparian Area	GI in MS4	GI in CSS	Stream Restor.	Natives/ Invasives	Trees	Land Cons.	Water Cons.	Pollution ID	CSS Infrast.
Partnerships	√	√	√	√	√	√	√	√		
Maintenance	√	√	√	√	√	√				
Monitoring	√	√	√	√	√	√			√	√
Incentives	√	√			√	√		√		
Regulations	√	√	√			√		√		
Outreach	√	√	√	√	√	√	√	√	√	√

Partnerships

The purpose of establishing partnerships is to facilitate a greater level of future implementation. This could be as the result of partnerships within the City, such as with Department of Planning or the Parks, Recreation, and Community Facilities. Partnerships may also include non-City agencies, such as watershed groups or neighborhood associations that can help facilitate implementation of strategies on private property. Non-DPU City departments, watershed groups, or neighborhood associations could work collectively with DPU to cost share implementation of strategies through shared staff and resources or through collaboration of actions. Additional specificity related to partnerships (along with other supporting actions) are expected to be refined over time as additional discussions and agreements are made with potential partners.

Maintenance

Many of the selected strategies require maintenance to ensure the strategy is performing as it should and will continue to meet its intended objectives. Part of this supporting action includes ensuring that sufficient funding is available and is part of each applicable strategy.

Monitoring, Assessment & Planning

The intent of this supporting action is to gather data and information and use these results to help inform and guide future implementation. This can include monitoring of specific practices, such as pre- and post-construction monitoring of a stream restoration project. It could also include the inventory and mapping of areas associated with the various strategies, such as riparian buffers or invasive species. Monitoring also includes the continuation of the James River and tributary sampling that is being used to evaluate the status and trends that are seen in the City's water quality and aquatic biological communities. As DPU is just one of the organizations that is conducting monitoring, another supporting action could include the initiation of a workgroup to improve coordination of data collection efforts.

Incentives & Credits

These supporting actions are intended to further evaluate, develop, and implement mechanisms to incentivize new initiatives or higher levels of future implementation. Specific actions can relate to expansion of the stormwater credit program to include reference to additional strategies, such as restoration of riparian buffers or removal of invasive and planting of native species on private land.

Regulations, Ordinances & Codes

This includes analyzing and modifying, if necessary, the framework within which implementation will occur. For instance, the Riparian Area Strategy is based on implementation within a 100 foot stream buffer. This supporting action could include evaluating expansion of this buffer to a 200 foot buffer. Additionally, City zoning and planning-related ordinances could be reevaluated to include language related to impervious area or to protect existing trees on developed property.

Outreach

Each of the 10 main strategies includes opportunities for education and outreach. This can include identifying ways to potentially expand upon future implementation by conveying information on resources available or ways for partners and the public support implementation of a strategy. As the implementation portion of the IWRM Plan is developed in more detail, specific activities will be identified and opportunities to implement these activities will be discussed with partner organizations.

COSTS

Costs were evaluated for each of the Supporting Actions. This information is summarized in the table below and detailed further in Appendix 5 (Strategy Cost Estimation) of the IWRM Plan.

Supporting Action	Estimated Cost
Partnerships	$655,000
Maintenance	Cost was included in association with the individual strategies
Monitoring	$1,208,000
Incentives/ Credits	$500,000
Regulations	Assumed to be part of City staff's normal job duties
Outreach	$500,000

	Riparian Areas	Green Infrastructure (in MS4)	Green Infrastructure (in CSS)	Stream Restoration	Native/ Invasives	Trees	Land Conservation	Water Conservation	Pollution Identification	CSS Infrastructure
Supporting Actions										
Partnerships	**20** acres of riparian buffers on private properties: * Through purchase of land * Partnerships with residents: Promote program for buffers on private properties (include tiers of level of involvement - (1) maintenance agreement with city, (2) conservation agreement/ easement.)] * Partner with Master Naturalists to enlist their support to assist with riparian restoration	* **5** acres on DPW property (rights of way, roadways, green alleys) Implement **10** acres of GI on private property: * Adopt a rain garden program - coordinate with residents, non-profits, commercial entities * Partner with City's community garden program to identify **3** acres of area for additional GI implementation * Partner with Public Works to ensure City greenways include GI (**5** acres of GI)	* **5** acres on DPW property (rights of way, roadways, green alleys) Implement **10** acres of GI on private property. : * Adopt a rain garden program - coordinate with residents, non-profits, commercial entities * Partner with City's community garden program to identify **1** acres of area for additional GI implementation * Partner with Public Works to ensure City greenways include GI (**2** acres of GI)	Promote requests for stream restoration by private landowners. Streamline the process by which these requests are addressed.	* Develop a program to encourage the use of native plants in private landscaping - sign up **20** private landscapers. * Initiate an adopt-a-lot program (**10** lots with invasive species removed, replanted, and maintained) * Partner with organizations, such as the James River Park System Invasive Plant Task Force, to better determine areas with significant invasive species issues and resources to deal with the problem.	* Partner with the public and other stakeholders, such as the Richmond Tree Stewards, to plant and maintain trees on public properties.	Partner with the public and other stakeholders to identify land to put in conservation easements. Include an additional **100** acres of non-City property in conservation easements.	* Partner with Richmond Redevelopment and Housing Authority to identify homes/properties that are eligible for upgrades to water efficient fixtures. * Partner with upstream localities and Virginia Department of Health to update/maintain Source Water Protection Plan		
	Hire DPU staff or assign 1 FTE to coordinate volunteers from corporate entities, watershed/environmental groups, and public with partnership opportunities associated with the IP effort. Staff to enlist/maintain **6** of partnerships per year									
	Hold **3** stakeholder meetings per year to continue communication with partners/stakeholders and add purpose to the IP effort.									
	Evaluate partnership network in 5 years (at the end of the permit cycle) to assess gaps and identify new public/private partners.									
Maintenance	Include funding to support maintenance of newly replanted / restored riparian buffers (to ensure success of plantings, prevention of establishment of invasive species, etc.)	Include funding to support maintenance of green infrastructure practices based on findings of the inspection program to ensure continued pollutant reduction credit.		Include funding to support maintenance of restored streams.	Include funding to support maintenance of newly planted native plants as well as to maintain newly established plantings where invasives have been removed from the landscape	Provide funding to support maintenance of trees on city property to ensure their survival and health.				
Monitoring, Assessments & Planning	Inventory and map riparian areas to better understand loss or growth of riparian buffers	Evaluate potential for conducting pre and post construction monitoring of key stormwater BMPs.		Conduct pre and post restoration monitoring per Chesapeake Bay Program requirements	Monitor growth/expansion of invasive species.	Inventory and map locations of trees and tree boxes to better understand loss or growth of tree coverage.			Implement IDDE-related monitoring to support this effort - supported by a desktop analysis of high risk dischargers	Continue monitoring effort associated with the CSO and WWTP discharge programs.
	Continue monitoring of 8 locations across the city for macroinvertebrate, habitat, and instream water quality. Continue monitoring at two locations for flow. Evaluate opportunities to expand the flow monitoring network across the City.									
	Evaluate the development of a monitoring data portal to facilitate sharing of data collected within the City with stakeholders and the public.									

	Riparian Areas	Green Infrastructure (in MS4)	Green Infrastructure (in CSS)	Stream Restoration	Native/ Invasives	Trees	Land Conservation	Water Conservation	Pollution Identification	CSS Infrastructure
	Initiate monitoring workgroup in year one made up of technical stakeholders and other key groups/individuals to evaluate current monitoring efforts and identify potential efficiencies and additional monitoring needs moving forward.									
	Conduct assessments of **4** stream segments across the four watershed groupings to support the development of watershed restoration plans to address pollutant sources and watershed stressors.									
Incentives/ Credits	Reevaluate the stormwater credit program to determine potential to include practices such as replacing or restoring riparian buffers.	* Reevaluate the stormwater credit program (through updates to the credit manual) to include additional practices including tree planting, green roofs, etc. Reevaluation of the credit program will also include increases of funding available for these credits to incentivize implementation on private property. * Provide credits for residential and non-residential properties to reduce stormwater fees based on implementation of "green practices".			Evaluate incentives/credits for purchasing / planting native species (such as Montgomery County, MD).	* Reevaluate the stormwater credit program to determine potential to include practices such as planting trees on private property. * Provide **500** trees for planting on private property or equivalent incentives to purchase native trees.		* Offer grants to replace **20** % of inefficient fixtures in moderate to low-income units. * Evaluate expansion of incentive program to cover washing machines and dishwashers		
Regs/ Ordinance/ Code	Evaluate expanding the regulatory buffer from 100ft to 200ft	Evaluate inclusion of language in City zoning and planning-related ordinances to limit impervious area on developed property.				Evaluate inclusion of language in City zoning and planning-related ordinances to protect existing trees and add new trees on developed property.		Adopt permitting standards for water efficient appliances/ fixtures in city code		
Outreach		Conduct outreach to advertise the resources, requirements, and services available through city related to green infrastructure for private property owners				Conduct outreach to advertise the resources, requirements, and services available through city related to tree planting and maintenance.		* Promote ability to use grey water for toilet flushing. Promote as way to achieve higher LEED standards. * Encourage and incentivize water capture and reuse for landscaping * Promote water conservation for commercial, industrial, and residential customers through efforts such as "Fix a Leak Week" and the City's Every Drop Counts initiative.	Conduct targeted outreach to high-risk industries, particularly in areas of the city identified as hot spots.	
	Conduct outreach to educate the general public about the goals and objectives of RVAH2O, and the resources and services available through the city.									

Appendix 3. RVA Clean Water Plan Goals, Objectives & Metrics

RVAH2O WATERSHED METRICS

GOAL	OBJECTIVES	METRICS
Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.	Develop one stormwater management plan to cover the City's four watershed groupings based on the City's watershed characterization report.	Plan produced (yes=1, no=0)
	Reduce nitrogen, phosphorus and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).	• N reduction (lbs.) • P reduction (lbs.) • TSS reduction (lbs.)
	Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).	• Percent increase in monthly geomean WQS compliance • Average yearly E. coli load reduction (billion cfu) • Average yearly reduction in CSO events (number) • Average yearly reduction in CSO volume discharged (million gallons)
	Reduce toxics (e.g., mercury, PAHs, PCBs), trash and other pollutants and address TMDLs for these pollutants.	• PCB, metals and toxics reduction (yes=1, no=0) • Trash reduction (lbs.)
	Develop green infrastructure, including riparian buffers and removal of impervious surfaces on development, existing development and redevelopment.	• Area treated by GI (acres) • Impervious surface reduced or treated (acres)
Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities.	Restore streams to improve, restore and enhance native ecological communities.	• Streams restored (miles of streams) • Reduce stormwater volume discharging to streams (gallons) • Riparian buffers restored and/or increased (acres)
	Identify, protect and restore critical habitats.	Critical habitat protected or restored (acres)
	Enhance aquatic and terrestrial habitat connectivity.	Habitat connected by green corridor (acres)
	Investigate and, where feasible, promote actions that might surpass regulatory requirements.	Exceeds regulatory requirements (yes=1, no=0)
Engage and educate the public to share responsibility and take action on achieving healthy watersheds.	Engage and efficiently educate the public about standards, processes and actions associated with watershed health and public health.	Residents reached by effort (# of people)
	Assist in the education of citizens about overall water quality issues and benefits of improved water quality.	Residents reached by effort (# of people)
	Support and encourage local action to improve water quality.	• NGOs/community groups provided support by City (# of groups) • Money available for incentives (dollars)
	Provide quicker public notifications of spills or pollution from regulators or other "river watchers."	Time to notify (days)
Implement land conservation and restoration and incorporate these into planning practices to improve water quality.	Protect, restore and increase riparian buffers.	Riparian buffers restored and/or increased (acres)
	Reduce impervious surfaces.	Impervious surface reduced or treated (acres)
	Increase natural land cover with a focus on preserving, maintaining and increasing tree canopy.	Trees planted (acres)
	Incorporate green infrastructure in new development and redevelopment.	Area treated by GI (acres)
	Conserve lands where possible and consistent with Richmond's Comprehensive Plan.	Conservation easements added (acres)
Create partnerships across the watersheds internal and external to the City of Richmond to maximize benefits and minimize impacts to all stakeholders.	Develop and implement a source water prevention plan/strategy.	Plan produced (yes=1, no=0)
	Establish public-private partnerships to secure funding, implement strategies and projects, and achieve plan goals.	Partnerships implemented (# of)
	Maintain and expand the RVAH20 group.	Meetings held (# of)
Maximize water availability through efficient management of potable water, stormwater and wastewater.	Reduce use of potable water for industry and irrigation.	• Potable water consumption reduced (gallons) • Rainwater and stormwater used for irrigation (gallons)
	Achieve water conservation by improving the existing water conveyance system.	Amount of water conserved (gallons)
	Achieve water conservation by incentivizing upgrades to end-user water fixtures where appropriate.	Money available for incentives (dollars)
Provide safe, accessible, ecologically sustainable water-related recreational opportunities for all.	Improve water quality to promote safe recreation consistent with the City's Riverfront Plan.	• Percent increase in monthly geomean WQS compliance • Average yearly E. coli load reduction (billion cfu) • Average yearly reduction in CSO events (number) • Average yearly reduction in CSO volume discharged (million gallons)
	Promote ecologically sustainable management of riverfront and riparian areas.	Streams with buffers (length of streams with 100-foot buffer added)
	Improve river and waterfront access for recreation.	Access points (yes=1, no=0)
Work collaboratively to gather consistent high-quality data to characterize the status and trends of water resources and to gauge the effectiveness of restoration efforts.	Conduct water quality and biological monitoring.	Stations monitored (# of stations)
	Provide timely water quality information.	Time necessary for monitoring results (days)
	Collaborate with citizens and local/state agencies for coordinated monitoring.	Citizen groups/agencies coordinated with (# of)
	Utilize results to target restoration efforts and convey progress.	Project with monitoring component (yes=1, no=0)

RVA H2O
EVERY DROP COUNTS

CITY OF RICHMOND
DEPARTMENT OF PUBLIC UTILITIES

Appendix 4. Calculator Spreadsheet Tool

See attached Excel document.

Appendix 5. Strategy Cost Estimation

See attached Excel document.

Richmond-Crater Multi-Region Hazard Mitigation Plan

APPROVAL PENDING ADOPTION
JULY 2022

PlanRVA
THE REGIONAL COMMISSION

CRATER PLANNING DISTRICT COMMISSION

REPORT DOCUMENTATION

TITLE	REPORT DATE
Richmond-Crater Multi-Region Hazard Mitigation Plan	JULY 2022

ABSTRACT

The *Richmond-Crater Multi-Region Hazard Mitigation Plan* has been updated for 2022. The region is vulnerable to a wide range of hazards that threaten the safety of residents and have the potential to damage or destroy both public and private property and disrupt the local economy and overall quality of life. While the threat from hazards may never be fully eliminated, the *Richmond-Crater Multi-Region Hazard Mitigation Plan* recommends specific actions designed to protect residents, business owners and the built environment.

GRANT/SPONSORING AGENCY	ACKNOWLEDGEMENTS
This report was funded by the Federal Emergency Management Agency through the Virginia Department of Emergency Management, via grant Agreement number FEMA-DR-4411-VA-013 for $262,500.	The PDCs would like to acknowledge the contributions of Salter's Creek Consulting, Inc., Hampton, Virginia, and Wood throughout the planning process, and contributions of members of Steering Committee.
PlanRVA is where we come together to look ahead. Established in 1969, the Richmond Regional Planning District Commission, known as PlanRVA, has been the home of cooperation among the nine jurisdictions of Central Virginia for more than 50 years. Today, we focus in areas of community development, emergency management, the environment and transportation. We are the seer of the future, convener of our member jurisdictions and regional partners, creator of plans of action and shaper of Central Virginia's future.	The Crater Planning District Commission is a regional planning agency with major emphasis in the areas of transportation, economic and small business development, the environment, and serving as the convener for major military-related discussions among the region's communities. The PDCs mission is to strengthen the quality of life throughout the Crater planning District region by serving as a regional forum of member local governments to address issues of regional significance, providing technical assistance to localities, and promoting and enhancing the collective consensus on the economic, transportation, social, environmental, and demographic interests of the region.

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1.0 Executive Summary

The Richmond-Crater Multi-Region Hazard Mitigation Plan is an update to plans approved in 2006 by the jurisdictions of PlanRVA and Crater Planning District Commission (PDC), and the combined Richmond-Crater 2011 and 2017 Multi-Regional Hazard Mitigation Plans.

PlanRVA and Crater PDC convened a joint Hazard Mitigation Steering Committee and Working Group, comprised of representatives from the participating localities. The committee and working group met several times during the planning process and worked closely with Salter's Creek Consulting, Inc., to develop the multi-regional plan update. Public input was sought throughout the process in accordance with Federal requirements. The planning process is documented in Section 3.

The area covered by this plan includes the following communities:

Town of Ashland
Charles City County
Chesterfield County
City of Colonial Heights
Dinwiddie County
City of Emporia
Goochland County
Greensville County
Hanover County
Henrico County
City of Hopewell
Town of Jarratt
Town of McKenney
New Kent County
City of Petersburg
Powhatan County
Prince George County
City of Richmond
Town of Stony Creek
Town of Surry
Sussex County
Town of Wakefield
Town of Waverly

1.1 Hazard Identification and Risk Assessment

The Hazard Identification and Risk Assessment (HIRA) serves as the fact base for the regional hazard mitigation plan. The HIRA consists of three parts, found in Section 5:

1. Identification of which hazards could affect the Richmond-Crater region;

2. Profile of hazard events and determination of what areas and community assets are the most vulnerable to damage from these hazards; and,

3. Estimation of losses and prioritization of the potential risks to the community.

For this plan update, hazards in the previous plan were examined and discussed in detail. Several hazards were combined and new hazards were added as a result. A discussion of the impacts of climate change on each hazard, and the social vulnerability of the study area to hazard impacts were added. **Table 1.1** summarizes which hazards were retained and how they were ranked by the planning participants.

Table 1.1: Conclusions on Hazard Risk for Richmond-Crater Region	
CRITICAL HAZARD - HIGH RISK	FLOODING SEVERE WIND EVENTS TORNADOES
CRITICAL HAZARD - MODERATE RISK	SEVERE WINTER WEATHER DROUGHTS AND EXTREME HEAT THUNDERSTORMS
NONCRITICAL HAZARD - LOW RISK	WILDFIRES INFECTIOUS DISEASES EARTHQUAKES SHORELINE EROSION FLOODING DUE TO IMPOUNDMENT FAILURE RADON EXPOSURE
NEGLIGIBLE CONSEQUENCES	SINKHOLES LANDSLIDES

1.2 Capability Assessment

The capability assessment (Section 6) evaluates the current capacity of the communities of the Richmond-Crater region to mitigate the effects of the natural hazards identified in the HIRA. By providing a summary of each jurisdiction's existing capabilities, the capability assessment serves as the foundation for designing an effective hazard mitigation strategy.

The capability assessment includes an examination of the following local government capabilities:

- *Administrative Capability* – describes the forms of government in the region, including the departments that may be involved in hazard mitigation.
- *Technical Capability* – addresses the technical expertise of local government staff.
- *Fiscal Capability* – examines budgets and current funding mechanisms.
- *Policy and Program Capability* – describes past, present, and future mitigation projects in the region and examines existing plans (e.g., emergency operations plan, comprehensive plan).
- *Legal Authority* – describes how jurisdictions in the region use the four broad government powers (i.e., regulation, acquisition, taxation, and spending) to influence hazard mitigation activities.

1.3 Mitigation Strategy

As part of the plan update, the committee examined and evaluated the goals stated in the 2017 plan word for word. Each of the following updated goal statements represents a broad target to achieve through associated objectives which are fulfilled through implementation of specific Mitigation Action Plans, both for the region as a whole and for each community.

Goal 1: Equitably prepare and protect the whole community against natural hazards

1.1 Increase staff capabilities regarding multi-hazard management and mitigation

1.2 Conduct outreach and educational opportunities for diverse groups of citizens

1.3 Share mitigation successes with citizens and stakeholders

1.4 Reduce disparities in how communities prepare for, respond to, and recover from hazards.

Goal 2: Strengthen and develop partnerships for mitigating and reducing hazard impacts

2.1 Include stakeholders and other regions in planning and training actions.

2.2 Expand outreach and educational opportunities to influence and inform a broad spectrum of stakeholders.

2.3 Collaborate on public safety and support effective system redundancies

Goal 3: Encourage sustainable government practices that support the short- and long-term health, safety and welfare of citizens

3.1 Identify and protect important elements of the economic, social, cultural, historic, and environmental fabric of the community and neighborhoods

3.2 Address restoration of long-term housing and continuity of basic government services for affected populations, especially socially vulnerable communities, during recovery from hazard events

Goal 4: Protect critical infrastructure

4.1 Identify opportunities for information- and intelligence-sharing regarding threats and hazards

4.2 Collaborate on utility management and support effective system redundancies

4.3 Identify and assist owners to maintain and upgrade high hazard potential dams, and protect the people and property downstream

Section 7 contains all of the mitigation action plans for each participating jurisdiction and the region, as well as information on how and when the community expects to implement the actions.

1.4 Plan Maintenance Procedures

The plan outlines a procedure for implementation, maintenance, and plan updates. PlanRVA and Crater PDC will be responsible for monitoring this plan. Annual progress reports from the communities will include corrective action plans if needed.

In accordance with Federal Emergency Management Agency (FEMA) regulations, a written update will be submitted to the Commonwealth and FEMA Region III every five years from the original date of the plan, unless circumstances (e.g., Presidential disaster declaration, changing regulations) require a formal update earlier. The public will be continually informed of changes to the plan as they occur.

1.5 Conclusion

This Richmond-Crater Multi-Regional Hazard Mitigation Plan embodies the continued commitment and dedication of the local governments and community members of the Richmond-Crater region to enhance the safety of residents and businesses by taking actions before a disaster strikes. While little can be done to prevent natural hazard events from occurring, the region is poised to minimize the disruption and devastation that so often accompanies these disasters.

2.0 Introduction

2.1 Updates for 2022

Each section of this plan has been broadly updated as part of the 2022 update process. At the beginning of each section, there is a synopsis of the changes made to that section as part of the update.

Section 2 was updated to modify the scope to include all 23 communities participating in this planning process.

2.2 Background

Mitigation is commonly defined as sustained actions taken to reduce or eliminate long-term risk to people and property from hazards and their effects. A mitigation plan states the aspirations and specific courses of action that a community intends to follow to reduce vulnerability and exposure to future hazard events. These plans are formulated through a systematic process centered on the participation of residents, businesses, public officials, and other community stakeholders.

A local mitigation plan is the physical representation of a jurisdiction's commitment to reduce risks from natural hazards. Local officials can refer to the plan in their day-to-day activities and in decisions regarding regulations and ordinances, granting permits, and funding of capital improvements and other community initiatives. Additionally, these local plans will serve as the basis for states to prioritize future grant funding as it becomes available.

The Richmond-Crater Multi-Regional Hazard Mitigation Plan will continue to be a useful tool for all community stakeholders by increasing public awareness about local hazards and risks, and providing information about options and resources available to reduce those risks. Educating the public about potential hazards will help each jurisdiction protect itself against the effects of future hazards, and will enable informed decision-making regarding where to live, purchase property, or locate business.

The area covered by this plan includes the following communities, as shown in **Figure 2.1**:

- Town of Ashland
- Charles City County
- Chesterfield County
- City of Colonial Heights
- Dinwiddie County
- City of Emporia
- Goochland County
- Greensville County
- Hanover County
- Henrico County
- City of Hopewell
- Town of Jarratt
- Town of McKenney
- New Kent County
- City of Petersburg
- Powhatan County
- Prince George County
- City of Richmond
- Town of Stony Creek
- Town of Surry
- Sussex County
- Town of Wakefield
- Town of Waverly

Figure 2.1: Study Area Communities

2021

2.2 The Need for Local Mitigation Planning

On October 30, 2000, President Clinton signed into law the Disaster Mitigation Act of 2000 (DMA 2000), which required state and local mitigation plans that would help to reduce loss of life and property, human suffering, economic disruption, and disaster assistance costs resulting from natural disasters.

DMA 2000 amended the Robert T. Stafford Disaster Relief and Emergency Assistance Act and added a new section to the law, Section 322, Mitigation Planning. Section 322 requires local governments to prepare and adopt jurisdiction-wide hazard mitigation plans for disasters declared after November 1, 2004, as a condition of receiving Hazard Mitigation Grant Program (HMGP) project grants and other non-disaster related mitigation grant assistance programs. Local governments must review and, if necessary, update their mitigation plans every five years from the original date of the plans in order to continue Hazard Mitigation Assistance (HMA) program eligibility.

The requirements for local mitigation plans are found in Section 44 Code of Federal Regulations Part 201.6. FEMA's *Local Multi-Hazard Mitigation* Planning Guidance issued on October 1, 2011 provides updated FEMA interpretation and explanation of local plan mitigation regulations and FEMA's expectations for mitigation plan updates. In addition, the Virginia Department of Emergency Management (VDEM) and FEMA now use the 2021 *Local Mitigation Plan Review Tool* to ensure that a plan meets FEMA's regulatory requirements as well as additional requirements identified by the Commonwealth.

2.3 Organization of the Plan

Section 3.0 – Planning Process defines the process followed throughout the update of this plan, including a description of the Richmond-Crater region's stakeholder involvement and the plan for public involvement.

Section 4.0 – Community Profile provides a physical description and demographic profile of the region, and examines characteristics including geography, hydrology, development patterns, demography, and land use.

Section 5.0 – Hazard Identification, Risk Assessment and Vulnerability Analysis identifies, describes and evaluates the natural hazards likely to affect the Richmond-Crater region, and provides a quantification of the impacts those hazards have on the people, infrastructure and resources of the region.

Section 6.0 – Capability Assessment analyzes the region's and each of the local jurisdictions' policies, programs, plans, resources, and capabilities to reduce exposure to the hazards identified in Section 5.0.

Section 7.0 – Mitigation Strategy addresses the Richmond-Crater region's issues and concerns for hazards by establishing a framework for mitigation activities and policies. The strategy includes updated goals and a range of updated mitigation actions to achieve these goals.

Section 8.0 – Plan Maintenance Procedures specifies how the plan will be monitored, evaluated, and updated.

Appendices are included at the end of the plan, and contain supplemental reference materials, including 2022 resolutions of plan adoption and the 2017 mitigation action status updates.

3.0 Planning Process

3.1 Updates for 2022

Summaries of each meeting and the procedures followed during the update process were updated for each subsection. Summaries of previous planning processes were removed for brevity and because they are available in previous plans.

3.2 Overview of Mitigation Planning

Local hazard mitigation planning involves the process of organizing community resources, identifying and assessing hazard risks, and determining how to minimize or manage those risks. This process results in a hazard mitigation plan that identifies specific actions designed to meet the goals established by those that participate in the planning process. To ensure the functionality of each mitigation action, responsibility is assigned to a specific individual, department or agency along with a schedule for its implementation. Plan maintenance procedures are established to help ensure that the plan is implemented, as well as evaluated and enhanced as necessary. Developing clear plan maintenance procedures helps ensure that the Hazard Mitigation Plan remains a current, dynamic, and effective planning document over time.

Participating in a hazard mitigation planning process can help local officials and residents achieve the following results:

- save lives and property;
- save money;
- speed recovery following disasters;
- reduce future vulnerability and increase future resiliency through wise development and post-disaster recovery and reconstruction;
- enhance coordination within and across neighboring jurisdictions;
- expedite the receipt of pre-disaster and post-disaster grant funding; and
- demonstrate a firm commitment to improving community health and safety.

Mitigation planning is an important tool to produce long-term recurring benefits by breaking the repetitive cycle of disaster loss. A core assumption of hazard mitigation is that pre-disaster investments will significantly reduce the demand for post-disaster assistance by lessening the need for emergency response, repair, recovery, and reconstruction. Furthermore, mitigation practices will enable local residents, businesses, and industries to re-establish themselves in the wake of a disaster, getting the community economy back on track sooner and with less interruption.

The benefits of mitigation planning go beyond reducing hazard vulnerability. Measures such as the acquisition or regulation of land in known hazard areas can help achieve multiple community goals, such as preserving open space, improving water quality, maintaining environmental health, and enhancing recreational opportunities. It is the intent of this document to help identify overlapping community objectives and facilitate the sharing of resources to achieve multiple aims, and to include information wherever possible to demonstrate when the plan is or has been implemented through other planning mechanisms.

<u>44 CFR Requirement</u>

44 CFR Part 201.6(c)(1): The plan shall include documentation of the planning process used to develop the plan, including how it was prepared, who was involved in the process and how the public was involved.

3.3 Preparing the Plan

The PDCs used FEMA guidance (FEMA Publication Series 386) to develop and update this Hazard Mitigation Plan. A *Local Mitigation Plan Review Tool*, found in Appendix A, provides a detailed summary of FEMA's current minimum standards of acceptability for compliance with DMA 2000 and notes the location where each requirement is met within the Plan. These standards are based upon FEMA's Interim Final Rule as published in the Federal Register on February 26, 2002, and October 31, 2007, in Part 201 of the Code of Federal Regulations (CFR).

The planning process included eight major steps that were completed during 2021 through 2022; they are shown in green and yellow in Figure 2.1. Each of the planning steps illustrated in **Figure 3.1** resulted in work products and outcomes that collectively make up the Hazard Mitigation Plan.

Table 3.1 provides a summary of the National Flood Insurance Program's Community Rating System (CRS) User's Manual 10-step guidance for plan preparation and how that guidance fits within the 10-step, 4-phase process advocated by FEMA. This plan strives to accomplish the steps in each of these processes.

Figure 3.1: Richmond-Crater Hazard Mitigation Planning Process

Table 3.1: Guidance for Hazard Mitigation Plan Preparation	
FEMA Guidance	**CRS Guidance**
Phase I: Organize Resources Step 1. Get Organized Step 2. Plan for Public Involvement Step 3. Coordinate with Other Departments & Agencies	Step 1. Organize Step 2. Involve the Public Step 3. Coordinate
Phase II: Assess Risk Step 4. Identify the Hazards Step 5. Assess the Risks	Step 4. Assess the hazard Step 5. Assess the Problem
Phase III: Develop Mitigation Plan Step 6: Review Mitigation Alternatives Step 7: Draft an Action Plan Step 8: Set Planning Goals	Step 6. Set Goals Step 7. Review Possible Activities Step 8. Draft an Action Plan
Phase IV: Adopt & Implement Step 9: Adopt the Plan Step 10: Implement the Plan	Step 9. Adopt the Plan Step 10. Implement, Evaluate, Revise

3.4 The Planning Committee

A community-based planning team made up of local government officials and key stakeholders has continually helped guide the development of this Plan. The committee organized local meetings and planning workshops to discuss and complete tasks associated with preparing the Plan, including reviewing plan drafts and providing timely comments. Additional participation and input from residents and other identified stakeholders were sought through public meetings that described the planning process, the findings of the risk assessment, and the proposed mitigation actions. The committee convened in 2021.

3.4.1 Richmond-Crater Planning Committee

Due to the large geographic area covered and the number of communities participating, the project leaders felt that a Steering Committee was necessary to help more efficiently guide the planning process and facilitate the numerous Working Group members. Thus, the representatives for the communities and stakeholders were divided into a primary Steering Committee and a Working Group. The division was based on discussions with potential committee members from each community and stakeholders and a determination as to which members were most willing to commit themselves to the entire process, to do the majority of the work, to debate goals and objectives and discuss alternatives, and to report back to their constituencies and Working Group members. The participants listed in **Table 3.2a** are the Steering Committee and **Table 3.2b** shows the Working Group members for the 2022 Richmond-Crater Hazard Mitigation Plan Update. Names marked with an asterisk indicate the lead person responsible for that community in the planning, update and maintenance process. Specifically, the tasks assigned to the Steering Committee members included:

- participate in mitigation planning meetings and workshops;
- provide best available data as required for the risk assessment portion of the Plan;
- provide copies of any mitigation or hazard-related documents for review and incorporation into the Plan;
- support the development of the Mitigation Strategy, including the design and adoption of community goals and objectives;
- help design and propose appropriate mitigation actions for incorporation into the Mitigation Action Plan;
- review and provide timely comments on all study findings and draft components of the plan; and
- support the adoption of the Hazard Mitigation Plan by community leaders.

The Working Group includes the Steering Committee members. Working Group members were provided the opportunity and invitation to participate in workshops and public meetings, asked for best available data, asked to review and comment on plan elements, and relied upon to ensure successful adoption of the plan in their community. In many cases, the Working Groups for individual communities also met outside of the more official planning process in additional meetings facilitated by Steering Committee members. Additional participation and input from other identified community staff and stakeholders was sought by the Steering Committee during the planning process primarily through e-mails and phone calls. Stakeholder involvement is discussed in more detail later in this section.

Table 3.2a: Hazard Mitigation Planning Steering Committee Members

Name and Title	Community and Agency	Expertise
Troy Aronhalt, Acting Major	Town of Ashland Police Department	Emergency Management/Public Information
*Nora Green Amos, Director	Town of Ashland, Planning & Community Development	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Christopher A. Workman, FPA/Environmental Engineer	Chesterfield County Environmental Engineering	Structural Flood Control Projects, Property Protection, Planning/Preventive Measures
*Jessica Robison, Emergency Management Coordinator	Chesterfield County, Emergency Management	Emergency Management/Public Information
*Tim Blumenschine, Emergency Manager	City of Colonial Heights, Fire & EMS	Emergency Management/Public Information

Table 3.2a: Hazard Mitigation Planning Steering Committee Members		
Name and Title	**Community and Agency**	**Expertise**
*John Woodburn, Environmental Manager	Goochland County, Dept of Public Utilities	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Corey Beazley, Deputy Coordinator	Hanover County, Fire-EMS Department	Emergency Management/Public Information
Gregory Martin, Battalion Chief	Hanover County, Fire-EMS Department	Emergency Management/Public Information
Danielle Curtis, Engineering Technician (Floodplain)	Henrico County, Public Works	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Kristin Owen, Floodplain & Dam Safety Manager	Henrico County, Public Works	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Kate Hale, Deputy Emergency Management Coordinator	New Kent County, Emergency Management	Emergency Management/Public Information
Joshua Airaghi, Director	New Kent County, Environmental Dept	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Darryl Walker, Manager	City of Petersburg, Stormwater Program	Structural Flood Control Projects, Property Protection
*Frank Hopkins, FPA/Planning Director	Powhatan County, Planning	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Brianne Fisher, Coordinator	City of Richmond, Office of Sustainability	Planning/Preventive Measures, Property Protection, Resiliency
Surani Olsen, Manager & CRS Coordinator	City of Richmond, Water Resources	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Michael Poarch, County Planner	Sussex County, Planning	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Kathryn Tolliver, Government Operations Liaison	American Red Cross, Stakeholder	Emergency Management/Public Information
Michael Tolliver, Government Operations Liaison	American Red Cross, Stakeholder	Emergency Management/Public Information
Dana Adkins, Tribal Environmental Director	Chickahominy Indian Tribe, Stakeholder	Natural Resource Protection
Jay Ruffa, Director of Planning	Crater PDC, Stakeholder	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection

Table 3.2a: Hazard Mitigation Planning Steering Committee Members		
Name and Title	**Community and Agency**	**Expertise**
Heather Barrar, Regional Trails Program Director	FOLAR, Stakeholder	Natural Resource Protection
Warren Taylor, Natural Resource Manager	Pamunkey Indian Tribe, Stakeholder	Natural Resource Protection
Sarah Stewart, Program Manager - Environmental Program	PlanRVA, Stakeholder	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Katie Moody, Emergency Management Program Coordinator	PlanRVA, Stakeholder	Emergency Management/Public Information
Rebekah Cazares, Planner	PlanRVA, Stakeholder	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Leigh Chapman, President	Salter's Creek Consulting, Inc., Stakeholder	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Tony Williams, Mobility Manager	Senior Connections, Stakeholder	Emergency Management/Public Information
Anne Witt, Geohazards Geologist	Va Dept. of Energy, Stakeholder	Natural Resource Protection
Alanna Ostrowski, Forest Technician	Va Dept. of Forestry, Stakeholder	Natural Resource Protection
Jeremey Falkenau, Senior Area Forester	Va Dept. of Forestry, Stakeholder	Natural Resource Protection
Mark Killgore, Lead Dam Safety Engineer	Va Dept. of Conservation & Recreation, Dam Safety, Stakeholder	Structural Flood Control Projects, Property Protection
Angela Davis, NFIP State Coordinator & Floodplain Program Planner	Va Dept. of Conservation & Recreation, Floodplain Management, Stakeholder	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Amanda Weaver, All Hazards Planner	Va Dept. of Emergency Management Region 1, Stakeholder	Emergency Management/Public Information
Nicole Mueller, Planning Specialist	Va. Dept. of Transportation, Stakeholder	Structural Flood Control Projects, Property Protection
Jim Kaste, Professor	College of William & Mary, Stakeholder	Natural Resource Protection
David Stroud, Emergency & Hazard Mitigation Lead	Wood, Stakeholder	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection

* Lead person responsible for that community in the planning, update and maintenance process outlined in Section 8.

Table 3.2b: Hazard Mitigation Planning Working Group Members		
Name and Title	**Community and Agency**	**Expertise**
*Rhonda Russell, Asst County Administrator	Charles City County	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Steven Herring, Public Outreach & CERT Coord	Chesterfield County Fire & EMS	Emergency Management/Public Information
Darshan Parikh, Deputy Emergency Mgmt Coordinator	Chesterfield County Emergency Management	Emergency Management/Public Information
Janet Llewellyn, Planning Manager	Chesterfield County Parks & Recreation	Natural Resources Protection
Kimberly Conley, Asst Director	Chesterfield County Citizen Information and Resources	Public Information
Susan Pollard, Public Information Officer	Chesterfield County, Communications & Media	Public Information
Rachel Chieppa, Senior Planner	Chesterfield County, Planning & Community Development	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
David Kissner, Deputy Fire Chief	Colonial Heights Fire & EMS	Emergency Management/Public Information
Doug Smith, City Manager	Colonial Heights	Emergency Management/Public Information
Brandy Payne, Assistant Director	Colonial Heights, Planning & Community Development	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Kevin Kiddy, Emergency Manager	Colonial Heights, Emergency Mgmt	Emergency Management/Public Information
Kevin Massengill, County Administrator	Dinwiddie County	Emergency Management/Public Information
*Dennis Hale, Division Chief	Dinwiddie County, Fire & EMS	Emergency Management/Public Information
Morgan Ingram, Director	Dinwiddie County, Economic Development	Planning/Preventive Measures
Tammie Collins, Deputy County Administrator	Dinwiddie County	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Michael Rae, Emergency Services Coordinator	Emporia, Emergency Management	Emergency Management/Public Information
Paul Drumwright, Administrative Services Manager	Goochland County Administration	Public Information
Robin Hillman, Deputy Emergency Services Coordinator	Goochland County	Emergency Management/Public Information
Amanda Huskey, GIS Manager	Greensville County, Geographic Information Systems	Public Information

Table 3.2b: Hazard Mitigation Planning Working Group Members		
Name and Title	**Community and Agency**	**Expertise**
*Lin Pope, Planning Director/Zoning Official	Greensville County, Planning & Community Development	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Mike Flagg, Director	Hanover County, Public Works	Structural Flood Control Projects, Property Protection
Brendan McHugh, Planner	Hanover County, Planning	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Randy Hardman, Deputy Director	Hanover County, Public Works	Structural Flood Control Projects, Property Protection
Michael Dieter, Engineering Manager	Hanover County, Public Works	Structural Flood Control Projects, Property Protection
Alex Mease, Civil Engineer	Hanover County, Public Works	Structural Flood Control Projects, Property Protection
Courtney Cornell, Information Technology System Engineer	Hanover County, Information Technology	Public Information
Bill Rose, Manager	Hanover County, Information Technology	Public Information
Donald Lee, Deputy Director	Hanover County, General Services	Planning/Preventive Measures, Property Protection
Tom Harris, Public Information Officer	Hanover County	Public Information
Ben Felton, Project Engineer	Henrico County, Dept of Public Works	Structural Flood Control Projects, Property Protection
Rob Rowley, Chief	Henrico County, Emergency Mgmt & Workplace Safety	Emergency Management, Public Information
Jen Cobb, Director	Henrico County, Engineering & Environmental Services Director	Natural Resource Protection
Tevya W. Griffin, Director	Hopewell, Dept of Development	Planning/Preventive Measures, Property Protection, Resiliency
Robert Williams, Emergency Services Specialist	Hopewell Bureau of Fire	Emergency Management/Public Information
*Ben Ruppert, Emergency Services Coordinator	Hopewell, Office of Emergency Mgmt	Emergency Management/Public Information
Chris Ward, Senior Planner	Hopewell, Development Department	Planning/Preventive Measures, Property Protection, Resiliency
Reginald Tabor, Director	Petersburg, Planning	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Joanne Williams, Public Information Officer	Petersburg	Public Information
Cynthia Boone, Project Manager	Petersburg, Economic Development	Planning/Preventive Measures, Property Protection

Table 3.2b: Hazard Mitigation Planning Working Group Members		
Name and Title	**Community and Agency**	**Expertise**
Curt Nellis, Asst Emergency Mgmt Coordinator	Powhatan County, Emergency Management	Emergency Management/Public Information
*Donald Hunter, Deputy Emergency Mgmt Coordinator	Prince George County, Emergency Management	Emergency Management/Public Information
Tim Graves, Planner	Prince George County Planning & Zoning	Planning/Preventive Measures, Property Protection, Resiliency
Jeff Stoke, County Administrator	Prince George County	Public Information
Julie Walton, Director	Prince George County, Community Development	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Dave Alley, Acting Building Commissioner	Richmond, Permits & Inspections	Planning/Preventive Measures, Property Protection, Resiliency
Bill Lawson, Deputy Emergency Coordinator	Richmond, Office of Emergency Management	Emergency Management/Public Information
Reid Foster, Public Safety Coordinator	Sussex County, Public Safety Department	Emergency Management/Public Information
Beverly Walkup, Director	Sussex County, Planning	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Richard Douglas, Administrator	Sussex County	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
*Bennie Savedge, Mayor	Town of Surry	Public Information
Molly Rickmond, Town Clerk	Town of Surry	Public Information
*Melanie Willson, Mayor	Town of Jarrett	Public Information
*Meagan S. Haire Abby, Mayor	Town of McKenney	Public Information
Martha Stone, Clerk of Council	Town of McKenney	Public Information
*Brian Laine, Mayor	Town of Wakefield	Public Information
Anne Monahan, Town Clerk	Town of Wakefield	Public Information
*Angela McPhaul, Mayor	Town of Waverly	Public Information
*Franklin Jackson, Mayor	Town of Stony Creek	Public Information
Marsha Bishop, Town Clerk	Town of Stony Creek	Public Information

Table 3.2b: Hazard Mitigation Planning Working Group Members		
Name and Title	**Community and Agency**	**Expertise**
John Fitzgerald, Fire Chief	Capital Region Airport Commission	Planning/Preventive Measures, Property Protection
Ron Svejkovsky, MPO Director	Crater PDC - TCAMPO	Planning/Preventive Measures, Property Protection
Rashaunda Lanier-Jackson, Community Engagement Manager	PlanRVA	Public Information
Michelle Hamor, Chief of Planning and Policy Branch	USACE, Norfolk	Planning/Preventive Measures, Property Protection, Resiliency, Structural Flood Control Projects
John Highsman, Forester	VA Dept of Forestry	Natural Resource Protection
Heather Dowling, Senior Area Forester	VA Dept of Forestry	Natural Resource Protection
Brandy Buford, Floodplain Program Planner	VaDCR, Floodplain Management	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Michael Barber, Floodplain Program Planner	VaDCR, Floodplain Management	Planning/Preventive Measures, Property Protection, Resiliency, Natural Resource Protection
Tiffany Dubinsky, Statewide Transit Planning Manager	Va Dept of Rail & Public Transportation	Emergency Management/Public Information

* Lead person responsible for that community in the planning, update and maintenance process outlined in Section 8.

3.5 2021/2022 Community Meetings and Workshops

Below is a summary of the key meetings and community workshops during the 2021/2022 update process. Routine discussions and additional meetings were held by local officials to accomplish planning tasks specific to their department or agency. A consultant (Salter's Creek Consulting, Inc., of Hampton, Virginia) was hired with grant funds to update the hazard identification and vulnerability analysis, to guide the committee through the planning process based on the revised information and to assist each community with adoption of the final plan. All meeting summary information is included in Appendix C, which includes committee and public meeting minutes, attendance sheets, and correspondence with committee members and stakeholders.

NOVEMBER 20, 2021: PROJECT KICKOFF MEETING

Participants in the Kickoff Meeting discussed the overall approach to updating the Hazard Mitigation Plan, including strategies for outreach and public participation, as well as the steps necessary to meet the requirements of the DMA 2000, and the CRS of the National Flood Insurance Program (NFIP). The consultant initiated data collection efforts at the meeting and reviewed the existing list of hazards with the representatives present.

The group discussed project schedule and potential stakeholders and how they would be asked to participate, including tasks such as: reviewing drafts, participating on the committee, and/or attending public meetings. Due to the ongoing COVID 19 safety protocols in place at the time , the group and the consultant decided that each of the main three meetings would be held virtually through online meeting software. Committee meetings would be held virtually, as well.

JUNE 21, 2021: FIRST PLANNING COMMITTEE MEETING

The consultant provided an overview of the proposed update approach to committee members. The Committee reviewed the Hazard Identification and Vulnerability Assessment information presented. Committee members discussed the hazards of most critical concern to the region, and concurred to adjust the names of several hazards, removed several hazards and added hazards.

The committee members present voted on their mitigation priorities and ranked hazards using the methodology described in Section 5. The committee considered a list of hazards that included flooding, coastal and tropical storms, severe thunderstorm/hail/lightning, winter weather/storms, drought, high hazard dam failure, tornado, extreme heat, earthquake, wildfire, coastal erosion/landslides/sinkholes, radon exposure and pandemic flu.

The first part of the meeting focused on the flood analysis, including the hybrid modeling analysis conducted. Participants discussed their frustration with obtaining NFIP repetitive flood loss data and the inability to know flood insurance coverage happening in private flood insurance market. The group discussed nomenclature for Infectious Disease or Pandemic Flu.

OCTOBER 15, 2021: SECOND PLANNING COMMITTEE MEETING

The second Planning Committee meeting was the beginning of the "Mitigation Strategy Workshops." The meeting began with a presentation on how a complete capability assessment contributes to identification of effective mitigation strategies. The discussion focused on local capabilities and the capability matrix each community was asked to complete.

The consultant helped Committee members review several documents in preparation for the goal setting exercise which was the focus of the workshop. This background helped Committee members maintain continuity and to develop linkages between various local, regional, and state planning efforts.

Data, documents, plans and procedures reviewed as part of the goal setting portion of the planning process included, but were not limited to, the following:

- 2018 *Commonwealth of Virginia Hazard Mitigation Plan* goals and objectives;
    - These items were reviewed by committee members prior to the work on updating the goals and objectives to help ensure that the regional plan supports and does not contradict the State's goals and objectives.
- Goals and objectives from Virginia Beach Resiliency planning effort;
- Goals and objectives from the *Virginia Coastal Resilience Master Planning Framework*, 2020;
- Draft goals and objectives from the 2022 *Hampton Roads Hazard Mitigation Plan* update going on concurrently;
- Goals and objectives from the 2016 *Middle Peninsula Hazard Mitigation Plan;*
- Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards, FEMA January 2013;
- Each of the existing plan's three primary goals and related objectives; and
- Dam safety reports for state-regulated dams, state dam safety regulations and interviews with dam safety officials at the Virginia Department of Conservation and Recreation (DCR).

The group was provided a list of potential, broad community goal key phrases extracted from the existing plans in order to encourage brainstorming about revising the goal statements. The members also reviewed existing goal statements from the current plan and other plans pertinent to the region. The group then went to work carefully reviewing the existing mitigation plan goal statements. Participants were encouraged to critique each word in light of the goal key words identified earlier and any changes that had taken place in their communities in the previous five years. The facilitator provided early recommendations, reworked, grouped together, and then presented the revised goals and objectives in real time during the meeting so that the group could arrive at a consensus on the broader mitigation goals and objectives associated with the updated mitigation plan. Detailed notes on the reasoning behind why the mitigation goals and objectives were modified is included in Section 7, which shows the changes and the revised goals and objectives.

The group discussed the current status of COVID 19 protocols and the ability to meet in person for the third workshop. Those present preferred a hybrid approach for Workshop #3 and the development of new and revised mitigation actions for 2022. The consultant proposed a virtual group workshop that would discuss the types of mitigation actions and provide examples and some suggested reading materials, followed by a series of in-person working group meetings, termed "office hours" at three locations in the study area to facilitate review, revision and development of each community's existing mitigation actions.

NOVEMBER 23, 2021: THIRD MITIGATION PLANNING COMMITTEE MEETING

The group reviewed a general list of potential mitigation actions categorized by type and the consultant provided examples, both local and national, of various successful mitigation actions. A brief discussion of the various categories followed. The consultant discussed a variety of mitigation categories for considering and evaluating possible mitigation action alternatives appropriate to each community. Suggested reading materials for the group included:

Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards, FEMA 2013;

Mitigation Best Practices – FEMA web site;

Mitigation Success Stories, Association of State Floodplain Managers, 2002;

Mitigation Matters: Policy Solutions to Reduce Local Flood Risk, Pew Charitable Trusts web site;

Zoning for Coastal Flood Resiliency, New York City Planning;

Mitigation Action Portfolio, FEMA web site;

Buoyant City: Historic District Resiliency & Adaptation Guidelines, Miami Beach, 2020; and

Coastal Flood Resilience Design Guidelines, Boston Planning & Development Agency, 2019.

The consultant then facilitated a discussion on regional mitigation actions from the 2017 plan and made real-time edits to those actions. The group also discussed the addition of several proposed, new regional mitigation actions regarding: NFIP repetitive flood loss data analysis at the state or regional level and preparation of repetitive flood loss area analyses; use of radon test kits to test structures; verifying status of significant hazard dams region-wide; and, strengthening/creating transportation networks for evacuation; and partnering with private companies on critical lifeline continuity.

COMMUNITY-SPECIFIC WORKING GROUP MEETINGS

All communities were invited by email to schedule a one-on-one meeting with the consultant toward the end of the planning process. Most of the communities involved in the plan took advantage of consultant-facilitated brief, in-person meetings at the community level to discuss their final Mitigation Action Plan. Participants worked carefully through a review of the list of existing mitigation actions from their existing plan, deciding which actions to modify or delete based on their progress toward completion. The group then selected and discussed priorities for several new proposed actions provided by the consultant.

The consultant shared additional review notes on several items that varied by community, and that typically included:

- comprehensive plan, resilience plan and strategic plan review notes;

- floodplain management regulation review notes;
- capabilities or capability gaps noted over the course of the planning process;
- repetitive loss area maps (hard copies provided during the meeting);
- community-specific critical facility vulnerabilities as shown in the HIRA, and as discussed in the First Planning Committee Meeting; and
- other pertinent materials such as news clippings.

While previous plans have benefitted from the synergies of having all communities attend a large workshop to address the MAP revisions and share mitigation ideas, COVID 19 protocols in 2021 required a revised methodology to allow some one-on-one discussion of mitigation actions, but to limit the number of people convened at any one time. The meetings were held over the course of several days in December 2021. On Monday December 6, Hanover County, Ashland and Henrico County representatives met at the Hanover ECC Training Room. On Tuesday, December 7, representatives of Powhatan County, Richmond, Sussex County and Goochland County met in the PlanRVA Conference Room. On December 10, representatives of Dinwiddie County, Colonial Heights, Prince George County, Hopewell, Charles City County and New Kent County met in the Crater PDC conference room, and a representative from Friends of the Lower Appomattox River (FOLAR) also met with the contractor separately. The contractor also met virtually with Chesterfield County on December 9. Attendance for each community was as follows:

Hanover County	Courtney Cornell
	Bill Rose
	Donald Lee
	Tom Harris
	Gregory Martin
Ashland	Troy Arnholt
	Nora Amos
	Corey Beazley
Henrico County	Ben Felton
	Kristin Owen
	Rob Rowley
Powhatan County	Curt Nellis
Richmond	Surani Olsen
	Brianne Fisher
	Bill Lawson
Sussex County	Beverly Walkup
	Michael Poarch
Goochland County	John Woodburn
Dinwiddie County	Dennis Hale
	Morgan Ingram

Colonial Heights	Tammie Collins Tim Blumenschine
	Brandi Payne
	Kevin Kiddy
	David Kissner
FOLAR	Heather Barrar
Prince George County	Donald Hunter
	Tim Graves
Hopewell	Chris Ward Benjamin Ruppert
	Robert Williams
Charles City County	Rhonda Russell
New Kent County	Kate Hale
Chesterfield County	Jess Robison
	Chris Workman
	Rachel Chieppa

In addition, the consultant met virtually with the Mayor of Stony Creek, Frank Jackson, on February 9, 2022, to discuss the town's risk and vulnerability and to brainstorm mitigation actions to address that risk. Several new mitigation actions were developed for the town as a result of this extended conversation.

Initial participation by the communities of Greensville County, Jarratt, McKenney, Surry, Wakefield and Waverly was less than preferred; thus, the planning team checked several times throughout the process to confirm that the communities were all on the email list notifying them of all meetings and planning opportunities. Finally, in June 2022, planners reached out by phone to each community and requested their review of pertinent information in the plan and approval to move forward with the mitigation actions as described. The following communication log documents these phone calls and emails by Jay Ruffa from the Crater PDC:

Town of McKenney: June 7 and 8 email communications with Mayor Meagan Haire Abby confirmed that McKenny is working with Dennis Hale from Dinwiddie County and that they have depended on him to relay and approve information on their behalf.

Town of Surry: On June 9, 2022, Mr. Ruffa spoke with Town Clerk and confirmed that the town worked with Ray Phelps from Surry County on reviewing their actions. Clerk indicated that Mitigation Action 2 is OK, but stated that in regard to mitigation action 1, they really have no flood prone property or structures because they are not in the floodplain. However, the rest of the mitigation strategy sounded adequate. Consultant suggested keeping mitigation action 1 because flood damage can and does occur outside the 100-year mapped floodplain, and retaining the action helps provide financial resources should that type of flooding occur.

Town of Jarrett – June 9, 2022, Town Clerk returned his call and indicated they will have Mayor contact Mr. Ruffa this week. No additional contact to date.

Town of Wakefield - June 8, 2022 – Mr. Ruffa spoke with the Town Clerk and indicated they will get us a response by Monday June 13 at the latest.

Town of Waverly - June 8, 2022 – Mr. Ruffa spoke with Town Clerk. Mr. Ruffa resent actions to Town Clerk and the Mayor. On June 10, 2022, he spoke with the Mayor and she indicated approval of the mitigation actions and invited Mr. Ruffa to come to the August 9th meeting for expected adoption of the plan.

Greensville County – February 10, 2022 and July 18, 2022 – Written correspondence from Linwood E. Pope, Jr., Director of Planning, via email, and E. Lynn Parker, Greensville County Emergency Services Coordinator, via letter, indicated that County personnel had reviewed and approved the plan components and had no further comments or issues with the mitigation action plan in the February 2022 draft. Those written correspondence are provided in Appendix C.

44 CFR Requirement

Part 201.6(b)(1): The planning process shall include an opportunity for the public to comment on the plan during the drafting stage and prior to plan approval.

3.6 Involving the Public

Individual resident involvement provides the planning committee with a greater understanding of local concerns and increases mitigation success by developing community "buy-in" from those directly affected by public policy and planning decisions. As residents become more involved in decisions that affect their life and safety, they are more likely to gain appreciation of the natural hazards present in their community and take personal steps to reduce hazard impacts. Public awareness is a key component of an overall mitigation strategy aimed at making a home, neighborhood, school, business or city safer from the effects of natural hazards.

Public input was initially sought using three primary methods: (1) open public meetings advertised locally; (2) broadly-distributed public survey; and, (3) the posting of the draft Hazard Mitigation Plan on each PDC's web site. Public meetings were held at three stages of the planning process; early in the process to introduce the plan update process, again in the middle stage to share results of the Hazard Identification and Risk Assessment; and again, after the planning committee workshops, but well prior to adoption by governing bodies.

3.6.1 2021/2022 Public Meetings

Three open public meetings were held virtually via Zoom to present the planning process and to review mitigation actions to be included in the Hazard Mitigation Plan.

The first public meeting was held March 9, 2021. The goal was to introduce the public to the planning process and invite their involvement. The group discussed the hazards in the 2017 plan and provided comments on hazards proposed to be included in the update. The facilitator polled the group about their concerns regarding various hazards and provided a question and answer session at the end.

Upon completion of the Hazard Identification and Risk Assessment, the Committee held another open, virtual public meeting on June 28, 2021. This meeting included review of the results of the hazard study for the region, including detailed information regarding exposure, risk assessment and social vulnerability.

Upon completion of a draft Plan, the Committee held another public meeting on the draft Hazard Mitigation Plan on March 16, 2022. The meeting provided further opportunity for the public and identified stakeholders to review and comment on the draft plan. The plan was posted on the PDC web sites earlier that week, and PDC contact information and a comment form were provided to assist the public with submitting comments. The 2-week review period concurrent with the March 16, 2022 meeting provided residents with an opportunity to review the content of the Plan's sections.

All public meetings were advertised broadly by the communities on social media, on physical bulletin boards, and via email to help ensure that local officials, residents, businesses, and other public and private interests in the region, including neighboring communities, were notified on how to be involved in the local mitigation planning process. Additionally, the PDCs and the communities advertised the meetings on their web sites. The public meeting advertisements are included in Appendix C, which also includes all committee and public meeting minutes, attendance sheets, and invitation correspondence.

The public meeting on March 16, 2022 was termed the "Feedback Forum" in an effort to solicit public comment and feedback on the draft plan. Once again, the committee relied on the efforts of multiple community Public Information Officers, web masters, and other communication specialists to use a variety of sources to spread the word about the planning effort. Records of advertisements and solicitations for involvement are included in Appendix C (meeting minutes), Appendix D (public survey response summaries), and Appendix E (responses to public comments).

Additionally, the plan was reviewed and presented to each community's elected officials at a public hearing prior to adoption. Though the plan was in its final format for these meetings, this did provide additional opportunity to answer questions and present findings to the public and elected officials. The resolution of adoption by each community is included in Appendix B. Adoption dates are shown in **Table 3.3**.

Table 3.3: Date of Plan Adoption by Each Jurisdiction	
Community	**Date Of Plan Adoption**
Charles City County	
Chesterfield County	
City of Colonial Heights	
Dinwiddie County	
Town of McKenney	
City of Emporia	
Goochland County	
Greensville County	
Town of Jarratt	
Hanover County	
Town of Ashland	
Henrico County	
City of Hopewell	
New Kent County	
City of Petersburg	
Powhatan County	
Prince George County	
City of Richmond	
Town of Surry	
Sussex County	
Town of Stony Creek	
Town of Wakefield	
Town of Waverly	

3.6.2 Public Survey

A public survey was distributed early in the planning process to solicit additional feedback from attendees. As indicated above, the public survey was also distributed online in spring

2021 as part of the committee's effort to improve and use public feedback. The results of a total 192 responses collected are summarized in Appendix D.

3.6.3 PlanRVA Web Site

Throughout the planning process, PlanRVA maintained a web site at https://planrva.org/emergency-management-home/the-alliance/hazard-mitigation/ that provided a description of the planning process and posted meeting information. The page included a copy of the draft plan prior to the final Public Meeting to provide the public an opportunity to comment. Those comments are addressed through the standard comment/response format documented in Appendix E. Crater PDC linked to the PlanRVA web site from their web site during the planning process.

3.6.4 Better Together Webinar

On October 21, 2021, PlanRVA used one of their regular "Better Together" webinar series to focus on the 2022 update to the regional hazard mitigation plan. Each month, PlanRVA hosts one of these public forums with a different theme, hosted by experts in that particular topic or field of investigation. The organization invites the public, as well as a variety of public officials, agency representatives and stakeholders to listen in and ask questions to foster discussion, and then posts the forums on their YouTube channel for posterity. The October 2021 webinar is posted online at: https://www.youtube.com/watch?v=XS-H2ph9Hnc.

3.6.5 Brochure

In addition to the public meetings, web site and survey, the Committee issued a brochure template that was distributed by many of the jurisdictions, primarily via social media and web postings on their respective web sites. The brochure template is shown in Figure 3.2 below and provides background information on the planning process, the Community Rating System, and how citizens can become involved. The blank lines are intended for individual jurisdictions to input contact information for their staff point of contact.

Figure 3.2: Richmond-Crater Hazard Mitigation Planning Brochure

2022 Richmond-Crater Regional Hazard Mitigation Plan Update Process

Hazard Mitigation Planning

A Hazard Mitigation Plan is the result of a planning process to identify hazards and develop strategies to reduce loss of life and property. This planning process is structured around the four phases of the Disaster Mitigation Act of 2000, which the region's planning consultant has aligned with the ten steps of the Community Rating System (CRS). Having an adopted Hazard Mitigation Plan that is updated every five years helps ensure each community in the region is eligible for federal disaster funding following a disaster event.

The Community Rating System (CRS)

The CRS is a national program developed by the Federal Emergency Management Agency (FEMA) to encourage communities to reduce their risk to flood-related hazards. The CRS rewards the efforts communities take that go above and beyond the minimum requirements of the National Flood Insurance Program (NFIP) by providing discounts on flood insurance premiums.

Citizen Involvement

Citizen participation is an important component of mitigation planning for any community. The planning team needs your input on the types of hazards that are your priority concern, and your opinion on ways to lessen their impact.

- Visit the web site. Get more information and follow the planning process at https://planrva.org/emergency-management-home/the-alliance/hazard-mitigation/. The website contains announcements for upcoming meetings, minutes and presentations from past planning meetings, information on the identified hazards, draft planning documents for review, a public survey, and more.
- Take the survey. A public outreach survey is available online here. Please complete the survey as soon as possible to ensure that your opinion is captured! If you would like a hard copy, please use the email below.
- Send us information or comments. If you have information to share for inclusion in the plan, please contact our planning consultants, Salter's Creek Consulting, by email: leigh.morgan2@verizon.net. The draft plan will be made available for public review on the web site prior to being submitted to FEMA.

Hazards Addressed by the Richmond-Crater Hazard Mitigation Plan

The planning committee has identified the following hazards for inclusion in the Richmond-Crater Hazard Mitigation Plan:

- Tropical Storms
- Severe Wind
- Tornados
- Severe Thunderstorms
- Flooding
- Winter Weather
- Drought
- Wildfire
- Earthquake
- Geological Events
- Pandemic

3.7 Involving Stakeholders

> **<u>44 CFR Requirement</u>**
>
> **Part 201.6(b)(2):** The planning process shall include an opportunity for neighboring communities, local and regional agencies involved in hazard mitigation activities, and agencies that have authority to regulate development, as well as businesses, academia and other private and non-profit interests to be involved in the planning process.

A range of stakeholders, including neighboring communities, agencies, businesses, academia, nonprofits, hospitals, and other interested parties were invited and encouraged to participate in the development of the Hazard Mitigation Plan. Stakeholder involvement was encouraged through notifications and invitations to agencies or individuals to participate in Planning Committee meetings, the Mitigation Strategy Workshops and document review.

In addition to the Planning Committee meetings, the committee encouraged open and widespread participation in the mitigation planning process through the design and publication of advertisements that promoted the open public meetings. These media and social media advertisements and the PDC web page postings provided opportunities for local officials, residents, and businesses to offer input.

During the 2021/2022 update process, additional stakeholders were contacted and invited to participate in one of three ways: 1) attend and participate in Committee meetings; 2) attend and participate in the Public Meetings; and/or 3) review draft documents and provide comments and critique. The stakeholders identified as such in **Table 3.2** responded to a more formal request to serve as stakeholders and to participate in the planning process through one of the methods identified above. The additional stakeholders invited that did not choose to participate included:

- State agency representatives;
    - Virginia State Police
    - Virginia Coastal Zone Management Program
    - ChamberRVA
    - Soil & Water Conservation Districts
        - James River
        - Colonial
        - Hanover Caroline
        - Monacan
        - Henricopolis

- Representatives of local tribes;
    - Chickahominy Eastern Division Tribe
    - Rappahannock Tribe
    - Upper Mattaponi Tribe
- Neighboring jurisdictions;
    - Hampton Roads Planning District Commission (HRPDC)
- Representatives from colleges and universities in the region;
    - Virginia Institute of Marine Science
    - Virginia Commonwealth University (several students attended public meetings)
    - Richard Bland College
    - University of Richmond
    - Randolph Macon College
    - Virginia State University
    - Virginia Community College System
- National Weather Service, Wakefield;
- Non-profit organizations;
    - The Nature Conservancy
    - Capital Region Land Conservancy
- Representatives from utilities servicing the region;
    - Dominion Energy
- Social service providers in the region;
    - Central Virginia Healthcare Coalition
    - United Way
- Representatives from military bases in the region; and,
    - Fort Lee
    - Defense Supply Center

- Representatives from the medical community
    - HCA Healthcare
    - Central Virginia Health Services
- Other groups
    - Port of Virginia;
    - Virginia Hispanic Chamber of Commerce;
    - Virginia Asian Chamber of Commerce;
    - National Association for the Advancement of Colored People;
    - Greater Richmond Transit Company
    - Richmond City Schools
    - DuPont

4.0 Community Profile

4.1 Updates for 2022

Section 4 has been updated to reflect more current conditions. Tables and figures have been updated, as necessary, to reflect recent data and to modify discussion for Surry County, and the Towns of Claremont and Dendron, which are all now participating in the HRPDC hazard mitigation planning process. Census data from 2020 were incorporated, where possible.

4.1 Introduction

This Richmond-Crater study area encompasses approximately 3,728 square miles and is bordered generally by Fluvanna, Cumberland, Amelia, Nottoway, and Brunswick Counties to the west; Louisa, Spotsylvania, Caroline, King and Queen, and King William Counties, as well as the Pamunkey River to the north; James City, Newport News, Isle of Wight, Surry and Southampton Counties as well as the James and York Rivers to the east; and the State of North Carolina to the south.

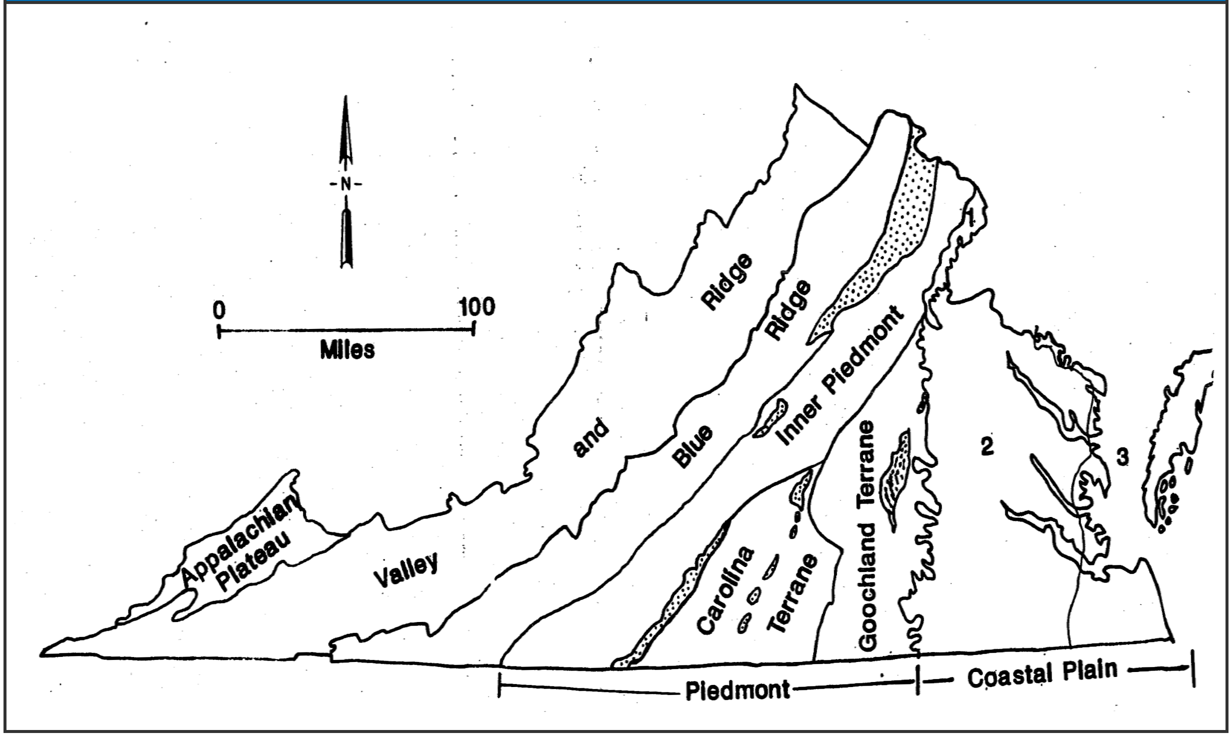
Based on total land mass, Dinwiddie County is the largest jurisdiction at 504 square miles. The Cities of Emporia and Colonial Heights are the smallest jurisdictions in the area at around seven square miles each (excluding the towns), while Charles City County is the smallest county at 182 square miles.

4.2 Physiography

The Richmond-Crater region is characterized by two distinct physiographic regions, the Southern Piedmont and the Atlantic Coastal Plain, as shown in **Figure 4.1**. The Fall Line serves as the dividing line between these two regions. The Southern Piedmont is characterized by deeply weathered, exposed bedrock and a rolling topography. The Fall Line is the easternmost extent of rock-filled river rapids, the point at which east-flowing rivers cross from the hard, igneous, and metamorphic rocks of the Piedmont to the relatively soft, unconsolidated strata of the flat Coastal Plain. The areas of the region in the Coastal Plain are gently dissected by streams but can be locally quite rugged where short, high-gradient streams have incised steep ravine systems.[1] The Cities of Richmond, Petersburg, and Emporia lie approximately at the Fall Line, which is where the James, Appomattox, and Meherrin Rivers, respectively, become unnavigable west of the Fall Line.[2]

[1] "The Natural Communities of Virginia: Classification of Ecological Community Groups (Version 2.4)," DCR, accessed July 18, 2011, http://www.dcr.virginia.gov/natural_heritage/ncintro.shtml.
[2] "Physiographic Regions of Virginia," Virginia Places, accessed July 18, 2011, http://www.virginiaplaces.org/regions/physio.html.

Figure 4.1: Physiographic/Geologic Provinces of Virginia



Source: U.S. EPA, undated

Land elevations in the Richmond-Crater region vary from mean sea level in the eastern, coastal counties to approximately 500 feet above sea level west of Richmond. Generally, the western portions of the region are at higher elevations.

4.3 Hydrology

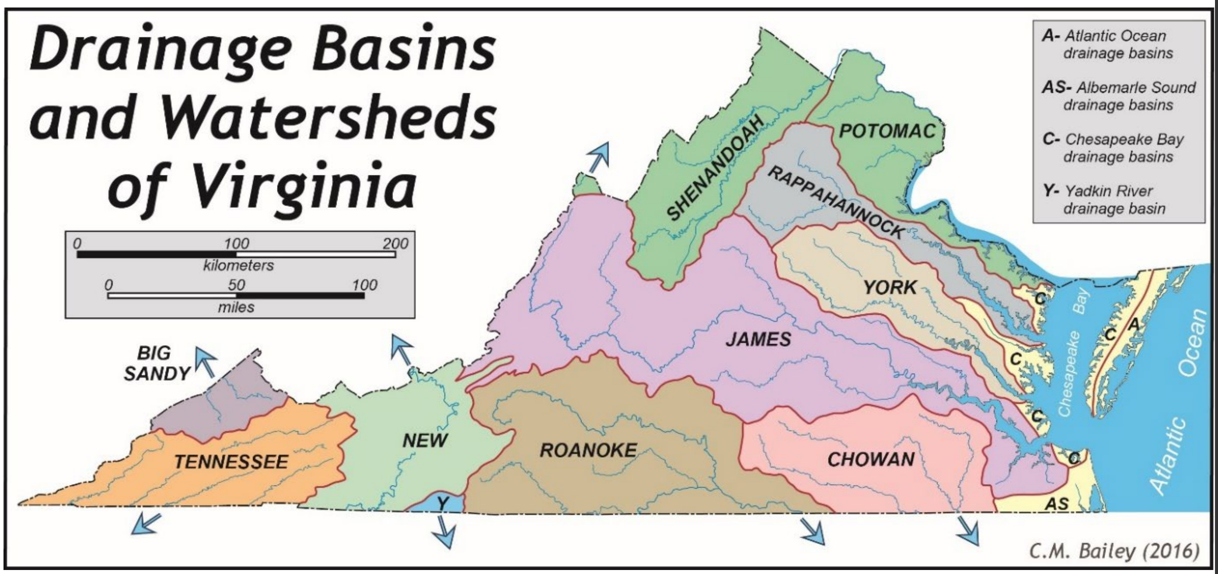
As shown in **Figure 4.2**, rivers in Virginia drain to one of three main watersheds: the Chesapeake Bay, the North Carolina Sounds, and the Mississippi River. The Richmond-Crater study area lies within three major watersheds. The James and York, which flow into the Chesapeake Bay, and the Chowan, which flows south to the North Carolina Sounds.

The James River watershed is the largest watershed in Virginia, spanning 10,236 square miles, including 39 counties and 19 cities and towns. The watershed covers approximately one-fourth of Virginia's area and is home to one-third of its people, who live largely along the I-64 corridor from Richmond to Hampton Roads. The watershed itself is fed by more than 25,000 miles of tributaries, but primarily the James, Appomattox, Maury, Jackson, and Rivanna Rivers. It is Virginia's largest tributary to the Chesapeake Bay.

The York River watershed covers a much smaller area, comprised of all or portions of 11 counties to the north and east of Richmond. It has a drainage basin of 2,669 square miles and is the only watershed located entirely within the Coastal Plain. Its main tributaries are the York River, Pamunkey River, and Mattaponi River. It is one of the most studied watersheds in the country and is in relatively good health ecologically. The upper areas of the basin are buffered by freshwater marshes and lowland, hardwood swamps that help protect the surrounding area from the effects of severe weather and human activity. Downstream, saltwater marshes provide a similar service. However, rapid population growth and related construction over the past 20 years has increased the need for more intense land use planning.

The Chowan River basin spans 3,675 square miles and is comprised of the Nottaway River, Meherrin River, and the Blackwater River. These rivers flow southeast toward the North Carolina border and empty into Albemarle Sound, located mostly within North Carolina. The Albemarle-Pamlico Estuarine System is the second-largest estuarine system in the United States. The Virginia portion of the basin is the second largest in area of the three major Virginia watersheds, but the least populated.

Figure 4.2: Physiographic/Geologic Provinces of Virginia



Source: Accessed online at: http://geology.blogs.wm.edu/hydrology/, 2016

The James River flows through the City of Richmond. Numerous small streams flow through the city before discharging into the James. Many of these urban watersheds are contained entirely within city limits. Others originate in suburban areas surrounding the city. The floodplains of these smaller streams contain varied residential, commercial and industrial development. The floodplains of Broad Rock and Grindall Creeks above the Seaboard Coastline, and Powhite Creek above the Powhite Freeway are undeveloped.

Below Powhite Freeway, Powhite Creek parallels the road in an improved channel and the road takes up nearly all the remaining floodplain.

The Meherrin River flows in a southeastern direction through the center of the City of Emporia. The channel is relatively well defined, with overbank areas generally covered with varying amounts of vegetation and tree cover. Fall Run borders the corporate limits of the City of Emporia on the south.

The Appomattox River bisects the City of Petersburg and the City of Colonial Heights, about 20 miles south of Richmond, and approximately 6 miles above its confluence with the James River. The natural development of Petersburg began at the Appomattox River and progressed southward. This progression resulted in heavy industrial and commercial development along the flood plains of the Appomattox River and the lower reaches of the smaller streams penetrating the city. Beyond the highly developed core and along the small streams to the south, there is a mixture of industrial, commercial, and residential development. The Appomattox River forms the southern and eastern boundary of Colonial Heights. Swift Creek, a tributary to the Appomattox River, forms the northern boundary of the city. Swift Creek's watershed is generally rectangular in shape and measures approximately 30 miles long and 9 miles wide at its broadest points. It has a drainage area of approximately 184 square miles. Old Town Creek flows east to the Appomattox River. The creek's narrow watershed is approximately 7.5 miles long and has a drainage area of approximately 13.5 square miles.

The City of Hopewell is located just south of the confluence of the Appomattox and James Rivers. The City's location in the Coastal Plain is typified by its low relief. The land is generally level, but some streams are short in length with steep gradients. Sandy soil and clay subsoil are predominant, where much of the soil has been formed from rock fragments washed down from the Piedmont region. Cabin Creek drains a large portion of the western end of the City, flowing south to north into the Appomattox River. One of the main tributaries of cabin Creek is Bullhill Run. Bailey Creek drains the southern portion of Hopewell and flows west to east along the southern corporate limits before emptying into the James River. Cattail Creek drains the central portions of Hopewell.

Additional rivers in the region include the Blackwater River, Chickahominy River, and the North Anna River. The Blackwater originates in Prince George County as a coastal plain swamp, then meanders east into Surry County. The Chickahominy begins about 15 miles east of Richmond, then continues east for 87 miles. It marks the eastern border of Charles City County. The North Anna River originates in Lake Anna and flows southeast through central Virginia for 62 miles. It is a major tributary to the Pamunkey River.

There are also several large creeks that run through the region. Stony Creek, formed by the merging of White Oak Creek and Butterwood Creek in Dinwiddie County, passes through the center of the Town of Stony Creek. Twenty-one miles in length, it is a tributary of the Nottaway River.

According to the DCR natural heritage inventory, there are at least seven important ecological community groups in the Richmond-Crater study area that are interrelated with the water resources of the region:

- Pine/Scrub Oak Sandhills
- Fluvial Terrace Woodlands
- Bald Cypress – Tupelo Swamps
- Coastal Plain/Piedmont Swamp Forests;
- Coastal Plain/Piedmont Floodplain Forests;
- Tidal Bald Cypress Forests and Woodlands; and,
- Tidal Freshwater and Oligohaline Aquatic Beds

The Virginia Scenic Rivers program, administered by DCR, identifies, recognizes and provides limited protection to rivers whose scenic beauty, historic importance, recreation value, and natural characteristics make them resources of particular importance. Reaches of the Blackwater, lower James, and Nottoway Rivers are all designated scenic rivers through the program, although the part of the Blackwater River that is designated scenic is outside the study area. Similarly, the Nationwide Rivers Inventory is a register of river segments that possess unique, rare or exemplary features that are significant at a comparative regional or national scale. Segments of the Blackwater, Chickahominy, James, Northwest, Nottoway, Ware, Yarmouth, and York Rivers are designated on the Nationwide Rivers Inventory for various reasons.

4.4 Climate

The present-day climate of Virginia is generally classified as humid subtropical, but within-state variation of temperature, precipitation, and length of growing season is dramatic. Average temperatures in the region are about 76 degrees Fahrenheit in the summer and 39 degrees in the winter. Average annual rainfall is around 43 inches, spread fairly evenly throughout the year. Average snowfall ranges from 12 to 17 inches annually, with highest amounts recorded in January and February. Additional discussion of weather extremes, including winter storms, are included in Section 5.

4.5 Land Use and Development Trends

The jurisdictions in the Richmond-Crater region vary dramatically from primarily rural to urban, sometimes within the same jurisdiction. While the Cities of Colonial Heights, Emporia, Hopewell, Petersburg, and Richmond have typical urban/suburban development patterns, most of the counties are rural in character. Charles City, Dinwiddie, Goochland, Greensville, Hanover, New Kent, Powhatan, Prince George, Surry and Sussex Counties are mainly rural with some pocketed areas of suburban development. Approximately 22% of Hanover County is Suburban Service Area and the planned region for about 70% of the county's expected residential growth; the remaining 78% of the county is rural.

Chesterfield and Henrico Counties and the City of Richmond are more suburban and urban in character.

In Virginia, the authority for land use planning and land use regulations resides at the local level. As required by the Code of Virginia, all jurisdictions in the Richmond-Crater region maintain local Comprehensive Plans that include a land use element and manage land development through zoning and subdivision regulatory ordinances.

In addition to local authority, state and regional programs and processes encourage regional coordination when planning for land use, transportation, economic and environmental matters. For example, the urbanized area of the Richmond-Crater region constitutes two regional transportation planning organizations for federal programs: the Richmond Regional Transportation Planning Organization and the Tri-Cities Metropolitan Planning Organization. As required by federal code, these organizations regularly update a long range regional transportation plan that includes population, housing, and employment projections in the urbanized area and considers land use trends. Most of the population in the Richmond-Crater region lives within the urbanized area, which is expected to continue. The Richmond and Crater regions also have Comprehensive Economic Development Strategies (CEDS). Analysis of population and employment data are foundational to the development of the CEDS, as well as their annual updates over successive years.

4.5.1 Charles City County

Charles City County is a rural community located between the more urban areas of Richmond and Williamsburg-Newport News metropolitan areas. The county has a wealth of historic homes and other sites reflecting its pre-European settlement history and more than 400 years of post-European settlement. The county is heavily forested with small residential communities scattered throughout. As of 2014, about 80% of the county was used for agricultural or forestry purposes or was otherwise in a natural state.[3] Development tends to be clustered at road intersections or along the James and Chickahominy Rivers. Much of the undeveloped land is in large tracts under single ownership.

The county is divided into three magisterial districts. Almost half of the population is concentrated in the Harrison District that covers the western portion of the county. Most of the commercial and industrial development is also located in the western part of the county. About one-third of the population lives in the central portion of the county, in the Tyler District. The remaining population is in the Chickahominy District.

Most of the housing stock in Charles City County is single-family homes. Given trends in surrounding areas and the rapid increase in the cost of stick-built homes, it is likely the number of manufactured homes in Charles City County will continue to increase.

[3] "Forest Inventory Data Retrieval (2002-2007)," Virginia Department of Forestry, August 26, 2009, http://www.dof.virginia.gov/resinfo/FIA_2007_StandardTables.htm.

Forests cover approximately 73% of the County's land area. The majority of the forests, about 75%, is owned by private landowners. In 2007, accessible forest area accounted for 67% of the total available land.[6] Land used for rural residential and public/semi-public uses accounted for the difference.

A Dominion Energy substation provides electricity to the county, located on Chambers Road off Roxbury Road (Route 106). Two power substations provide electricity to the county. Efforts are underway to ensure that the courthouse and municipal complex are on both grids.

Charles City County seeks to preserve its rural character by establishing development controls which direct growth to neighborhood residential areas within centralized development centers. This marks a break from the historical growth pattern, which encouraged sprawl and consumed agriculture and farm lands. New controls are expected to relieve the pressure on agriculture and forest lands, leading to more orderly and attractive development patterns and allowing for efficient use of tax dollars. Transportation growth is anticipated to become focused due to this new policy of directing growth within development centers.

Commercial development is very low in Charles City County when compared to neighboring localities. Commercial land within Charles City County typically consists of country stores with gas pumps, antique shops, garages, greenhouses, banks, marinas, and retail and professional services. Charles City County encourages commercial growth, primarily in the development centers.

Light and heavy industrial growth is expected to continue, given the continued expansion of Ft. Lee in Prince George County. The fort's mission is focused on military supply, subsistence, transportation, maintenance, and munitions. In 2015, Ft. Lee became the US Army's third-largest training site after completing a ten-year expansion period. More recently, it was made the temporary home of approximately 2,500 Afghan refugees, primarily interpreters and their families. It can be reasonably assumed that a portion of these families will choose to make the area their permanent home, meaning that residential growth will continue to expand, as well.

Contrary to earlier projections, the population in Charles City County shrank 6.66% between 2010 and 2020, contracting from 7259 people to 6773 according to the US Census. It had previously been expected to increase by approximately seven percent. According to the Weldon Cooper Center for Public Service, the County's population is expected to increase slightly to 6941 in 2030 before declining to 6816 in 2040, thus remaining almost completely flat for the next 20 years. For comparison, Virginia's population grew 7.9% over the past decade, increasing from 8 million to 8.63 million people. Projections for Virginia's growth rates over the next two decades will be released by the Weldon Cooper Center in 2022.

The Charles City County Planning Commission expects a population increase of 819 people, or 11.9%, by 2040, based on four different projection scenarios. This will require the construction of approximately 350 additional housing units at a rate of 17-18 per year but will otherwise have only minimal impact on the area. Commercial and industrial growth is expected to increase but only moderately.[4]

4.5.2 Chesterfield County

Chesterfield County, which arcs below the south side of Richmond, has been split into numerous small areas for planning purposes and the development pattern varies immensely between these areas. Portions of the county are built out at suburban densities while other portions of the county remain undeveloped and rural. For instance, the western part of the Southern and Western Planning Area is designated as "rural conservation," meaning that uses should be restricted to large-lot residential, forestry, or agriculture. Closer to the City of Richmond, however, the development intensity increases. In this area, the Midlothian Turnpike corridor continues to be one of the county's prime locations for planned light industrial, commercial, and office uses.

Leapfrog development has characterized the Central Area, creating a disjointed development pattern. The types of development in the Central Area have included single-family subdivisions, scattered multi-family complexes, and small- to medium-sized shopping areas often along highway corridors, large employment centers, industrial parks, and an airport. This area is experiencing rapid growth, particularly west of U.S. Route 10.

Significant commercial and industrial development has occurred in the Eastern Area in recent years, and this trend is expected to continue. The Eastern Area also has a great deal of residential development, often adjacent to older commercial-strip zoning and uses. This pattern is particularly seen along U.S. Route 10.

A dominant theme of the county's comprehensive plan is a commitment to maintain a strong and growing economic base in Chesterfield County. New and existing business and industrial development provides diverse employment opportunities and revenue, and is vitally important in providing the types of services that promote a high quality of life in the county.

Since the 19th century, development patterns have been greatly influenced by the changing transportation and public utilities networks. Traditionally, the economic development base consisted primarily of large manufacturing and chemical industries. Today, the economic base has been enhanced by development of a variety of commercial and corporate office uses providing a range of services and employment opportunities for the county and region. In 2017, there were 136,000 jobs within the county, an increase of 20% over the number of jobs in 2010. PlanRVA projects that Chesterfield County will have approximately 166,000 jobs by 2035, an increase of 47 percent over 2010.

Chesterfield County is a community committed to promoting and maintaining a high quality of life for all residents and employers. As such, it is important that the county's

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[4] Charles City County web site, accessed online at:
http://charlescitycountyva.info/AgendaCenter/ViewFile/Agenda/_02272020-325

neighborhoods and business corridors be maintained in the highest quality possible and stabilized to ensure continued vitality. The public sector's role for ensuring long term stability and supporting a high quality of life is to provide equitable distribution and efficient allocation of public resources. Provision of equitable public services will promote private investment and reinvestment in aging and maturing areas.

Between 2010 and 2020, the County's population increased just over 15% to 364,548 people. This is a slower rate of growth than the County experienced between 2000 and 2010 when the population increased by 22%. Still, the total recorded in the census was nearly 10,000 more than the County had been projecting. Residents under the age of 14 constituted the largest segment of the population while residents over the age of 65 made up the fastest growing segment and those 55 and older the second largest. In coming years, a slowing birthrate is expected to keep the youth population stable while the population of older residents will continue to grow. The County is becoming more racially and ethnically diverse and approximately 12% of households speak a language other than English at home. Of those who speak English "less than 'very well'," the vast majority are Spanish-speakers.

Chesterfield County boasts a population that is better-educated and better paid than others in the region and the average population of Virginia. Lastly, the size of the average household has increased slightly over the past decade to 2.74 members.[5]

4.5.3 City of Colonial Heights

Colonial Heights is located at the Fall Line, or where the Coastal Plain meets the Piedmont. The city shows a linear development pattern along U.S. Route 1. The City is almost completely developed, with very few options for new building other than scattered infill possibilities. More land is devoted to residential purposes than any other use, with single-family detached homes representing the norm. There is some multi-family housing, including duplexes, townhomes, and apartment buildings. The 500 new housing units built since 2000 are primarily two, new multi-family units. The city recognizes that there is a need for increased housing suitable for its growing population of senior residents and for younger, single people if it wants to attract new residents, and is considering the feasibility of mixed-use property, particularly near the Southpark Mall Regional Shopping Center.

The city's comprehensive plan indicates that most commercial property is located along major transportation corridors, specifically The Boulevard (US Route 1/301), Temple and Ellerslie Avenues, and at the Southpark Mall. Industrial properties are primarily located in specific segments of West Roslyn Road, on Ellerslie Avenue, and on Charles Dimmock Parkway, although most of these properties are really for more intense commercial use than traditional industrial properties like factories.

Institutional properties, mostly churches and buildings owned by civic organizations, are scattered throughout Colonial Heights, as are parks and public schools. About 29% (1,625

[5] Chesterfield County Demographic Report, accessed online at: https://www.chesterfield.gov/DocumentCenter/View/20197/Chesterfield-County-Demographic-Report-2020,

acres) of the city is not developed, but the majority of the undeveloped land (983 acres) is unbuildable because of site constraints such as the presence of wetlands, floodplains, or steep slopes.

Land use patterns are generally well-established in Colonial Heights, and there is minimal need for significant land use change. The city has existing plans for development and revitalization of particular areas of Colonial Heights, while taking care to protect the elements that make living in the city desirable. These plans currently extend to 2044.

There is minimal need for additional public facilities; however, there may be need for additional public parks and open spaces in specific sections of the city that are currently underserved. Where possible, Colonial Heights will incorporate transitional land uses between higher activity uses, such as commercial, to lower activity uses such as single-family neighborhoods with less intense commercial or higher density residential uses, and create a mixture of recreational, commercial and residential uses along the river as recommended in the Appomattox River Corridor Plan.

The most significant growth period for the city was between 1950 and 1960. This was due, in part, to the 1954 and 1957 annexations. The city continued to grow at a relatively fast pace until the 1980s when the population stabilized. Between 2010 and 2020, the population of Colonial Heights increased from 17,411 to 18,170 and is expected to continue to increase slightly through 2040.

The city is also expected to become more racially diverse over this time period. According to Data USA, in 2019 there were nearly five times more whites than people of any other ethnicity in Colonial Heights. Blacks made up 14.6% of the population, Asians 4.15%, and Hispanics 5.87%. Approximately 7.32% of the city's population is foreign-born. According to the Weldon Cooper Center, the number of Black people in Colonial Heights is expected to decrease over the next two decades while the percentage of Asians is expected to increase. The number of Hispanics is expected to remain essentially flat. The white population is expected to decrease.

According to the Virginia Employment Commission, there were 8,363 people employed in the City of Colonial Heights as of June 2020. Retail is the largest industry with 27% of workers, followed by health care-related and food service/hospitality, both with 17% of workers. Local, State, and Federal Government employment combined equals approximately 15% of the workforce[6].

4.5.4 Dinwiddie County

Dinwiddie County, like many of the jurisdictions in the Crater Planning District, is divided by the Fall Zone into two physiographic provinces, the Piedmont to the west and the Coastal Plain to the east. Approximately three-fourths of the county is located in the Piedmont Plain. The major rivers that flow through this area, the Appomattox and Nottoway, occupy narrow floodplains with only minor meandering. These rivers divide the

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[6] Virginia Employment Commission, Economic Information & Analytics, Quarterly Census of Employment and Wages, 2nd Quarter [April, May June], 2020

County into two unequal portions, with the Appomattox River Basin defining the northern 16% of the county and the Nottaway River Basin the southern 83%. The Appomattox River drains into the James River Basin and the Nottoway into the Chowan River Basin. The eastern portion of the county in the Coastal Plain tends to be flat and swampy, which deters development.

The county has grown in three distinct areas. The first area is along major highways such as River Road, U.S. Route 1, and U.S. Route 460. Such development occurs individually or in small strips. Clusters of development are also located in the fringe parts of the Town of McKenney and existing villages and crossroads such as Dinwiddie Courthouse and Sutherland areas. Finally, as the City of Petersburg has expanded, development has begun to cluster in its outskirts in the northeastern part of the county. Approximately 40% of county residents live in this portion of the county. It is also one of the areas where public utilities are available. Residential development patterns include single-family and duplex units, apartment complexes, and manufactured housing parks.

In Dinwiddie County, commercial development tends to occur near residential development. Most of the commercial establishments are located in the northeastern section of the county, a few businesses are located in the Courthouse area, and travel service facilities such as gasoline stations, motels, and restaurants are located mainly along U.S. Routes 1 and 460. The county has an industrial park at the municipal airport. There is also some industrial presence in the Town of McKenney.

Most of the open space land in Dinwiddie County is under the ownership of timber companies. It is estimated that 244,049 acres of land, or 73% of the county's land area, are in some sort of timber production. The timber stands are mainly located in the western half of the county.

Future growth will be centered in the urban Northeastern Area of the county and scattered throughout the rest of the county. There is concern that farmers will find it difficult to continue using their land for agricultural purposes as development increases.

According to the Bureau of the Census, the increase for Dinwiddie County during the decade of 2000 to 2010 was about 14.2% or 3,468 persons. From 2010 to 2020, the population dropped slightly, from 28,001 to 27,947, which contravened the Virginia Employment Commission projection of 5.5% growth. Approximately 62% of County residents were white alone (not Hispanic or Latino), just over 32% were Black, almost 4% were Hispanic or Latino, and the remainder were multi-racial or Asian. The Virginia Employment Commission projects population growth between 2020 and 2030 of 3.3% and an additional 2.49% by 2040.

4.5.5 City of Emporia

The City of Emporia is located approximately 65 miles south of Richmond, 10 miles north of the North Carolina border, in the center of Greensville County. The Meherrin River runs from west to east through the center of town. Like several other cities in Virginia, Emporia is located at the Fall Line, with the western side of the city in the Piedmont and the eastern part in the Coastal Plain. The Meherrin River flows to the southeast and eventually drains into the Chowan River Basin.

Thanks to its location, Emporia has always been a trade center. Originally, there were two towns – Hicksford, founded in 1796 on the south bank, and Belfield, founded in 1798 on the north bank. Following the establishment of the Atlantic and Danville Railroad in the 1870s, the railroad's president (and local General Assembly representative) Sam Tillar convinced the Assembly to approve a merger of the two towns in 1887 and renamed it Emporia. Today, Emporia is a crossroads for cars and trucks traveling on I-95 and Route 58, with much of the city's commercial activity located near the intersection of the two highways and most recent development located to the immediate northwest of it.

In addition to providing travel services for drivers, Emporia is the county seat. The primary use of land within the city limits is residential, with mostly single-family detached homes, some multi-family developments and a few trailer parks. Most of the higher-density units are found in the northeastern part of the city while most of the newer residential developments are single-family homes on larger lots scattered around the periphery of the town. There has also been some construction of single-family homes on infill properties in the older parts of town.

Industrial use is the second most common land use in Emporia. These developments tend to be concentrated near major transportation routes, such as adjacent to railroad tracks and near the Meherrin River Dam. There are three main retail areas. One is north of the river and is made up of a part of the central business district and the Emporia Shopping Center. The second is south of the river and is comprised of the other part of the central business district and the area near the courthouse. The third area is at the intersection of I-95 and U.S. Route 58, which is the site of a large shopping center.

The Emporia comprehensive plan states that demand for development will continue along its traditional pattern. Single-family homes will continue to be in demand as will auto-oriented commercial uses. The plan notes a focus on downtown revitalization and a desire to discourage rampant strip development.

As of 2014, 44.2% of the land (1897 acres) within the city limits was vacant or underdeveloped, a drop from 52.6% in 2007 About a quarter of this land has site constraints such as floodplains or steep slopes that prevent it from being developed. Of the remaining area, vacant land was mostly concentrated in two places: around Route 58 and East Atlantic Avenue on the eastern edge of the city and the area extending north from Route 58 to the northern boundary of the city. New construction will have to be built in those locations or on limited infill property.

According to the latest census, the population of Emporia dropped from 5,927 in 2010 to 5,766 in 2020, contravening the Weldon Cooper Center's 2017 projection of an increase to 6,214. The Center projected a population of 6,447 in 2030 and 6,586 in 2040 but will likely revise these figures downward in the future to reflect the reality of the 2020 census results. The existing population of Emporia is aging, which will likely increase the demand for one-level houses, independent living communities, assisted living centers, and full-service retirement homes with nursing and medical facilities. A growing elderly population will also create demand for specialized types of health care, social, and human services. In addition, both families and seniors benefit from access to parks and recreational opportunities.

Heavily-traveled corridor growth has fueled strip development along Route 58 and Market Drive. These developments have negatively affected Emporia's traditional commercial centers in the downtown areas. However, the growth of regional retail and travel services also benefit the city. Many people traveling along I-95 view Emporia as a destination city and one which is able to provide goods and services required by travelers.

Over the next twenty years, industrial growth will continue to play an important role in shaping Emporia's future. This will be particularly true of the city's surrounding environs, where larger, more favorable sites for industry are generally located. Although Emporia enjoys a diverse economy, growth prospects for the surrounding area will hinge on the community's ability to retain and attract industry.

4.5.6 Goochland County

Goochland is located approximately 30 miles west of downtown Richmond, 45 miles east of Charlottesville, and 105 miles south of Washington, D.C. It is squarely in the Piedmont Province of Virginia with the James River serving as the county's southern boundary for more than 40 miles. Goochland County is still mostly rural with land that is well-suited to its agriculture and forestry operations.

Development has been deliberately concentrated in the eastern part of the county closest to the Richmond metropolitan area. Development pressure from the western Richmond suburbs has led to the County's creation of a development plan showing a strong commitment to preserving the open space, rural nature, and agricultural and forest lands of the county while allowing the growth of residential and commercial areas in the eastern portion.

Since the 1970s, Goochland County has been using zoning and the comprehensive plan to implement the village concept. These land use tools have been shaping development that supports the county's goals of preserving open space and retaining rural character while directing new development toward established villages. Goochland's Land Use Plan divides population centers into Major Villages and Rural Crossroads. Population growth is directed toward the Major Villages where County services (water, sewer, electricity, etc.) are already established and can be expanded when needed with the least amount of difficulty and expense. Rural Crossroads are meant to provide necessary goods and services to the surrounding area but where population growth is not encouraged to protect the rural nature of the area.

While the population was expected to grow 4.77% between 2010 and 2020, it actually grew 13.86% and is projected to grow another 5.87% by 2030 and another 11.43% by 2040, according to the Weldon Cooper Center projections of 2017. The county attributes its attractiveness to its strong school system, rural atmosphere, and proximity to the amenities and businesses located in western Henrico County. In addition, pandemic-related shifts in where people live and work may make Goochland County a more attractive option to those who no longer need to be physically close to their jobs.

The county's comprehensive plan defines its goal of balanced development as:

- High quality commercial, industrial, and employment hubs
- Vibrant, healthy villages that respect the character of each community
- High quality residential development that is compatible with adjacent land uses
- Preserved natural, cultural, and historic resources
- Viable agricultural and forestry resources that are important components of the local economy

The county also has recently completed a Major Thoroughfare Plan Update that lays out plans for the development of the road network to support and complement the expected land development through 2040. The plan examines the assets and needs of multiple forms of transportation (car, bicycle, etc.) and serves as a living document that can be modified over the years to keep pace with both the county's plans and any modifications that may be necessary.

Goochland's location in the central Piedmont region with the James River on the southern border, away from most developed areas, makes it less subject to hazards related to weather and water. The James River has three watershed regions – the upper, middle, and lower. Goochland County lies in the Middle James River region. Most of Goochland County is drained by the James River and its tributaries, but eastern portions of the county are drained by Tuckahoe, Dover, and Genito Creeks. This area is mostly agricultural, with a few low-density subdivisions. Central Goochland County is drained by the Beaverdam Creek/Courthouse Creek watershed and the James River/Mohawk Creek watershed. This area also mostly agricultural with low-density residential housing, but with higher density in the Goochland Courthouse area. Finally, the western portion of the County is drained by Byrd, Little Lickinghole, and Big Lickinghole Creeks. The land use there is almost entirely agricultural or forest lands with very few residential units. The watersheds are of particular interest in this County, as approximately 87% of households rely on wells for drinking water and the quality of the groundwater is a major consideration where development is being considered.

4.5.7 Greensville County

Rolling hills give way to flat land midway through Greensville County, which is bisected by the Fall Line and I-95. Like many other counties in the Richmond-Crater area, Greensville's highest elevations lie in the west and slope downward to the southeast. This topography has a strong influence on development patterns in the county, as the location, size, and prevalence of slopes, drainage patterns, wetlands, floodplains, soil types, and land cover dictate where and how development can occur.

The land cover of Greensville is 54.5% forest, 14.1% wetlands, and 12.6% active croplands. An additional 8.6% of the land is harvested forest/disturbed land. The County is further defined by its network of rivers, creeks, ponds, small lakes, and swamps, with the Meherrin and Nottoway Rivers comprising the main surface waters. The Nottoway serves as the county's northern border, while the Meherrin River flows through the middle of the county from west to east. Both rivers drain into the Chowan River system.

The county's 2020 population of 11,399 represents a drop of 7.5% from 2010. The highest concentration of people in the region is found in the City of Emporia, located in the center of the County. The next-largest town is Jarratt, which has 554 residents. There is some residential development scattered along the primary roads and highways in the county. Approximately 59.4% of the population is Black, 37.7 % is white, and 2.5% is of Hispanic or Latino heritage. The population of the county is projected to remain flat through 2040, though steadily increasing in median age. The demographic profile of the county is skewed by the inclusion of Greensville Correctional Center, which houses 3,123 institutionalized adult men. That number accounts for 27.1% of the county population.

Single-family detached homes dominate the housing stock, with very few multi-family units. Mobile homes account for more than 20% of single-family housing. The supply of affordable housing is a major concern of residents.

Other concerns include the lack of job opportunities, the quality of local education and school buildings, the lack of population growth, and the lack of internet and broadband. These issues present challenges to the improvement of the school system and the growth of business and commercial opportunities.

Residents treasure their rural character and open space, the sense of community in Greensville, and the natural environment. The area's strength as a transportation crossroads is recognized as a valuable asset, along with its manufacturing economy and an industrial mega site in the county. Greensville's proximity to Richmond, Hampton Roads, and Raleigh – all within 80 miles of the county – is also an asset. Because of the importance of transportation infrastructure, the need to invest in road maintenance and public transportation is widely supported.

Future growth will be shaped by the county's priorities, physical topography, financial resources, as well as the county's commitment to remaining primarily rural. Growth areas are expected in the Emporia fringe area and along the I-95/U.S. Route 301 corridor. In recent years, Greensville County has made significant investments in housing, economic development, and infrastructure. The county's next priority is to refocus their efforts on some of the issues of greatest concern to its residents, as described above.

4.5.8 Hanover County and the Town of Ashland

Hanover County is the northernmost county in the Richmond-Crater region, located immediately north of Henrico County and includes the northern edge of the Richmond Metropolitan Area. Although most of the county's population lives in the southern portion that lies closest to Richmond, much of the county is rural. County policies have been shaped around the goal of retaining the rural and agricultural nature of Hanover County while accommodating the needs of the ever-growing population.

Population growth is one of the biggest issues – possibly the biggest issue – faced by Hanover County in recent decades. Since the 1990s, the county has seen steady population growth of 1% or more each year. In 2010, the county's population was 99,863, in 2020 it was 109,979. For planning purposes, the county assumes a growth rate of 1.5% annually. To preserve the rural nature of the county, planners have deliberately directed approximately 70% of development into the Suburban Service area around I-95 that serves as the major commuter route between Hanover and Richmond. The remainder of county land is categorized according to its primary use(s), and each type of land use has guidelines for development and restrictions on density to ensure that growth proceeds in an orderly and efficient fashion that will not overtax county resources or significantly change the primarily rural and agricultural feel of the county.

These categories are: Rural Areas (open land, wetlands, wildlife habitats, and forests), with the subcategories of Agricultural Land Use (farms and farmed forests, low-density residential), Rural Villages (small towns) and Rural Commercial Node Land Use (mostly road intersections with commercial services for the local community); the Suburban Service Area near Richmond, which includes several subcategories for residential, commercial, industrial, and recreational uses; Commercial Land Use that can be located anywhere in the county; Destination Commerce Land (businesses that serve an entire region and are unique in character); Planned Business Land Use (office and industrial parks); and several subcategories that are industrial in nature. Each category has its own strategies and goals for usage that, combined, meet the county's overall strategic goals for shaping where and how growth takes place.

Like other counties in the Richmond-Crater district, the Fall Line divides the land between the Piedmont and the Coastal Plains. The highest elevation in the county lies in the west at approximately 370 feet and drops gradually to the east until it reaches sea level. Most of the county is located within the York River watershed but the southernmost part falls within the James River watershed. Hanover County is located within three primary sub-watersheds: the Pamunkey, the Middle James, and the Lower James. Most of the steep slopes of the county are found along rivers and streams. Around the Fall Line, the banks of several rivers, particularly the South Anna River, have fairly steep bluffs characterized by exposed rock. Further to the east, there are some steep slopes along the tributaries that flow into the Pamunkey River.

The Town of Ashland is located in the heart of Hanover County. Established in 1858, the early growth of the town was fueled by the railroad. In more recent times, Randolph-Macon College and I-95 have influenced the town's development. The town is approximately 7 square miles. Ashland is largely developed, so emphasis is placed on community stabilization and preservation. Although the area to the north and west of Ashland has been under consideration for further development, no plans have yet been made.

4.5.9 Henrico County

Henrico County forms a rough semicircle around the northern portion of Richmond, and much of the land closest to the city is urban or suburban. The county is a major transportation hub, hosting Richmond International Airport, an Amtrak station, and portions of I-95, I-295, I-64, and Route 895. The county has seen steady increases in both population and new businesses, gradually increasing the amount of land used for residential and commercial purposes. Over the last three decades, much of the county has gone from rural to suburban or commercial, which has brought both challenges and benefits. Henrico County has responded by creating a detailed comprehensive plan outlining guidelines and strategies for the county's growth through 2026.

While the largest category of land use is described as "vacant," this is misleading as a lot of this land is actually used for agricultural purposes. Additionally, some of this land cannot be developed because it lies in a floodplain, contains wetlands, or is otherwise undevelopable. The second-largest category is single-family residential, occupying a quarter of the county's land area. Other categories occupy considerably less area, including public and semi-public land, commercial property, and industrial purposes. Approximately 3% of the County is occupied by water, including the James and Chickahominy Rivers and Tuckahoe Creek.

The population of Henrico increased nearly 9% between 2010 and 2020, growing from 306,935 to 334,389. This is significantly lower than the Weldon Cooper Center's projection of 352,577 for 2020. Projections for 2030 and 2040 are 400,396 and 450,630, respectively. Although previous trends were consistent with an annual 2% growth rate, the county has now adopted a scenario that uses a declining growth rate over the subsequent planning period.

The planning department expects that demand for retail, residential, and office space will be concentrated in the western portion of the county while industrial demand will be primarily in the eastern portion, but significant residential development continues in the eastern portion of the county. During this plan update, Henrico County began the process of updating its Comprehensive Plan. The new Comprehensive Plan will provide the framework for how the county will grow and develop through 2045 and will be incorporated into future iterations of this plan.

4.5.10 City of Hopewell

The City of Hopewell is located 18 miles southeast of Richmond at the confluence of the James and Appomattox Rivers. Hopewell was founded more than 400 years ago and is the second oldest continually inhabited English settlement after Hampton. It is known for its historic buildings and architecture, although much of the city was destroyed by fire in 1915. Unfortunate urban renewal projects in the 1960s did further damage to the city's character, although recent projects have begun a turnaround. Most significantly, an attractive Riverwalk was completed in 2019.

The city occupies approximately 11.3 square miles and is comprised of an industrial sector, regional commercial properties, and several compact urban neighborhoods. Approximately

80% of Hopewell's working population commutes outside of the city for work, mostly to Richmond. The proximity of the capital is a major influence on Hopewell, providing employment, shopping and services not found locally.

Hopewell's population began steadily declining in 1980, then increased slightly in 2010 and again in 2020 when the population reached 23,033. The Weldon Cooper Center projects the population to increase at a rate of about 1,000 people (4.8%) every ten years through 2040

The Appomattox River serves as the city's northern border and the James River serves as most of the eastern border. Neighboring counties are Chesterfield to the north, Charles City to the northeast, and Prince George to the east, south, and west.

The City of Hopewell falls entirely within the Coastal Plain (close to the western edge of the province) and the area governed by the Chesapeake Bay Preservation Act. The steepest slopes in the county can be found along the James and Appomattox Rivers.

Residential properties dominate the land use pattern of the city. Single-family homes are the main housing type, though there are some multi-family units such as apartments, townhomes, and condominiums. Much of the housing was built in the 1900s for workers. Five large subdivisions have been built since 2000.

Industrial uses are found in the northeastern part of the city along the James River and Bailey Creek. The vacant industrial land is owned by existing businesses and is reserved for their future growth. According to the comprehensive plan, a large part of the industrial development is in the floodplain.

The amount of vacant land in the city is not enough to meet future demands for growth. Infill development and redevelopment of existing parcels will have to be pursued. As of 2010, there was limited vacant land available at the new I-295 interchange for commercial development. One goal of the city is to promote industrial development through a commercial business park, but available land is limited. Significant residential structures are being converted to business uses in core village areas. Most residential "development" is infill.

In comparison to peer communities, Hopewell's economic and demographic metrics show room for improvement. The income for city residents is substantially below Virginia's average and the rate of new employment is static. A disproportionate number of city residents (8,300+) are out-commuters for employment. The in-commuter city workforce (6,700+) spends little non-work time and money in the city. Unemployment rates are high. The marketplace for goods and services is severely underperforming.

4.5.11 New Kent County

Rural land uses have long dominated New Kent County's landscape but the last decade has seen significant change and growth. After the 2020 Census was completed, New Kent was seen as the fastest growing county in Virginia after Loudoun County in northern Virginia, jumping from 18,429 people in 2010 to 22,945 in 2020 – an increase of 24.5%. The arrival of more than 4,400 new residents in one decade is attributed primarily to New Kent's appeal as an attractive location with a high quality of life and home prices that compare favorably to other counties in the greater Richmond area. Like Loudoun, New Kent County is a desirable exurb.

New Kent County is located in the northeast corner of the Richmond-Crater district. Hanover and Henrico counties lie to the west and Charles City County to the south. The county is located well east of the Fall Line in the Coastal Plain.

Although the county is still predominantly rural, with population clusters scattered along rural roads, New Kent County also has clusters of subdivisions of various kinds, with most of them concentrated in the western third of the county closest to Richmond. This is the area currently experiencing the highest levels of growth. However, there are also population clusters located in the eastern third, particularly around Lanexa and the Diascund Creek Reservoir, where commuting to jobs in Williamsburg is feasible.

Commercial centers are located at Bottoms Bridge, Providence Forge, and Eltham, all of which are complemented by nearby residences. There are smaller clusters of residential and commercial development at Lanexa, Barhamsville, and Quinton. New Kent Courthouse has few commercial uses but is a center for government and institutional uses with residences interspersed and nearby. Perhaps the most significant area of commercial growth in recent years is at the old Colonial Downs racetrack where Rosie's Gaming Emporium opened in 2021. Lastly, several golf course residential communities and vineyards have proven attractive to residential development and have brought festival events to the county. The 2012 comprehensive plan called for concentrating future development in mixed-use village centers. The exception was industrial uses, which should take advantage of the large amount of vacant property along I-64 and U.S. Route 33. While an updated comprehensive plan has not yet been published, the process of creating Envision New Kent Strategic Plan was kicked off in January, 2020, with a draft writing process begun in April, 2021. This document will define the county's vision for growth and change through 2040.

4.5.12 City of Petersburg

The City of Petersburg is in the heart of the Richmond-Crater district, located 23 miles southeast of Richmond and 9 miles southwest of Hopewell. It is bordered by Chesterfield County to the northwest, Dinwiddie County to the southwest, and Prince George County to the east. The City of Colonial Heights is just north of Petersburg, separated from it only by the Appomattox River. Petersburg is 23.1 square miles (14,784 acres) and in 2020 had a population of 33,458, an increase of 3.2% from 2010. The percentage of Black residents is 76.7% of the population compared to about 20% in Virginia as a whole. Petersburg is a nexus of major roadways, with 1-85 and Routes 1/301 and 460 all merge with or cross 1-95 in the heart of the city.

In 2016, after years of mismanagement, Petersburg was in financial crisis with $19 million dollars in unpaid bills and a $12 million budget gap. A team of outside consultants imposed drastic budget cuts that staved off complete financial collapse. Since then, Petersburg has reached a new level of financial soundness that has increased its ratings by various agencies and improved its reputation with surrounding localities and with the Commonwealth. While the City is still years away from being debt-free and still struggles with high poverty and crime rates, local developers, entrepreneurs, and artists have been working hard to turn Petersburg around.

Given that annexation of county land is not an option, the City of Petersburg has a finite amount of land available for growth. Furthermore, developable land is limited by Chesapeake Bay Preservation Act requirements and other physical site constraints. Therefore, development and revitalization efforts are focused on existing neighborhoods with infill properties and/or properties in need of extensive renovation. Land use fragmentation is a major issue in Petersburg with incompatible uses often located side by side.

The city has two distinct residential patterns. The first is found in the "Old City," north of I-85. A mix of residential types (e.g., single family, multi-family, and duplexes) is found here. Newer developments, mainly suburban subdivisions, have sprung up south of I-85, in large part due to the Southside Regional Medical Center now located there. Some infill of single-family homes and duplexes has also taken place.

Recent progress has energized efforts to revitalize Petersburg. Some financial grants and funding have been secured and work is underway. The research and recommendation phase is complete and decisions are currently being finalized. Priorities include: building or redesigning the city's gateway areas, redevelopment of the riverfront Harbor Project, neighborhood revitalization in several specific areas, and working with Virginia State University regarding their expansion plans, among others.

4.5.13 Powhatan County

Powhatan County was one of the fastest-growing counties in the country earlier this century, experiencing a population jump of 46% between 1990 and 2000 and another 25% by 2010. The county's growth rate over the last 10 years slowed to 8% (30,333 people in 2020), but is projected to rise by another 13% by 2030 before slowing again. Powhatan's growth is largely due to its proximity to Richmond. Like Goochland and New Kent Counties, Powhatan offers an attractive rural location with a lower cost of living, higher quality of life, and lower housing costs than the Richmond Metropolitan Area. Like many exurban/rural areas, Powhatan is significantly wealthier and has more married-couple families than Virginia's population as a whole.

The eastern edge of Powhatan County is located about 15 miles west of downtown Richmond, with Chesterfield County lying between them. The county is bordered on the north by Goochland County and the James River, and on the south by Amelia County and the Appomattox River. Cumberland County lies to the west. The county is located entirely within the Lower Piedmont region and encompasses 272 square miles.

Originally inhabited by the Monacan Indians, Powhatan was first explored by Europeans in 1608 when Christopher Newport led an expedition up the James River. The first European settlers came in 1699 when hundreds of Huguenot refugees arrived after fleeing persecution in France. They gradually spread throughout the area and some of their original buildings still stand.

The county has always been primarily agricultural, and experienced steady population declines from the mid-nineteenth through the mid-twentieth century. In the 1970s, the county's population began to increase again as suburban development spread beyond Chesterfield County to the eastern edge of Powhatan County. Since 2000, most new development in the county has been in subdivisions that feature 5-acre lots, especially around the Route 711 corridor and near Courthouse Village. Commercial growth has been concentrated mostly alongside the Route 60 corridor and east of the interchange at Route 711 and Route 288. Agriculture is now made up mostly of smaller family farms and niche agricultural industries such as greenhouses, vineyards, or equestrian facilities. Some forestry is also still found in the county; however, government, construction, and retail trade are now the dominant employment industries.

Maintaining Powhatan County's rural character is paramount to the county's vision and plans for growth. Any development proposals will be considered with an eye to whether the plans would interfere with the preservation of "signature" parts of the county, wooded and rural landscapes, or cultural and environmentally-sensitive resources. The county supports reasonable levels of development, but only that which will allow the county to maintain its rural character, provide adequate services, and maintain fiscal sustainability.

4.5.14 Prince George County

Prince George County is situated about 25 miles southeast of Richmond and 75 miles northwest of Norfolk. The City of Hopewell and the James River form its northern border, Charles City County lies to the northeast, Surry County to the east, Sussex County to the southeast, and, continuing clockwise, Dinwiddie County, the City of Petersburg, and the Appomattox River to the west. The county is east of the Fall Line and within the Coastal Plain. In the northern half of the county, water drains into the Appomattox and James Rivers and eventually into the Chesapeake Bay. In the southern part, water flows into the Nottoway River and Blackwater River watershed and then into the Chowan River before reaching the Albemarle-Pamlico Sound.

Prince George County's character is shaped less by its location and more by Fort Lee, a large and growing military base located in the northwestern part of the county that lies between the Cities of Petersburg, Colonial Heights, and Hopewell. In 2005, under directives from the U.S. Congress's Base Realignment and Closure (BRAC) Commission, specific Army and Air Force training operations were combined at Fort Lee, transforming the base into a major military facility. Prince George County and the surrounding area reaped tremendous economic benefits from the BRAC expansion and used Federal monies to build a public library, and elementary school, and make a number of other investments in local infrastructure to accommodate the needs of the growing base and the families who came with it.

The daily population on Fort Lee rose from about 32,000 to 48,000 between 2005 and 2011. Military personnel came from all across the South to Fort Lee as well as from Alexandria and Fort Eustis, Virginia. In January 2009, the combined Sustainment Center of Excellence Headquarters was opened and transformed Fort Lee into the third largest Army training installation in the country. In July 2009, the Army Logistics University opened and began offering more than 200 courses and training 2,300 military and civilian students in logistics and military management techniques.

Since the expansion was completed in 2011, the county has been able to turn its attention to capital facility needs, including the improvement of parks and recreation facilities, school repairs and other maintenance and upkeep projects.

Largely because of Fort Lee, the population of Prince George County has continued to grow. Between 2010 and 2020, the population grew from 35,725 to 43,010, slightly more than 20%. The current population exceeds the numbers projected by the Weldon Cooper Center even through 2040. Given that no further base expansions are expected in the near future, growth population will likely be modest; however, 2,500 Afghan refugees were relocated to Fort Lee on a temporary basis in 2021, and it is likely that at least some will elect to stay in the area.

Aside from Fort Lee, Prince George County has a flourishing industrial base located in several industrial parks, along with product distributors like Ace Hardware, Goya Foods, and Service Center Metals. This has helped balance the tax base in the county. Rolls-Royce is a major investor in the county, beginning the manufacture of aircraft engines there in 2010 and investing in the Commonwealth Center for Advanced Manufacturing educational training facility that opened in the county back in 2011.

Approximately 89% of the county is forested or in crop production. The Virginia Department of Forestry (VDOF) estimates that roughly 74% of the total land area is forested, some of which is commercially owned, and 15% is cropland. The remaining 11% of land is used for residential, commercial, industrial, or public uses.. Single-family homes comprised about 74% of the housing stock, followed by manufactured homes that accounted for about 12%. Most of the single-family homes are found in subdivisions near the two cities. The remainder of the residential development is scattered throughout the county. Commercial development occurs primarily as strip development along major routes.

When considering future development, the county must assess a number of environmental factors as well as land use plans, etc., before approving rezoning requests or specific proposals. Not all land is suitable for development and the residents of Prince George County have expressed the desire to protect agricultural uses and environmentally important areas of the County.

4.5.15 City of Richmond

Richmond is located at the Fall Line of the James River, a feature central to the city since it was founded in 1737. The James River runs from west to east through the center of the city, although slightly more of Richmond is located on the north bank than the south. The city is

62.5 square miles and is not allowed to annex any further land, therefore nearly all new growth will come from redevelopment. Richmond has recently released a new comprehensive plan, "Richmond 300," outlining its vision and goals through 2037. The plan acknowledges that while the City's population has grown remarkably in recent years, its growth has not benefitted everyone and the city must change its approach to make sure that future growth is equitable, sustainable, and beautiful.

Six "Big Moves" were identified in the plan that will guide the City as it moves forward. Richmond will:

- Re-Write the Zoning Ordinance: Direct growth to appropriate areas while maintaining existing neighborhoods as well as creating new authentic neighborhoods adjacent to enhanced transit.
- Re-Imagine Priority Growth Nodes: Target growth in jobs and population to Downtown, Greater Scott's Addition, Route 1 Corridor, Southside Plaza, and Stony Point Fashion Park.
- Expand Housing Opportunities: Encourage the development of housing options throughout the city to expand the geography of opportunity by de-concentrating poverty.
- Provide Greenways & Parks for All: Develop parks and greenways so that by 2037 100% of Richmonders live within a 10-minute walk of a park.
- Reconnect the City: Cap highways to reknit neighborhoods destroyed by interstates, build/improve bridges, introduce street grids, and make the city easier to access by foot, bike, and transit.
- Realign City Facilities: Improve City buildings (schools, libraries, fire stations, police stations, etc.) to provide better services in efficient, shared-use, accessible facilities to better match and serve the growing city.

4.5.16 Surry County and the Town of Surry

Surry County is a rural county characterized by a rolling topography that gradually becomes more level in the eastern portions of the county. Seventy-five percent of the county is forested. Traditionally, forestry and agricultural land uses have supported the majority of employment but have experienced recent decline. Surry County is the location of the Surry Power Station, a nuclear power plant built in 1972 which is the County's main employer.

The Town of Surry is the only community in Surry County participating in this planning effort. The town was originally established in 1652 and was incorporated in 1928. It is the county seat and a hub for businesses serving the surrounding county. The town has a total land area of 0.8 square miles, and is located at the intersection of Virginia Routes 10 and 31, about 4 miles from the Jamestown-Scotland Ferry dock on the south side of the James River. The town's total population as reported in the 2020 Census was 357, a 7% decline since the 2010 Census population of 383.

The county's comprehensive plan calls for improved county and town cooperation, in order to build momentum in ensuring that future development is concentrated in and around the historic towns and crossroads that already exist in the county. The plan calls for "residential investment areas" and commercial areas around the Town of Surry, in particular, to counteract the population decline forecast by the Weldon Cooper Center for the county, and to preserve the rural character of the rest of the county. Zoned commercial areas would provide strategic growth to sustain commercial uses that are expected to diversify and bolster the county's tax base. In 2016, the Hampton Roads Sanitation District (HRSD) added Surry County to their service territory and in 2017, the county and town reached agreements for HRSD to assume ownership and operate their wastewater systems. HRSD is planning a series of system improvements in the long-term.

4.5.17 Sussex County

Sussex County encompasses 496 square miles in southeastern Virginia, about 45 miles southeast of Richmond and 70 miles west of Hampton Roads. The county is bordered by Dinwiddie and Prince George Counties to the north, Surry County and the Blackwater River to the northeast, Southampton County to the southeast, and Greensville County to the southwest. The county lies in the Coastal Plain, so the topography ranges from slightly rolling to relatively level with some marsh areas. Water in the county drains into Stony Creek and the Nottoway and Blackwater Rivers.

Sussex County is primarily rural with agriculture and agricultural-related manufacturing forming the basis of the local economy. Approximately 80% of the land is commercial forestry, the remaining agricultural land is devoted to peanuts, cotton, corn, flue-cured tobacco, small grains, and soybeans.

The towns of Jarratt, Stony Creek, Wakefield, and Waverly are located in Sussex County. Jarratt is split between Sussex and Greensville County, with the western half in Greensville County and the eastern half in Sussex County. The population in 2020 was 10,829, marking a drop of more than 10% from the 12,087 recorded in 2010. The majority of housing is comprised of single-family detached homes. The number of manufactured homes has risen dramatically since 1990, accounting for 58% of building permits issued between 1990 and 1996. In 1990, manufactured homes accounted for only 24% of the housing stock; by 1996, that percentage had risen to 40%. Most residential development is in subdivisions or as strips along the highway. This pattern preserves land for agricultural and forestry uses.

The Future Land Use Map shows a large portion of the county, including the floodplains, classified for conservation uses. Large-lot, residential development is allowed in this area as is agricultural, forestry, and passive recreation. In addition, the plan calls for development to be concentrated in existing community hubs instead of scattered throughout the county.

4.6 Population

The total population of the jurisdictions included in the Richmond-Crater region was 1,302,101 as of the 2020 U.S. Census. Between 2010 and 2020, New Kent County saw the greatest increase in population with a growth rate of 24.5%. Conversely, Sussex County saw a 10.4% population drop, according to the 2020 Census. **Table 4.1** shows population by jurisdiction, the associated change rate, and population projections for each jurisdiction to the year 2040. The region's growth rate is not projected to be evenly distributed across all jurisdictions. New Kent County is expected to continue its rapid growth by an astonishing 36% by 2040. Dinwiddie County's population is projected to grow by 22%. On the other hand, the City of Petersburg is expected to lose almost 14.5% of population and the City of Colonial Heights may lose 6.7%. Rural Sussex, Prince George, and Greensville Counties are also expected to lose population over the next two decades. New Kent and Dinwiddie Counties are growing because the regions of those counties that lie closest to Richmond are developing into exurbs.

Table 4.1: Population by Jurisdiction

Jurisdiction	2020 Population	Percentage Change in Population, 2010 – 2020	2040 Projected Population	Percentage Change in Population, 2020 – 2040
Charles City County	6,773	-6.65%	7,710	13.83%
Chesterfield County	364,548	15.27%	435,294	19.40%
City of Colonial Heights	18,170	4.35%	16,955	-6.68%
Dinwiddie County (inc. Town of McKenney)	27,947	0.19%	34,080	21.94%
City of Emporia	5,766	-2.71%	6,586	14.22%
Goochland County	24,727	0.12%	29,174	18.03%
Greensville County (inc. Town of Jarratt*)	11,391	-6.95%	11,404	-0.11%
Hanover County (inc. Town of Ashland)	109,979	10.12%	127,780	16.18%
Henrico County	334,389	8.94%	399,966	19.61%
City of Hopewell	23,033	1.95%	23,482	1.94%
New Kent County	22,945	24.50%	30,964	35.94%
City of Petersburg	33,458	3.20%	28,613	-14.48%
Powhatan County	30,333	8.15%	35,854	18.20%
Prince George County	43,010	20.39%	42,640	-0.86%
City of Richmond	226,610	10.96%	250,600	10.58%
Surry County (inc. Town of Surry)	6,561	-7.04%	5,992	-8.67%
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	10,829	-10.40%	10,563	-2.45%

* Although Jarratt is located in both Greensville and Sussex Counties, for the purposes of this plan, the Town is included under Greensville County in tables.
Sources: U.S. Census Bureau Decennial Census, 2010 and 2020, and University of Virginia Weldon Cooper Center, Demographics Research Group. (2020). Virginia Population Estimates. Retrieved from https://demographics.coopercenter.org/virginia-population-estimates

4.6.1 Race and Sex

Virginia has become more racially diverse in recent years. According to 2015 U.S. Census Bureau data, the majority of the population in the Richmond-Crater region was reported to be of a single race (98.1%). In American Community Survey (ACS) 2019 data, that percentage had dropped to 97.2. Of the total population reporting one race, 57.9% were white, 35.9% were Black, and 5.0% were Hispanic. In Virginia as a whole, 69.4% were white, 19.9% were Black, and 9.8% were Hispanic/Latino. In both Virginia and the United States as a whole, 50.8% of the population is female. In the Richmond-Crater study area, the percentage is 49.9.

4.6.2 Language

About 4.4% of the Richmond-Crater region's residents are foreign-born, which is a drop from 7.6% reported in 2015. An estimated 6.8% of the population speaks a language other than English at home. The recent influx of refugees from Afghanistan is currently centered in or near Fort Lee in Prince George County. As these refugees resettle, some will likely choose to stay in the area, particularly in the counties close to Richmond.

4.6.3 Age

Another segment of the population that may require accommodations related to hazard events is characterized by age. The 2019 ACS from the U.S. Census Bureau shows that 5.3% of the Richmond-Crater region's population is under the age of 5 and a total of 20.5% is under age 18. At the other end of the scale, 17.7% of the population is 65 or older, a jump of more than 5% in the last five years. Compared to the rest of Virginia, the Richmond-Crater area has slightly fewer small children and young people, but 1.8% more senior residents.

4.6.4 Education

In Virginia, 38.8% of adults have college degrees. This is 6.7% higher than the United States, reflecting the high number of jobs connected to the federal and state governments as well as defense, tech, and business. Within the Richmond-Crater region, Henrico County has the highest percent of college graduates (43.7%), followed by Goochland (41.8%), Chesterfield (41%), Hanover (39.8%), and the City of Richmond (39.6%).

The areas with the fewest college graduates are: Greensville County (9.2%), Sussex County (12.7%), the City of Emporia (13.8%), Charles City County (14.7%), and the City of Hopewell (14.8%). These areas also have the lowest percentages of high school graduates. These numbers, coupled with the age-related demographics described in the previous paragraph and the percentage of non-English speakers, are important to keep in mind when developing public outreach programs. The content and delivery of public outreach programs should be consistent with the audiences' needs and ability to understand complex information.

4.6.5 Income

Within the study area, the American Community Survey data for 2015-2019 indicate Goochland County had the highest household median income of $93,994, followed by Hanover County at $89,390, Powhatan at $89,090, and New Kent County at $87,904 (see **Table 4.2**). The average household income in the region in 2020 was $63,069, slightly above the American average of $62,843, but significantly below the Virginia average of $74,222.

Household median income was lowest in the City of Petersburg at $38,679, followed closely by the City of Hopewell at $39,030. The next closest was Sussex County at $47,250 in median household income.

The percentage of people in the region who lived in poverty in 2019 was 13.5%. Poverty in the region is concentrated in cities, with the most impoverished localities being the City of Emporia with 27.0% of the total population living in poverty, the City of Petersburg (24.1%), the City of Hopewell (23.6%), and the City of Richmond (23.2%). In rural areas, Greensville County (21.5%), and Sussex County (18.9%) had the highest levels of poverty. In the Commonwealth, 9.2% of the population lived in poverty, compared to 11.4% in the nation. The area's relatively high levels of poverty indicate that the Richmond-Crater region has some significant hurdles to overcome in terms of households being able to afford hazard mitigation projects reliant on self-funding.

Income levels between the jurisdictions included in the Richmond-Crater region vary greatly. Table 4.2 shows the breakdown by jurisdiction.

Table 4.2: Income Characteristics by Jurisdiction

Jurisdiction	Median Household Income, 2015-2019	Persons Living in Poverty (percent),
Charles City County	$57,198	9.9%
Chesterfield County	$82,599	6.6%
City of Colonial Heights	$54,550	12.1%
Dinwiddie County (inc. Town of McKenney)	$60,346	11.1%
City of Emporia	$27,063	27.0%
Goochland County	$93,994	5.8%
Greensville County (inc. Town of Jarratt)	$50,300	21.5%
Hanover County (inc. Town of Ashland)	$89,390	5.0%
Henrico County	$70,307	8.3%
City of Hopewell	$39,030	23.6%
New Kent County	$87,904	4.6%

Table 4.2: Income Characteristics by Jurisdiction		
Jurisdiction	**Median Household Income, 2015-2019**	**Persons Living in Poverty (percent),**
City of Petersburg	$38,679	24.1%
Powhatan County	$89,090	5.3%
Prince George County	$71,912	8.2%
City of Richmond	$47,250	23.2%
Surry County (inc. Town of Surry)	$57,.962	11.6%
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	$49,487	18.9%

Source: U.S. Census Bureau, American Community Survey 2015-2019

4.6.6 Broadband Access

In recent years, access to broadband internet service has become vital to the population's ability to receive information and services. The percentage of people in the Richmond-Crater region who have access to broadband reflects both income and availability. While broadband is widely available in heavily-populated areas, it is less widely available in rural ones and is also relatively more expensive. Regardless, broadband access is quickly becoming as vital a utility as electricity or phone service, as witnessed beginning in 2020 during the COVID-19 pandemic, when so many people had to work and attend school from home for long periods.

Table 4.3 shows the percentage of households with a broadband internet subscription between 2015 and 2019 in each locality. An average of 76.7% of residents in the region had access, trailing the Virginia average of 83.9% and the nationwide average of 82.7%.

Table 4.3: Broadband Availability	
Locality	**Households With Broadband Internet Access**
Charles City County	61.5%
Chesterfield County	90.1%
City of Colonial Heights	78.1%
Dinwiddie County	74.5%
City of Emporia	65.2%
Goochland County	83.2%
Greensville County	63.2%
Hanover County	86.0%
Henrico County	86.2%
City of Hopewell	75.7%

Table 4.3: Broadband Availability	
Locality	**Households With Broadband Internet Access**
New Kent County	79.1%
City of Petersburg	69.0%
Powhatan County	89.5%
Prince George County	83.3%
City of Richmond	75.4%
Surry County	64.8%
Sussex County	66.4%

Source: U.S. Census Bureau, American Community Survey, 2015-2019

4.7 Housing

As of 2019, there were 373,595 housing units in the study area according to the U.S. Census. The highest number of housing units were located in Henrico and Chesterfield Counties. About 67.8% of residents in the study area own their own homes, a drop from 70.1% in 2015. However, the district's percentage is higher than the national average of 64.0% or the state average of 66.3%. The average, however, is skewed by the significantly lower rate of homeownership in the cities of Emporia, Hopewell, Petersburg and Richmond. **Table 4.4** illustrates the housing characteristics of each jurisdiction in the Richmond-Crater region. When considering mitigation options, special attention should be given to the difference in capabilities between owners and renters.

Table 4.4: Housing Characteristics by Jurisdiction				
Jurisdiction	**Housing Units 2019**	**Owner-Occupied Housing Units 2015-2019**	**Median Value of Owner-Occupied Housing Units 2015-2019**	**Median Gross Rent 2015-2019**
Charles City County	3,391	83.9%	$167,900	$813
Chesterfield County	134,267	75.8%	$241,200	$1,251
City of Colonial Heights	N/A	62.9%	$171,700	$1,038
Dinwiddie County (inc. Town of McKenney)	11,856	77.2%	$168,300	$1,005
City of Emporia	N/A	40.1%	$116,800	$694
Goochland County	9,613	84.9%	$375,200	$1,208
Greensville County (inc. Town of Jarratt)	4,205	73.3%	$117.700	$854
Hanover County (inc. Town of Ashland)	42,264	82.5%	$282,900	$1,159
Henrico County	139,274	62.7%	$242,600	$$1,170
City of Hopewell	N/A	46.7%	$122,900	$886
New Kent County	8,956	86.5%	$281,100	$1,010
City of Petersburg	N/A	38.8%	$108,100	$947
Powhatan County	11,274	90.1%	$279,200	$980
Prince George County	12,605	67.6%	$213,300	$1338
City of Richmond	N/A	42.6%	$230,500	$1,025
Surry County (inc. Town of Surry)	3,611	74.3%	$197,800	$903
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	4,837	69.2%	$125,800	$807

Source U.S. Census Bureau, ACS 2015 – 2019

4.8 Business and Labor

The diversity of the region is strongly reflected within the business sector. While the Richmond-Crater region is home to seven Fortune 500 companies in 2020, the outlying area is primarily rural with limited commercial development. The Fortune 500 companies located in the region are shown in **Table 4.5.**

Table 4.5: Richmond-Crater Region Fortune 500 Companies		
Fortune 500 Company	**2020 Rank**	**Locality**
Altria Group	167	Henrico County
Performance Food Group	168	Henrico County
CarMax	173	Goochland County
Dominion Energy	197	Richmond
Owens & Minor	332	Hanover County
Markel	335	Henrico County
Genworth Financial	360	Richmond

Source: Fortune Magazine, accessed online March 2021

The sectors with the most employees in the Richmond-Crater region are:

- Health care and social assistance
- Retail trade
- Finance and insurance
- Accommodation and food services
- Manufacturing
- Construction
- Professional, scientific, and technical services
- Other services (except public administration)
- Administrative and Support and Waste Management
- Remediation Services
- Wholesale trade

Sectors with the largest annual payrolls are:

- Finance and insurance
- Health care and social assistance
- Professional, scientific, and technical services Manufacturing
- Retail trade
- Wholesale trade
- Construction
- Administrative and Support and Waste Management and Remediation Services
- Other services (except public administration)
- Accommodation and food services

Listed below are the largest 15 employers of the Richmond and Crater regions. Following is a list of the top 5 employers in each locality. Unless otherwise identified, all data comes from the Virginia Labor Market Information of the Virginia Department of Education posted in February, 2014, or the Virginia Economic Development Partnership, the most recent data available during the planning process.

Top Employers in the Richmond Region	**Top Employers in the Crater Region**
Capital One Bank	U. S. Department of Defense
Virginia Commonwealth University	Walmart
Henrico County School Board	Southside Regional Medical Center
Chesterfield County School Board	County of Prince George
MCV Hospital	Dominion Energy
Bon Secours Richmond Health System	Food Lion
HCA Virginia Health System	Greensville Correctional Center
Richmond City Public Schools	Central State Hospital
County of Henrico	City of Petersburg School Board
City of Richmond	Boars Head Provisions Company
Walmart	Honeywell International, Inc.
County of Chesterfield	Hopewell City School Board
Kroger	City of Petersburg
Hanover County School Board	Amazon
U.S. Department of Defense	Dinwiddie County School Board

Charles City County:

Charles City County School Board

U.S. Remodelers Inc.

County of Charles City

Atlantic Bulk Carrier Corporation

Charles City Timber & Mat

Chesterfield County:

Chesterfield County School Board

County of Chesterfield

U.S. Department of Defense

Amazon Fulfillment Services

HCA Virginia Health System

Dinwiddie County:

Walmart Distribution Center

Central State Hospital

Amazon Fulfillment Center

Dinwiddie County School Board

Southside Virginia Training Center

Goochland County:

Capital One Bank

CarMax Auto Superstores

Goochland County School Board

Luck Stone Corporation

Performance Food Group, Inc.

Greensville County and City of Emporia:

Greensville Correctional Center

Boars Head Provisions Company

Greensville County Schools

Western Express, Inc.

Beach Mold & Tool, Inc.

Hanover County:

Hanover County School Board

Bon Secours Health Systems Inc.

Kings Dominion

County of Hanover

Tyson Farms

Henrico County:

Henrico County School Board

County of Henrico

Bon Secours Richmond Health System

Capital One Bank

HCA Virginia Health System

City of Hopewell:

Honeywell International

Hopewell City School Board

HCA Virginia Health System

City of Hopewell

E.I. DuPont De Nemours & Co.

New Kent County:

New Kent County School Board

County of New Kent

AHS Cumberland Hospital

Curtis Contracting Company

Food Lion

City of Petersburg:

Southside Regional Medical Center

City of Petersburg School Board

City of Petersburg

Amsted Rail Company, Inc.

Powhatan County:

Anthem

Powhatan County School Board

Virginia Department of Juvenile Justice

Powhatan Correctional Center

Deep Meadow Correctional Center

Prince George County:

U.S. Department of Defense

County of Prince George

Food Lion

U.S. Department of Justice

U.S. Army Non-Appropriated Funds Division

City of Richmond:

Virginia Commonwealth University

MCV Hospital

Richmond City Public Schools

City of Richmond

U.S. Department of Veterans Affairs

Surry County:

Dominion Energy (Surry)

S. Wallace Edwards and Sons (Surry)

Seward Lumber Company (Claremont)

Windsor Mill Company (Dendron)

(Source: www.surrycountyva.gov)

Sussex County:

Sussex I Correctional Center

Sussex II Correctional Center

Sussex County School Board

Personal Touch Home Care

County of Sussex

4.9 Transportation

The Richmond-Crater region is located at a crossroads of transportation within the Commonwealth of Virginia. Rail lines radiate outward from Richmond in all directions, with both passenger (Amtrak) and freight (CSX, Norfolk Southern) services available. It should be noted that due to the Transforming Rail in Virginia program, rail service – both passenger and freight – will be expanding in the Commonwealth. The $3.7 billion program was established to build a 21st-century rail network across Virginia. As part of the program, former Governor Northam finalized an agreement with Norfolk Southern to expand passenger service to the New River Valley, for example.

In addition to rail, the region is served by the Richmond International Airport and numerous general aviation facilities, including the Emporia/Greensville Regional Airport, Chesterfield County Airport, Dinwiddie County Airport, Hanover County Municipal Airport, New Kent Airport, Petersburg Municipal Airport, and the Wakefield Municipal Airport. The Richmond International Airport normally attracts over 3 million travelers each year, although volume has been substantially reduced since spring 2020 as a result of COVID 19. The airport has 3 asphalt-grooved runways and handles about 150,000 operations annually (landings/takeoffs), including both passenger and freight operations. As of March 2021, the airport had 7 airlines operating passenger service, including: United, American Airlines, Delta, JetBlue Airways, Southwest Airlines, Spirit, and Allegiant.

The James River is navigable by large ships up to the eastern portion of the City of Richmond at the Fall Line. The region is served by the Richmond Marine Terminal, Central Virginia's domestic and international multi-modal freight and distribution hub. The port serves waterborne, rail and truck shippers throughout the mid-Atlantic states, and is owned by the City of Richmond and leased to the Virginia Port Authority. The port handles containers, temperature-controlled containers, breakbulk, bulk, and neo-bulk cargo. James River Barge Service, a thrice-weekly Container-on-Barge service from Hampton Roads to Richmond, provides a maritime alternative to I-95 by transporting goods on the James River via barges, removing container traffic off local roads and highways. Major export/import cargoes include chemicals, pharmaceuticals, forest products, paper, machinery, consumer goods, frozen seafood, produce, campers, steel, steel products, stone, tobacco leaf, aluminum, project cargo, vehicles, boats, wire coils, wire rods, pipe, and aplite. The port is the westernmost commercial maritime port on the North Atlantic coast.

Several interstates intersect the Richmond-Crater region. Interstate 64 is an east-west route extending from Norfolk to Staunton, Virginia. Interstates 95 and 85 are north-south routes, with I-95 being the primary route along the East Coast, extending from Maine to Florida, and I-85 serving as the main route between Richmond and Atlanta, Georgia. In addition, Richmond is encircled by I-195, I-895 (a toll road), and I-295 which begins north of Richmond in Henrico County, passing through Charles City County, extending through the

City of Hopewell to the City of Petersburg, providing an alternative to I-95 through the heart of Richmond. Interstate I-95 continues to be upgraded, including bridge improvements and other minor paving and shoulder improvements/repairs. A number of large U.S. highways also service the region, including: U.S.460, U.S.58, U.S.250, U.S. 522, U.S. 33, U.S. 1, U.S. 301/SR 2, U.S. 360, and U.S. 60. The state road network is extensive throughout the region. Some of the major routes include SR-6, SR-10, SR-54, SR-156, SR-288, SR-249, SR-155, and SR-5. U.S. 460 connects the City of Petersburg area with Norfolk and the ports of Hampton Roads, and U.S. 58 passes through the City of Emporia along Virginia's southern border. Henrico County is the only county in the region that maintains its own roads. The City of Richmond maintains its own road network.

4.10 Infrastructure

4.10.1 Electric

The Richmond-Crater region has five electricity suppliers: investor-owned Dominion Energy and three electric cooperatives – Prince George, Southside, and Mecklenburg

The western portions of New Kent County are on a "looped" scheme for electricity. If one portion of this area were to lose power, it could regain power rather easily because it is tied into the system. Dominion Energy has not found it to be cost-effective to institute a similar system in the eastern portion of the county and therefore this area is prone to electrical outages.

Two power substations provide electricity to Charles City County. Efforts are underway to ensure that the courthouse and municipal complex are on both grids. In addition, Ingenco, located at the landfill, provides electricity to the power grid.

Powhatan County is served by Dominion Energy (61% of the county) and Southside Electric Cooperative (39% of the county). Power outages primarily occur here because of ice or wind storms. Most of the Southside Electric grid is powered by one substation in the county, and the majority of the Dominion Energy feeds that serve the county enter on two distribution lines from substation(s) in Chesterfield.

4.10.2 Natural Gas

Natural gas is provided to the region by: the City of Richmond (City of Richmond and Henrico County); Virginia Natural Gas (Hanover, New Kent, and Charles City Counties); and Columbia Gas of Virginia (all remaining localities).

4.10.3 Telephone

Local telephone service is provided throughout Greater Richmond by Verizon Communications Inc. AT&T and Cavalier Telephone are the largest competitive providers. An extensive fiber optic network with digital switching capability and Synchronous Optical Network self-healing fiber optic rings insures uninterrupted service. Special Access

Services (DS1, DS3, OC-12 and OC-48) are available throughout the area. Verizon can provide dual capacity. Major long-distance carriers include AT&T, Verizon, and Sprint.

Telephone service providers are declining in importance as the percentage of homes in Virginia with land line service is now below 40% and dropping. Cell service providers are numerous and varied, but the providers with the most pervasive coverage in Virginia are the four major cell phone networks: AT&T, Verizon, Sprint, and T-Mobile. Verizon's 3G and 4G LTE cover the greatest percentage of the state at 93%, but AT&T is close behind at 90%. T-Mobile and Sprint also provide service coverage.

4.10.4 Public Water and Wastewater

In the region, public water and wastewater treatment is available in the City of Richmond and Hanover (including the Town of Ashland), Henrico, New Kent, and Powhatan Counties. Public water is also provided by the Appomattox River Water Authority, Chesterfield County, Dinwiddie County Water Authority, City of Emporia, Greensville County Water and Sewer Authority, Town of Jarratt, Town of McKenney, Petersburg and Dinwiddie Water Authority, City of Petersburg, Prince George County, City of Richmond, Town of Stony Creek, Surry County, Sussex Service Authority, and Virginia American Water Company. Private well and septic systems serve Charles City and Goochland Counties. Portions of Hanover, Henrico, and New Kent Counties are also served by private systems.

In Powhatan County, a public waterline runs from the Chesterfield County line to the eastern end of Route 60. Other providers are Aqua-Virginia, which serves the Courthouse area and portions of the Route 60 corridor, and Founder's Bridge Utility Company, which provides water to a few specific areas.

4.10.5 Cable Television, Broadband and Internet Providers

Cable television and internet service are almost always provided by the same companies. In the Richmond-Crater region, the primary providers are: Xfinity, Verizon FIOS, Verizon, Viasat, HughesNet, Comcast, and Cox Communication. Other providers are DISH, DIRECTV, Frontier FiberOptic, Spectrum, and Sparklight (CableONE).

The most common wired broadband internet connections in the greater Richmond area are provided via cable (97.38% coverage) and fiber (81.71% coverage), according to BroadbandNOW. Regular cable TV providers (using pre-existing TV wires) are the primary source for cable-based home internet service. Fiber technology, which uses fiber-optic lines, can be faster but because not all fiber connections can reach all subscriber addresses, some switch to copper cables nearby and thus do not necessarily offer true gigabit speeds.

The most commonly available internet option for Richmond-area residents is Viasat Internet. HughesNet is close behind, offering mostly satellite-based service. There are 18 internet service providers in Richmond, 8 of which offer residential service.

Outside of the Richmond area, there are usually 2 to 3 providers of internet service in any given area, but the more rural the area, the less likely it is to have access to broadband service. The Virginia Telecommunications Initiative, a $29.6 million initiative to extend broadband to lesser-served communities in Virginia, will begin accepting applications in June 2022, with announcement of the awards in December 2022. Counties in the Richmond-Crater region that are currently listed as applying for assistance are: Charles City County, Chesterfield County, Dinwiddie County, Greensville County, Hanover County, Henrico County, New Kent County, Sussex County, Goochland County, and Powhatan County,

5.0 Hazard Identification, Risk Assessment (HIRA) and Vulnerability Analysis

5.1 Updates for 2022

The 2022 update to the HIRA includes information on the most recent hazard occurrences, and updates regarding the frequency analysis and annualized damages to reflect recent history. Exposure data from Hazus and updated vulnerability data for flood, earthquake and wind from Hazus were included.

Each hazard was assessed for three new components of risk: 1) social vulnerability; 2) impacts of climate change; and 3) mass evacuation impacts. Following committee discussion, “Thunderstorms and Lightning” were removed from the plan due to the low risk and vulnerability associated with that hazard. The PDCs and Committee considered Radon Exposure and Infectious Diseases worthy of inclusion in the updated plan. A revised system of ranking the hazards was added as well. The tables at the end of the section regarding Conclusions on Hazard Risk were all updated. All figures were updated to reflect current conditions.

5.2 Introduction

The purpose of the HIRA is to identify the hazards that could affect the planning regions. The hazards are individually profiled to describe historical hazard events and determine what areas and community assets are the most vulnerable to damage from these hazards. The vulnerability analysis includes estimated losses for each hazard and a summary prioritization of hazards in terms of potential risks to the community.

The hazards discussed in this section are as follows:

Flooding

Flooding due to Impoundment Failure

Severe Wind Events

Tornadoes

Wildfires

Severe Winter Weather

Thunderstorms (including Hail & Lightning)

Droughts and Extreme Heat

Earthquakes

Landslides

Shoreline Erosion

Sinkholes

Radon Exposure

Infectious Diseases

5.2.1 Methodologies Used

Data from the National Centers for Environmental Information (NCEI) Storm Events Database were used to inform the weather-related hazard identification. The NCEI receives storm data from the National Weather Service (NWS), which in turn receives it from a variety of sources, which include but are not limited to: county, state, and federal emergency management officials, local law enforcement officials, Skywarn spotters, NWS damage surveys, newspaper clipping services, the insurance industry, and the general public. Information on hazard events not recorded in this database is provided in narrative format for each hazard subsection to supplement the NCEI data and to provide a more accurate depiction of historical hazard events in the region.

Two distinct risk assessment methodologies were used in the formation of the vulnerability assessment. The first consists of a quantitative analysis that relies upon best available data and technology, while the second approach consists of a somewhat qualitative analysis that relies on the local knowledge and rational decision making skills of local officials. Upon completion, the methods are combined to create a "hybrid" approach for assessing hazard vulnerability for the region that allows for some degree of quality control and assurance. The methodologies are briefly described and introduced here and are further illustrated throughout this section.

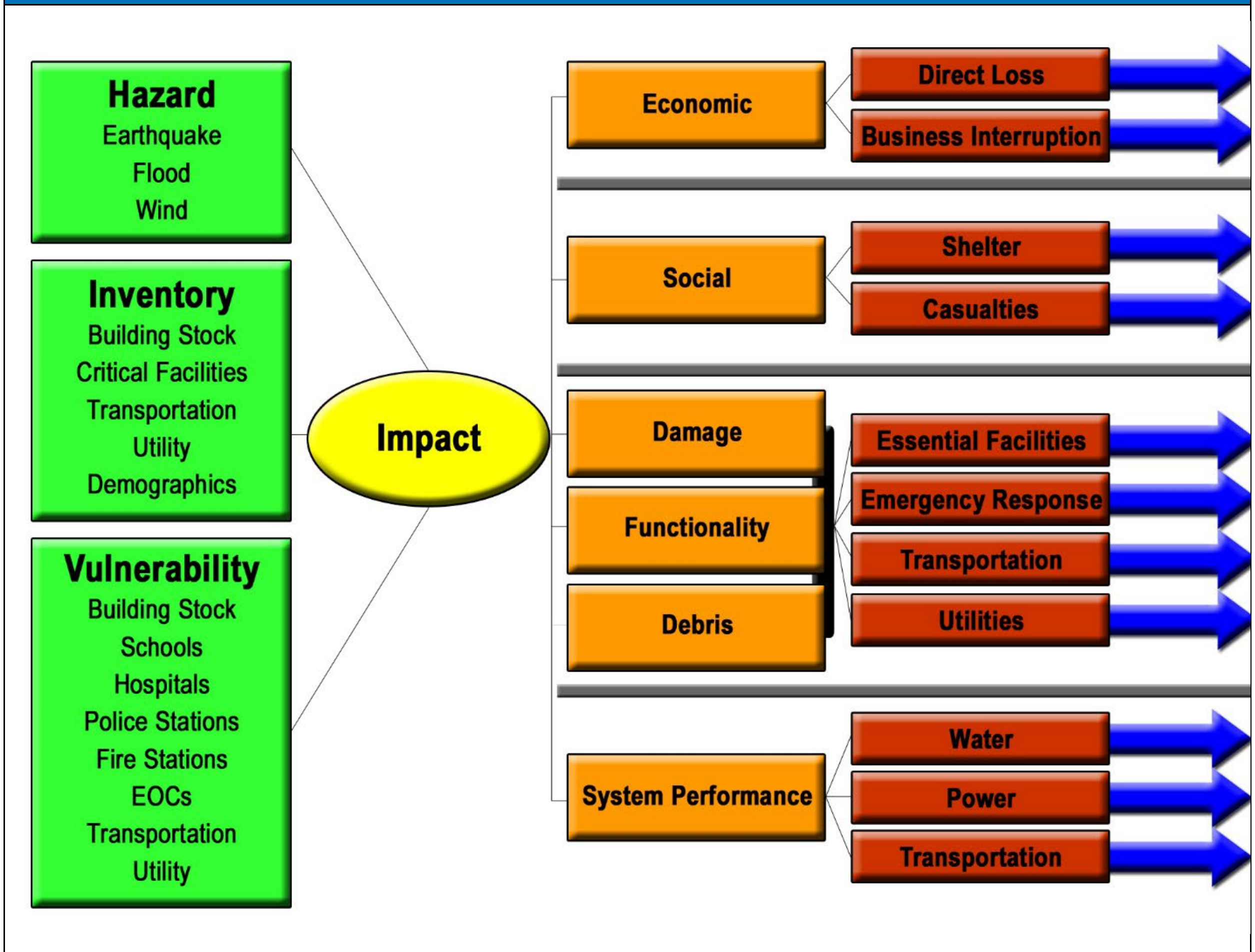
The quantitative assessment involved the use of the most recent version of Hazards U.S. Multi-Hazard software (Hazus), a geographic information system (GIS)-based loss estimation tool available from FEMA, along with a statistical risk assessment methodology for hazards outside the scope of Hazus. For the flood hazard, the quantitative assessment incorporates a detailed GIS-based approach. When combined, the results of these vulnerability studies are used to form an assessment of potential hazard losses (in dollars) along with the identification of specific community assets that are deemed at-risk.

Hazus is FEMA's standardized loss estimation software package, built on an integrated GIS platform using a national inventory of baseline geographic data (including information on the region's general building stock and dollar exposure). Originally designed for the analysis of earthquake risks, FEMA expanded the program in 2003 to allow for the analysis of multiple hazards: namely the flood and wind (hurricane wind) hazards. By providing estimates on potential losses, Hazus facilitates quantitative comparisons between hazards and assists in the prioritization of hazard mitigation activities.

Hazus uses a statistical approach and mathematical modeling of risk to predict a hazard's frequency of occurrence and estimated impacts based on recorded or historic damage information (see **Figure 5.1**). The Hazus risk assessment methodology is parametric, in that distinct hazard and inventory parameters—such as wind speed and building type—were modeled using the Hazus software to determine the impact on the built environment.

Figure 5.1 shows a conceptual model of Hazus methodology. More information on Hazus loss estimation methodology is available through FEMA at www.fema.gov/hazus.

Figure 5.1: Conceptual Model of Hazus Methodology



Source: FEMA

This risk assessment used Hazus to produce regional profiles and estimated losses for three of the hazards addressed in this section: flooding, tropical storm winds, and earthquake. For each of these hazards, Hazus was used to generate probabilistic "worst case scenario" events to show the extent of potential damages. Both earthquake and wind were modeled using Hazus Level 1 and flood was modeled using Hazus Level 2.

For hazards outside the scope of Hazus, a statistical risk assessment methodology was designed and in previous plans, this method was applied to generate potential loss estimates. The approach was based on the same principles as Hazus, but did not rely on readily available automated software. In recent years, the historical data from which hazard assessment conclusions were made have become less reliable. For example, damages for wildfire were not reported for the two most recent reporting periods, and the communities reviewing the historical damage data from the NCEI expressed concern that the damages were severely underestimated. Until more reliable historical damage data can be provided, planners determined that a qualitative methodology for examining historical losses and making conclusions about future risk was needed as shown below to supplement the quantitative analysis.

Despite the shortcomings of certain historical data, this analysis included collection of and updates to relevant GIS data from local, state and national sources. These sources include each community's GIS department, FEMA, VDOF, and NOAA. Once all data were acquired, GIS was used to demonstrate and spatially analyze risks to people, public buildings and infrastructure. Primary data layers included geo-referenced point locations for public buildings, critical facilities, and infrastructure elements. Using these data layers, risk was assessed and described by determining the parcels and/or point locations that intersected with the delineated hazard areas.

The qualitative assessment relies less on technology and more on historical and anecdotal data, community input, and professional judgment regarding expected hazard impacts. The qualitative assessment completed for the Richmond-Crater region is based on committee member dot voting to indicate their priorities for mitigation spending. The members present at the first planning workshop on June 21, 2021, were awarded hypothetical "mitigation grants" in the following amounts: 1 - $1,000,000 grant; 2 - $250,000 grants; and 4 - $25,000 grants.

Each participant was then tasked with determining how they would spend their mitigation dollars. The groups were reminded that projects must be cost-beneficial and that FEMA urges communities to "prioritize mitigation actions based on level of risk a hazard poses to lives and property." Each participant voted in the online forum for the hazards they considered a priority for spending. Results are shown in a series of tables at the end of this section. Communities were reminded of a full range of hazards, including the hazards in the previous hazard mitigation plan as well as Infectious Disease and Radon Exposure. Although the list was not a comprehensive list of all hazards that may ever impact the region, the resultant hazards summarized in this section were determined by committee members to be the necessary hazards for the purposes of determining mitigation actions.

While the quantitative assessment focuses on using best available data, computer models and GIS technology, this qualitative ranking system relies more on historical data, local knowledge, and the general consensus of the planning committee. The results allow identified hazards to be ranked against one another.

Using both the qualitative and quantitative analyses to evaluate the hazards that impact the region provided planning committee members with a dual-faceted review of the hazards. This allowed officials to recognize those hazards that may potentially be costly, but also to plan and prepare for hazards that may not cause much monetary damage but could put a strain on the local resources needed to recover.

All conclusions of the vulnerability assessment completed for the region are presented in "Conclusions on Hazard Risk" at the end of this section. Qualitative findings for each hazard are detailed in the hazard-by-hazard vulnerability assessment that follows, beginning with an overview of general asset inventory and exposure data for each jurisdiction.

5.2.2 National Risk Index

The National Risk Index (NRI) is a relatively new dataset and online application from FEMA that identifies communities most at risk to various natural hazards. For each of the 18 natural hazards explored, risk is calculated by multiplying each hazard's expected annual losses by social vulnerability (a consequence enhancing component of risk that measures the susceptibility of social groups to the adverse impacts of natural hazards) and dividing by community resilience (a consequence reduction component of risk that measures the ability of a community to plan for, absorb, recover from and adapt to the impacts of hazards). In other words:

Risk = *Expected Annual Loss* x *Social Vulnerability* x (1/*Community Resilience*)

In the risk equation, each component is represented by a unitless index score that depicts a community's score relative to all other communities at the same level. The Risk Index score is a unitless index and represents a community's relative risk in comparison to all other communities at the same level. All calculations are performed separately at two levels—County and Census tract—so scores are relative only within their level. It must be stressed that scores are relative, representing a community's relative position among all other communities for a given component and level. Scores are not absolute measurements and should be expected to change over time either by their own changing measurements or changes in other communities.

For every score, there is also a qualitative rating that describes the nature of a community's score in comparison to all other communities at the same level, ranging from "Very Low" to "Very High." Because all ratings are relative, there are no specific numeric values that determine the rating. For example, a community's Risk Index score for a single hazard could be 8.9 with a rating of "Relatively Low," but its Social Vulnerability score may be 11.3 with a rating of "Very Low." The rating is intended to classify a community for a specific component in relation to all other communities at the same level.

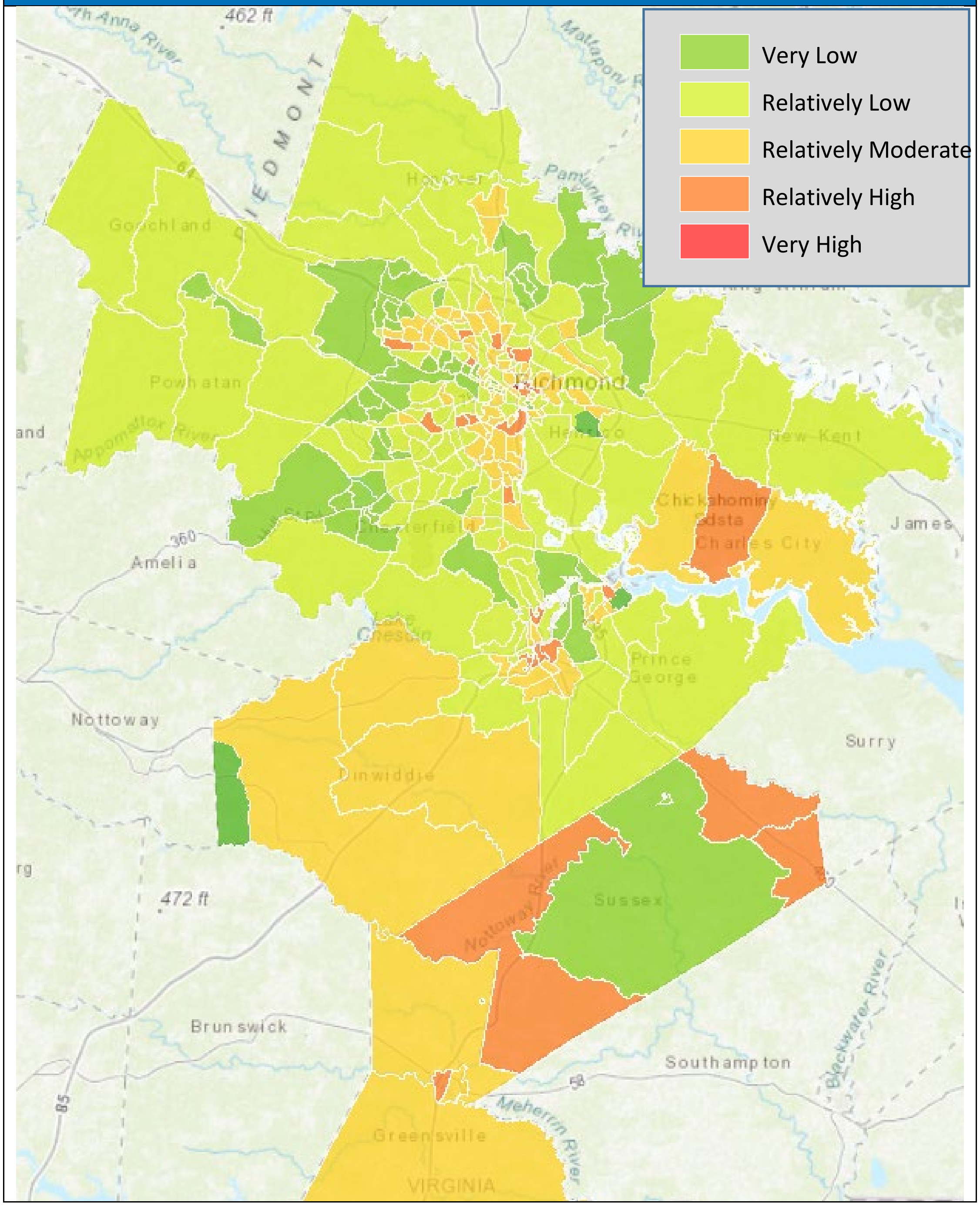
Source data for the social vulnerability component is derived from University of South Carolina's Hazards and Vulnerability Research Institute (HVRI) Social Vulnerability Index (SoVI). SoVI is a location-specific assessment of social vulnerability that utilizes 29 socioeconomic variables that contribute to a community's reduced ability to prepare for, respond to, and recover from hazards:

Median gross rent for renter-occupied housing units
Median age
Median dollar value of owner-occupied housing units
Per capita income
Average number of people per household
% population under 5 years or age 65 and over
% civilian labor force unemployed
% population over 25 with <12 years of education
% children living in married couple families
% female
% female participation in the labor force
% households receiving Social Security benefits

% unoccupied housing units
% families with female-headed households with no spouse present
% population speaking English as second language (with limited English proficiency)
% Asian population
% African American (Black) population
% Hispanic population
% population living in mobile homes
% Native American population
% housing units with no car available
% population living in nursing facilities
% persons living in poverty
% renter-occupied housing units
% families earning more than $200,000 income per year
% employment in service occupations
% employment in extractive industries (e.g., farming)
% population without health insurance (County SoVI only)
Community hospitals per capita (County SoVI only)

Figure 5.2 shows the foundational social vulnerability for the study area using the factors above, without analysis of resilience or loss data for a particular hazard. This map is used to interpret social vulnerability for hazards not specifically addressed in the NRI such as sinkholes. The map data are also used to rate mitigation actions for those hazards. This plan uses the full NRI dataset to produce maps of relative social vulnerability to several of the prominent natural hazards, including: flooding, severe wind events, and tornadoes.

Figure 5.2: NRI Social Vulnerability of the Study Area



Source: National Risk Index for Natural Hazards, FEMA 2021

Note: The Town of Surry is mapped in the *2022 Hampton Roads Hazard Mitigation Plan Update*; social vulnerability rating for the town is relatively moderate north of Route 10, and relatively low south of Route 10.

5.2.3 General Asset Inventory

The total dollar exposure of buildings within the study area is estimated to be $166 billion. This figure is based on the total number of buildings located throughout the region based on the Hazus default inventory (**Table 5.1**). The data provide an estimate of the aggregated replacement value for the region's assets and indicate that at least 61-percent of the structures are of wood construction.

Table 5.1: Exposure of the Built Environment

Community	Building Inventory by Type of Construction			
	Wood	Manufactured Homes	Masonry, Concrete, Steel	Total
Goochland County	$2,351,402,000	$26,620,000	$1,194,603,000	$3,572,625,000
Hanover County, inc. Ashland	$10,323,535,000	$41,239,000	$6,111,963,000	$16,476,737,000
Henrico County	$27,935,064,000	$24,559,000	$17,284,140,000	$45,243,763,000
New Kent County	$1,828,641,000	$23,172,000	$831,277,000	$2,683,090,000
Powhatan County	$2,518,231,000	$23,597,000	$1,200,380,000	$3,742,208,000
Richmond	$15,310,205,000	$38,719,000	$13,797,923,000	$29,146,847,000
Charles City	$523,409,000	$27,482,000	$271,230,000	$822,121,000
Chesterfield County	$29,732,123,000	$126,389,000	$15,045,912,000	$44,904,424,000
Colonial Heights	$1,484,948,000	$510,000	$1,079,487,000	$2,564,945,000
Dinwiddie County	$1,832,966,000	$89,731,000	$974,490,000	$2,897,187,000
Emporia	$356,446,000	$5,176,000	$389,636,000	$751,258,000
Greensville County, inc. Jarratt	$491,746,000	$51,033,000	$366,232,000	$909,011,000
Hopewell	$1,532,553,000	$6,872,000	$1,016,928,000	$2,556,353,000
Petersburg	$2,242,405,000	$21,342,000	$2,209,937,000	$4,473,684,000
Prince George County	$2,359,394,000	$53,205,000	$1,283,049,000	$3,695,648,000
Surry County	$509,304,000	$26,917,000	$259,858,000	$796,079,000
Sussex County, inc. Stony Creek, Wakefield, Waverly	$541,312,000	$58,292,000	$423,059,000	$1,022,663,000
Totals	**$101,873,684,000**	**$644,855,000**	**$63,740,104,000**	**$166,258,643,000**

Source: Hazus

5.3.3 Essential Facilities

There is no universally accepted definition of what constitutes essential or critical facilities and infrastructure, nor is one associated with FEMA and DMA 2000 planning requirements. However, for purposes of this Plan, essential facilities and infrastructure are identified as "*those facilities or systems whose incapacity or destruction would present an immediate threat to life, public health, and safety or have a debilitating effect on the economic security of the region.*" This typically includes facilities and systems based on their high relative importance for the delivery of vital services, the protection of special populations, and other important functions in the region; however, for this risk analysis, the default Hazus list of essential facilities was used and includes: Emergency Operations Centers (EOC); hospitals; police stations; fire stations; schools; hazardous materials facilities; water and wastewater facilities; energy facilities (electric, oil and natural gas); and communication facilities.

Table 5.2 shows the results of a simple overlay analysis of the number of essential facilities that are located in the 100-year floodplain, 500-year floodplain, and a Storm Surge Zone for a Category 1,2,3 or 4 hurricane.

Table 5.2: Critical Facility Vulnerability Analysis

Community	100-Year Floodplain	500-Year Floodplain	Storm Surge Zone
Goochland Co	1	0	0
Hanover Co	2	1	0
Henrico Co	32 in FEMA SFHA; 8 in County floodplain*	0	0
New Kent Co	0	0	1
Powhatan Co	1	0	0
Richmond	8, inc. 2 in floodway	4	4
Charles City	0	0	3
Chesterfield Co	2, inc. 1 in floodway	1	9
Colonial Heights	2	0	1
Dinwiddie Co	2	0	0
Emporia	1, inc. 1 in floodway	2	0
Greensville Co	1	0	0
Hopewell	0	0	2
Petersburg	3	1	2
Prince George Co	0	0	0
Sussex Co	2, inc. 1 in floodway	0	0
Totals	26, inc. 5 in floodway	9	22

** Henrico County used an internally-produced list of facilities for this analysis.*

5.3 Major Disasters

Twenty-two major disasters have been declared which included at least one county or city within the planning region since 1965. Numerous “emergency declarations have also been declared supporting federal reimbursement for emergency categories of the Public Assistance Program. One third of the events were hurricane disasters, one quarter were associated with severe storms, one fifth were snow and ice related, a few drought and flood disasters, and several unique events were included like a West Nile Virus disaster declared on May 30, 2000, support for Hurricane Katrina evacuees and the Louisa Earthquake which impacted Goochland County. Flooding is often included in severe storm, hurricane, and coastal storm disasters.

A summary of the total events declared is shown in Appendix F – HIRA. Appendix F-1 lists the presidentially declared disasters that have occurred in the Richmond-Crater region planning districts since disaster and emergency records supplemented with federal disaster declarations up to and including 2020.

5.4 Flooding

Hazard Profile

A flood occurs when an area that is normally dry becomes inundated with water. Floods may result from the overflow of surface waters, overflow of inland and tidal waters, or mudflows. Flooding can occur at any time of the year, with peak hazards in the late winter and early spring. Snowmelt and ice jam breakaway contribute to winter flooding, and seasonal rain patterns contribute to spring flooding. Torrential rains from hurricanes and tropical systems are more likely to occur in late summer. Development of flood-prone areas tends to increase the frequency and degree of flooding. The duration of flood events vary depending on the specific characteristics of the rain event. Floodwaters generally recede rapidly after the rain event has ended, but can last from a few hours to a few days.

Flooding can occur along all waterways in the region. Localized riverine flooding can occur in areas not adjacent to a major body of water. Some areas of the region are subject to tidal flooding during tropical storms and nor'easters. Flood duration is typically shorter for hurricanes and tropical storms than for riverine floods or nor'easters because the storms tend to move faster and affect only 1 to 2 tidal cycles. The main impacts from flooding include:

- Inundation of low-lying residential neighborhoods and subsequent damage to structures, contents, garages, and landscaping;
- Impassable road crossings and consequential risk for people and cars attempting to traverse flooded crossings;
- Damage to public and private infrastructure, possibly including but not limited to water and sewer lines, bridge embankments, and both small and large drainageways;
- Damage to hazardous materials facilities in the floodplain, resulting in leaching or spilling of toxic chemicals into the flooded waterways of the region;
- In coastal areas, wave action responsible for shoreline damage, and damage to boats and facilities;
- Inundation of critical facilities, possibly including some fire stations, police facilities, public shelters, EOCs, and several publicly-owned buildings. Public shelter

availability is limited by the expected severity of flooding. (See Table 5.2 for number of critical facilities in flood hazard areas.)

- Recovery time needed to bring critical infrastructure, schools and employers back online. Of particular concern in the region are transportation routes, including school bus routes, housing for displaced residents and debris management.

Communities in the study area have outlined specific plans for activating their EOC, protecting critical facilities and taking specific drainage system actions when faced with an impending flood. Since power outages and threats to the water supply can result from both the wind and flood hazard (which may occur simultaneously in the region), residents are advised of appropriate precautions and specific low-lying areas are evacuated to protect the safety of residents and responders, and to minimize loss of life.

When severe floods occur, the regional economy is severely impacted by the inability of flooded homeowners to get back to work quickly, the slow rebound of closed or debris-strewn transportation routes, the closing of schools and businesses, and the general state of emergency. Power outages and boil-water advisories are common and can affect many thousands of residents and businesses in the region for several days or even weeks if the damage is severe. Severely-flooded homes and neighborhoods result in displaced residents, including schoolchildren. Loss of life due to people traversing flooded roads, remaining in or becoming trapped in flooded structures, and curiosity-seekers watching the flooding is possible. Flooded businesses that decide to close, move or cease operations in the region have an impact on land values and the labor force, as does flood damage to the facilities of large employers in the region. Time spent repairing flood damage versus productive value-added labor is costly to employers.

Many roadways in the region are particularly vulnerable to inundation and damage from floodwaters. As a result, flooding can limit access to certain vulnerable areas, cutting off some residents from emergency services, schools and other economic foundations.

Flood damage to property and populations can be devastating, both emotionally and financially. Flood damage to businesses may result in loss of income, wages, and tax revenues. Buildings, including homes and critical facilities, are susceptible to damage and severe foundation damage or collapse as a result of a severe flood. Debris from vegetation and man-made structures is hazardous to drivers and pedestrians. In addition, floods may threaten water supplies and water quality, initiate power outages and create mold in flooded buildings. Left untreated, mold can cause respiratory illness and other maladies in a building's occupants. Other possible secondary effects of flooding include outbreaks of disease, widespread animal illnesses, disrupted utilities, water pollution especially from hazardous materials facilities in the flooded area, fires, washed out roads and culverts, and formation of sinkholes.

Location and Spatial Extent

Much of the land in the region's floodplains is designated for agricultural uses. Some localities, however, allow residential uses within agriculture areas. Agriculture is the dominant land use in Charles City, Dinwiddie, Goochland, Greensville, Hanover, New Kent, Powhatan Counties, Prince George, Surry and Sussex Counties. Henrico and Chesterfield Counties floodplain land use is primarily parks or buffered residential. Similarly, the floodplains in the Cities of Richmond and Petersburg are primarily industrial or park land.

Areas identified as vulnerable to flooding are depicted on FEMA's Flood Insurance Rate Maps (FIRMs). These maps were developed through the NFIP and show the existing potential flood hazard areas throughout the region based on the estimated 100-year floodplain (**Figure 5.3**). In addition to flood hazard areas identified on the FIRMs, Henrico County has also created Community-Identified flood hazard areas that represent the 100-year and 500-year floodplains in areas not captured by FEMA. The 100-year floodplain represents the areas susceptible to the 1% annual flood. The maps also show the 0.2% annual flood, or 500-year floodplain. The 100-year flood, or base flood, has at least a 26% chance of occurring over the life of a typical 30-year mortgage. FIRM data is available through several sources for more detailed viewing at the parcel level:

- Paper FIRMs are required to be available for viewing in each jurisdiction that participates in the NFIP;

- The Virginia Flood Risk Information System at https://consapps.dcr.virginia.gov/VFRIS/ allows online search and downloads of statewide flood hazard zone information and other pertinent water resources data;

- The FEMA Map Service Center at https://msc.fema.gov/portal/ is the official public source for digital flood hazard information produced in support of the NFIP (although the paper FIRMs mentioned above remain the legal tool for regulating floodplains); and,

- Several localities in the study area have property information viewer tools with a flood data layer, including the following:

  Chesterfield County - https://www.arcgis.com/apps/webappviewer/index.html?id=cd20724aa8c941a093b0df70f0c558ba

  Goochland County - https://gis.co.goochland.va.us/GoochlandPV/

  Greensville County and Emporia - https://www.webgis.net/va/greensville/

  Hanover County and Ashland - https://parcelmap.hanovercounty.gov/

  Henrico County - https://henrico.maps.arcgis.com/apps/webappviewer/index.html?id=e940e72a32244bf3ae9a8098766f2bdd

  City of Hopewell - https://qpublic.schneidercorp.com/Application.aspx?App=CityofHopewellVA&PageType=Search

  New Kent County - https://parcelviewer.geodecisions.com/NewKent/

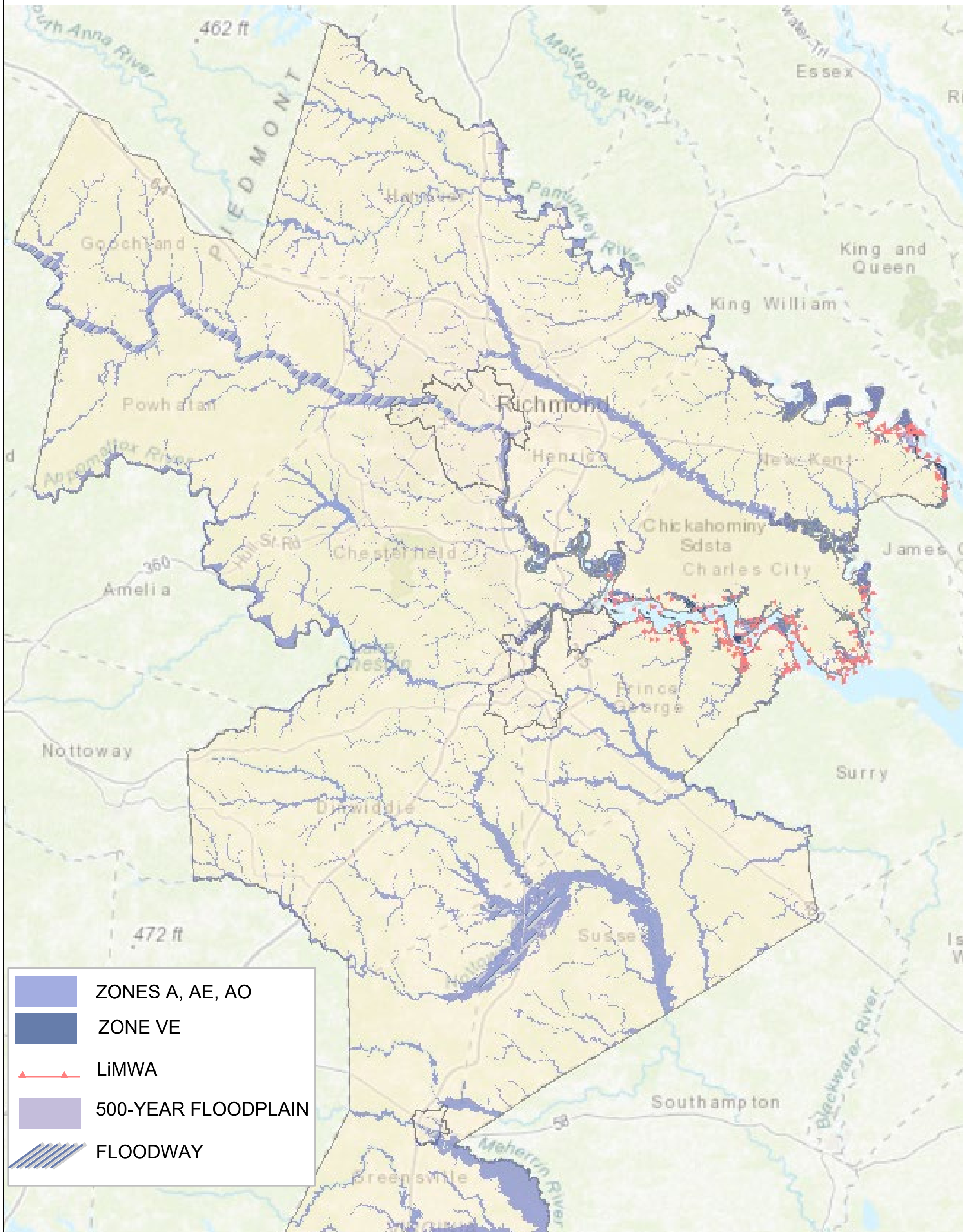
Powhatan County - https://powhatanvarealestate.org/ParcelViewer/

Prince George County - https://www.princegeorgecountyva.gov/business/gis_information/online_interactive_maps.php

City of Richmond - http://cor.maps.arcgis.com/home/webmap/viewer.html?webmap=d039492bec5346c8a75de1b6340da1c8&extent=-77.4795,37.5149,-77.4346,37.5348

Sussex County - https://parcelviewer.geodecisions.com/Sussex/

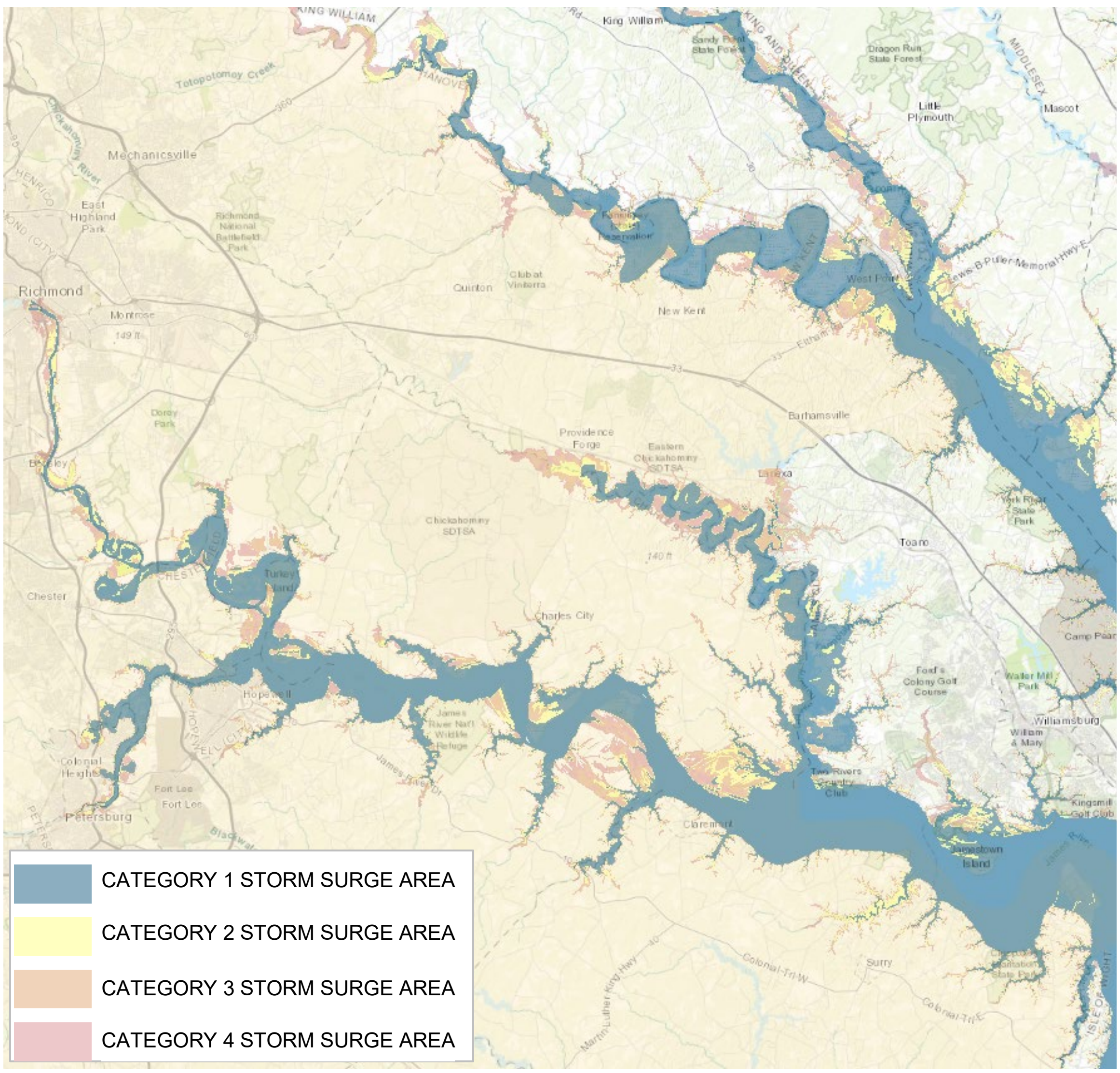
Figure 5.3: FEMA Flood Zones



Source: FEMA Flood Map Service Center, 2021

Figure 5.4a shows the most recent storm surge hazard areas that can be expected as the result of Category 1, 2, 3, and 4 hurricanes, based on the Sea, Lake and Overland Surge from Hurricanes (SLOSH) model. SLOSH is a computerized model run, conducted in this case by the U.S. Army Corps of Engineers, Norfolk District, to estimate storm surge heights resulting from hypothetical hurricanes by taking into account the maximum of various category hurricanes as determined by pressure, size, forward speed, and sustained winds. The regional analysis represents the composite maximum water inundation levels for a series of parallel tracks making landfall at various points along the coast. The SLOSH model, therefore, is best used for defining the "worst case scenario" of potential maximum surge for particular locations as opposed to the regional impact of one singular storm surge event.

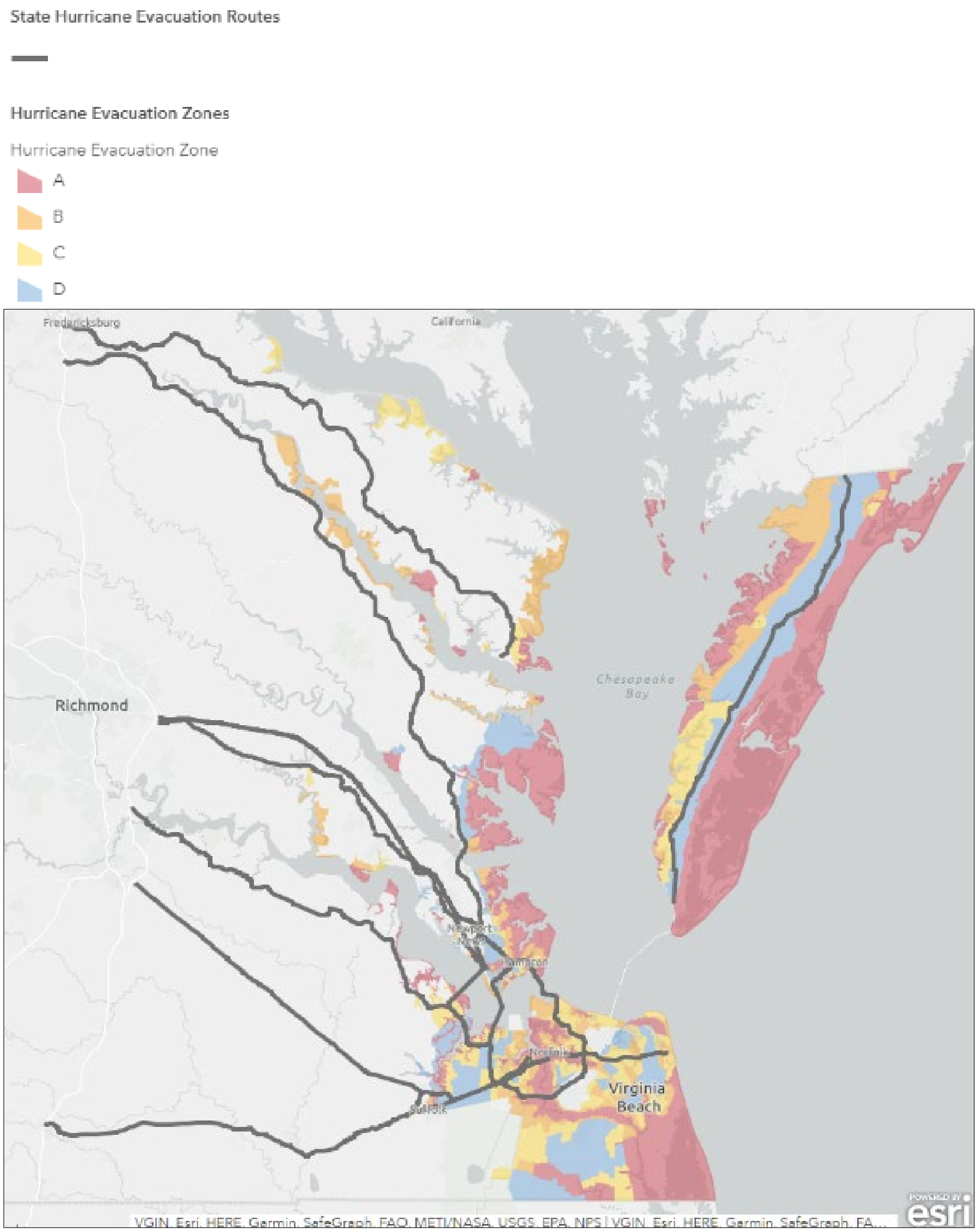
Figure 5.4a: Richmond-Crater Storm Surge Zones



Source: U.S. Army Corps of Engineers, Norfolk District, 2021

Figure 5.4b shows the Virginia Hurricane Evacuation Routes for Virginia, primarily from coastal regions inland. Termed the "Know Your Zone" initiative, this map and the effort to get the information engrained into residents' minds prior to impending hurricane-related flooding or high winds, emphasizes the importance of warning and evacuating residents and visitors well before weather conditions deteriorate. When a storm is approaching, emergency managers will determine which zones are most at risk considering the intensity, path, speed, tides and other meteorological factors. Emergency managers at the state and local level will work with local media and use social media and other tools to notify residents of impacted zones and what they should do to stay safe. Depending on the emergency, being safe might mean staying at home, a short trip to higher ground, or traveling to a different region of the state. Given the geography of the region and the reliance of the transportation system on tunnels and bridges, early evacuation is a crucial element in public safety.

Figure 5.4b: Virginia Hurricane Evacuation Routes



Source: VDEM, 2021

In addition to floodplains, tidal and non-tidal wetlands within all of the Richmond-Crater watersheds help store floodwaters, reduce erosion and filter pollutants. Wetlands are the transition area between aquatic and terrestrial habitats. A primarily low, marshy area, a wetland is saturated or even submerged all or part of the year, with soils that support unique plant and animal life. Wetlands work as a natural measure to help slow down the rising water from storms that may cause flooding, which is accomplished by acting as a giant sponge, absorbing and holding water during storms. Fast moving water is slowed by vegetation and temporarily stored in wetlands. Wetlands also filter pollutants carried by stormwater, which can be trapped by wetland vegetation. These excess nutrients are then used by the plants to promote growth.

Wetlands are resting, nesting, breeding, and spawning areas for many species of fish, shellfish, as well as other plant and animal life. More than one half of all threatened and endangered species depend on wetlands at one point of their life cycle. The study region spans a diverse range of habitats, including sandy beaches, salt marshes of the Chesapeake Bay, tidal fresh marshes, dry sandhills, seasonally wet ponds and blackwater swamps. These habitats support many rare and significant plant communities and rare species, including:

Mabee's Salamander	Ambystoma mabeei	State Threatened
Tiger Salamander	Ambystoma tigrinum	State Endangered
Henslow's Sparrow	Centronyx henslowii	State Threatened
Red-cockaded Woodpecker	Dryobates borealis	State and Federal Endangered
Peregrine Falcon	Falco peregrinus	State Threatened
Loggerhead Shrike	Lanius ludovicianus	State Threatened
Bachman's Sparrow	Peucaea aestivalis	State Threatened
Dwarf Wedgemussel	Alasmidonta heterodon	State and Federal Endangered
Yellow Lance	Elliptio lanceolata	State and Federal Threatened
Atlantic Pigtoe	Fusconaia masoni	State and Federal Threatened
Green Floater	Lasmigona subviridis	State Threatened
James Spinymussel	Parvaspina collina	State and Federal Endangered
Atlantic Sturgeon	Acipenser oxyrinchus	State and Federal Endangered
Blackbanded Sunfish	Enneacanthus chaetodon	State Endangered
Roanoke Logperch	Percina rex	State and Federal Endangered
Eastern Big-eared Bat	Corynorhinus rafinesquii macrotis	State Endangered
Tricolored bat (=Eastern pipistrelle)	Perimyotis subflavus	State Endangered
Sensitive Joint-vetch	Aeschynomene virginica	State and Federal Threatened
Virginia Quillwort	Isoetes virginica	State Endangered
Small Whorled Pogonia	Isotria medeoloides	State Endangered
New Jersey Rush	Juncus caesariensis	State Threatened
Michaux's Sumac	Rhus michauxii	Federal Endangered, State Threatened
Chaffseed	Schwalbea americana	Federal Endangered
Reclining Bulrush	Scirpus flaccidifolius	State Threatened

American Burying Beetle	Nicrophorus americanus	Federal Threatened
Virginia Piedmont Water Boatman	Sigara depressa	State Endangered
Swamp-pink	Helonias bullata	Federal Threatened, State Endangered
Narrow-leaved Spatterdock	Nuphar sagittifolia	State Threatened

Source: Virginia Natural Heritage Database Search, April 2022, online at: https://vanhde.org/species-search

Coastal wetlands absorb the erosive energy of waves, thus reducing further erosion. The vegetation provides a buffer to the shoreline from the wave action while the root systems provide support to help hold the soil together. Once plant material is removed or destroyed, the erosion potential increases dramatically. When any type of wetlands are filled in or drained, the areas designed by nature to control floodwaters from damaging storms, extreme high tides, and extreme precipitation are lost. In order to protect valuable natural communities and habitats for the rarest of plants and animals, Virginia through DCR has established natural area preserves. Existing natural area preserves in the region include: Cumberland Marsh in New Kent County; and Chub Sandhill in Sussex County.

Hazard History

Table 5.3 includes descriptions of major, recent flood events in the region. Events have been broken down by the date of occurrence and, when available, by individual community descriptions. Historical events pre-dating the 2011 version of this plan update can be found in Appendix F-2. The NCEI history reports minimal damages, no loss of life, and no injuries recorded in the 2016-2020 time period under examination; however, there were at least four water rescues during the period recorded in the database and others mentioned in news reports.

Table 5.3: History of Flood Events and Damages, 2011 – 2020*

Date	Damages
August 27, 2011	Hurricane Irene impacted the area with heavy rainfall and gusty winds which knocked power out to millions of people in the area. It took electrical crews several days to fully restore power in the planning area. Irene originated east of the Lesser Antilles and tracked north and northwest into the western Atlantic. The hurricane reached Category 3 intensity with maximum sustained winds of near 120 mph at its strongest point. The hurricane made an initial U.S. landfall in the eastern portions of the North Carolina Outer Banks on August 27, 2011, as a Category 1 hurricane. The storm then tracked north/northeast along the coast slowly weakening before making its final landfall in Brooklyn, New York on August 28 as a high-end tropical storm. Rainfall totals with the hurricane ranged from around two inches in western sections of the planning region to 5 to 9 inches in eastern sections closest to the coast. At its closest pass, Irene brought sustained winds of 30 to 45 mph with gusts of 60 to nearly 70 mph to the planning area. The winds downed power lines and trees throughout the area. A man was killed when a tree fell on his home near Colonial Heights. (Source: National Weather Service/Wakefield Office)
September 4, 2011	Tropical Storm Lee moved inland along the Mississippi/Louisiana Gulf Coast on September 4, 2011. The remnants of the weakening storm tracked northeast, producing rainfall over a wide swath extending from the Gulf Coast to New England.

Table 5.3: History of Flood Events and Damages, 2011 – 2020*	
Date	**Damages**
	Rainfall totals generally ranged from 4 to 8 inches in the planning area with the heaviest totals falling just east of Interstate 95. The rain fell on soils saturated only days earlier with Hurricane Irene's passage. The result was widespread flooding, particularly over the eastern sections of the planning region. Gusty winds in thunderstorms knocked down trees that had already been weakened from the hurricane resulting in thousands of power outages. (Source: National Weather Service/Wakefield Office)
May 18-19, 2018	Showers and thunderstorms associated with areas of low pressure along a frontal boundary produced heavy rain which caused lingering flooding across portions of central, south central, and eastern Virginia. Flooding occurred along the Chickahominy River, North Anna River, South Anna River, and Pamunkey River over a couple of days, with roads and low-lying areas near the river impacted the most. Numerous road closures in Charles City County, Chesterfield County (Otterdale Rd, Enon Church Rd off Rte 10), Dinwiddie County, Goochland County (Riddles Bridge Rd washed out), Hanover County (Horseshoe Bridge Rd, Greenwood Rd), Ashland, Henrico County (water rescue on Gayton Rd at Cedarbluff Dr, Patterson Ave, Old Springfield Rd, Laurel area, lanes of I-195 North near Broad St, Raintree area), New Kent County, Petersburg, Powhatan County, Prince George County, Richmond, Charles City County, and Hanover County. Canterbury Dam, a high hazard dam, overtopped in Henrico County causing significant impacts, including Pump Road being shut down. The county had to spend roughly $1M to fix the dam and provide overtopping protection.
June 2-3, 2018	Scattered showers and thunderstorms in advance of and along a frontal boundary produced heavy rain which caused flash flooding across portions of central Virginia. Flash flooding and many inundated roads reported in Henrico County with vehicle stuck in water on Cox Road, New Kent County with water on road at I-64, exit 220, Hanover County with a sinkhole reported near Huguenot Trail and Rte 288, Charles City County, and Hanover County with sinkhole at Crown Hill Road ($2000 damage) and Cross Corner Road washed out ($1000 damage).
June 7, 2019	Slow moving thunderstorms produced intense rainfall of 4 to 6 inches resulting in flash flooding on June 7th, causing flash flooding in Charles City County (portion of Rte 5 closed), Chesterfield County (portion of Turner Rd closed), Ashland (home flooded with $2000 damage), Hanover County (portions of East Patrick Henry Rd), Henrico County (flooding of roads in Glen Allen) and Wakefield (Hwy 460 closed at Main and Hwy 31, impacts to Virginia Diner and James River Equipment with $100,000 damage).
August 15, 2020	Scattered showers and thunderstorms associated with low pressure and a frontal boundary produced heavy rain which caused flash flooding across portions of central and southeast Virginia. Flooding reported in Chesterfield County (Old Hundred Rd, Mt Hermon Rd, water rescue at Otterdale Rd, Rte 10 in Chesterfield), Colonial Heights (2 water rescues), Hopewell, Petersburg, and northwest Prince George County.

**Flood history from 1950-2010 can be found in Appendix F-2.*
Source: NCEI, 2021

Table 5.4 provides the number of events and damage caused by recorded flood events for each jurisdiction. These results represent only events recorded by the NCEI storm events database for flood. Some of the events listed in the table may be regional in nature, impacting multiple jurisdictions. Significant tropical storm or hurricane events resulting in flooding have been included although minor tropical storms may have resulted in flooding but may not have been recorded in the NCEI as flood events. See the tropical storm section for additional information. Chesterfield (41) and Henrico (30) Counties have the highest number of flood events, and Greensville County had over $1M in property damages during this time period.

Table 5.4: Flood Damage to Property and Crops, 1993 – October 2020

Jurisdiction	Flood Events	Property Damages	Crop Damages
Charles City County	14	-	-
Chesterfield County	41	$287,458	$2,986
City of Colonial Heights	8	$71,663	-
Dinwiddie County (inc. Town of McKenney)	11	$12,223	$3,285
City of Emporia	3	-	-
Goochland County	7	$38,818	$11,944
Greensville County (inc. Town of Jarratt)	13	$1,065,175	-
Hanover County (inc. Town of Ashland)	23	$163,993	$25,082
Henrico County	30	-	-
City of Hopewell	9	$71,663	
New Kent County	21	$109,340	-
City of Petersburg	17	$141,487	-
Powhatan County	13	$38,966	-
Prince George County	15	-	-
City of Richmond	16	$94,711	-
Surry County (inc. Towns of Claremont, Dendron, Surry)	22	$1,460,000	$750,000
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	18	$365,726	$62,187
Totals	**259**	**$2,461,223**	**$105,484**

Source: NCEI, February 3, 2021.

The most significant event in the past five years occurred June 7, 2019, in Sussex County. Slow moving thunderstorms produced intense rainfall of 4 to 6 inches resulting in flash flooding. Highway 460 was closed in both directions at Main Street and Highway 31 due to flooding. Flooding also impacted the Virginia Diner and James River Equipment. Property damages from this storm totaled $100,000.

Vulnerability Analysis

The vulnerability assessment for the flood hazard includes the findings of the qualitative assessment conducted, an overview of NFIP statistics, repetitive loss properties (as defined and identified by the NFIP), estimates of potential losses, future vulnerability, social vulnerability, expected impacts from climate change and discussion on impacts related to mass evacuations.

As shown in **Table 5.5**, communities in the Richmond-Crater region joined the NFIP throughout the 1970s, 1980s and into the 1990s. In order to join the NFIP, each participating jurisdiction is required to adopt and enforce its own floodplain management ordinance. As a result, structures built after joining the NFIP are assumed to be less vulnerable to flood hazards than those built prior to joining, assuming other environmental conditions remain constant.

Table 5.5: Communities Participating in the NFIP as of March 15, 2021

Community	NFIP Entry Date	Current FIRM Effective Date
Charles City County	09/05/90	07/06/15
Chesterfield County	03/16/83	12/18/12
City of Colonial Heights	09/02/81	08/02/12
Dinwiddie County	01/17/79	10/21/21
Town of McKenney	11/20/81	No Special Flood Hazard Area identified
City of Emporia	09/30/77	07/07/09
Goochland County	03/01/79	12/02/08
Greensville County	09/29/78	07/07/09
*Town of Jarratt**	10/08/82	07/07/09
Hanover County	09/02/81	12/02/08
Town of Ashland	05/26/78	12/02/08
Henrico County	02/04/81	12/18/07
City of Hopewell	09/05/79	07/16/15
New Kent County	12/05/90	08/03/15
City of Petersburg	03/16/81	02/04/11
Powhatan County	09/15/78	02/06/08
Prince George County	05/01/80	06/02/15
City of Richmond	06/15/79	07/16/14
Sussex County	03/02/83	07/07/09
Town of Stony Creek	09/16/82	07/07/09
Town of Wakefield	03/12/14	07/07/09

*Jarratt is included in Greensville County for purposes of the NFIP.
Source: National Flood Insurance Program Community Status List, 2021

Table 5.6 provides data regarding the number of flood insurance policies and the value of those policies for NFIP-participating communities in the study area. As of April 8, 2021, there were 3,438 flood insurance policies-in-force in the region, an increase of 56 policies since June 2016. These policies amounted to more than $983 million in total insurance coverage, an increase of 7-percent since 2016. With just over 1,400 claims filed, the NFIP has paid out $21.6 million in payments since 1978 in the Richmond-Crater region.

Just three communities in the study area have absorbed almost 84% of the NFIP claims: Richmond 52%; Henrico County 17% and Chesterfield County 15%. The Town of Surry is 0.4 miles from mapped SFHA, which is approximate Zone A of Green Swamp. The town has decided not to participate in the NFIP. In the course of investigating why Waverly is not in the NFIP, planners discovered that the boundaries of the town on the FIRM do not match State records. The FIRM town boundary is incorrect and should include SFHA of Spring Branch. A mitigation action to address this issue is included in this plan.

Table 5.6: NFIP Claim Statistics by Participating Jurisdiction												
Jurisdiction Name	Policy Statistics 2016		Claim Statistics 1978-2016		Policy Statistics 2021		Claims Statistics 1978-2021		Policy Delta 2016-2021		Claims Delta 2016-2021	
	Policies -In-Force	Insurance In-Force	Total Claims	Total Payment	Policies-In-Force	Insurance In-Force	Total Claims	Total Payment	Policies -In-Force	Insurance In-Force	Total Claims	Total Payment
Charles City County	20	$6,320,700	7	$42,606	21	$6,731,500	8	$51,299	1	$410,800	1	$8,693
Chesterfield County	864	$231,463,100	175	$2,580,112	903	$258,952,800	219	$3,265,460	39	$27,489,700	44	$685,348
Colonial Heights	112	$27,581,600	79	$1,061,117	93	$25,331,500	85	$1,201,552	-19	-$2,250,100	6	$140,435
Dinwiddie County	39	$10,729,600	2	$11,979	36	$10,374,600	2	$11,979	-3	-$355,000	0	$0
Town of McKenney	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Emporia	38	$5,400,900	10	$6,060	30	$5,403,500	13	$21,020	-8	$2,600	3	$14,960
Goochland County	47	$14,506,100	12	$137,267	56	$17,890,100	11	$126,623	9	$3,384,000	-1	-$10,644
Greensville County	17	$3,630,900	4	$26,145	14	$3,489,100	6	$28,061	-3	-$141,800	2	$1,916
Town of Jarratt	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0
Hanover County	177	$51,675,300	23	$253,608	207	$63,928,100	27	$359,874	30	$12,252,800	4	$106,266
Town of Ashland	44	$13,629,600	3	$4,655	50	$16,290,200	8	$22,009	6	$2,660,600	5	$17,354
Henrico County	986	$246,491,700	240	$2,978,970	1032	$274,960,700	303	$3,585,760	46	$28,469,000	63	$606,790
Hopewell	26	$7,607,000	11	$101,018	29	$9,569,900	17	$145,880	3	$1,962,900	6	$44,862
New Kent County	119	$34,367,100	29	$488,862	113	$33,582,000	31	$517,274	-6	-$785,100	2	$28,412
Petersburg	137	$38,183,500	76	$481,948	98	$30,180,900	88	$727,738	-39	-$8,002,600	12	$245,790
Powhatan County	30	$8,480,000	1	$4,867	38	$12,595,000	1	$4,867	8	$4,115,000	0	$0
Prince George County	94	$25,420,500	27	$223,737	92	$26,886,600	31	$248,986	-2	$1,466,100	4	$25,249
Richmond	586	$183,772,500	515	$10,666,886	582	$176,882,300	537	$11,133,693	-4	-$6,890,200	22	$466,807

Table 5.6: NFIP Claim Statistics by Participating Jurisdiction												
Jurisdiction Name	**Policy Statistics 2016**		**Claim Statistics 1978-2016**		**Policy Statistics 2021**		**Claims Statistics 1978-2021**		**Policy Delta 2016-2021**		**Claims Delta 2016-2021**	
	Policies -In-Force	**Insurance In-Force**	**Total Claims**	**Total Payment**	**Policies-In-Force**	**Insurance In-Force**	**Total Claims**	**Total Payment**	**Policies -In-Force**	**Insurance In-Force**	**Total Claims**	**Total Payment**
Sussex County	24	$5,016,700	12	$47,630	26	$6,565,700	12	$46,657	2	$1,549,000	0	-$973
Town of Stony Creek	22	$3,653,500	23	$96,039	15	$2,637,300	22	$96,039	-7	-$1,016,200	-1	$0
Town of Wakefield	0	$0	0	$0	3	$1,020,000	0	$0	3	$1,020,000	0	$0
Totals	**3,382**	**$917,930,300**	**1,249**	**$19,213,506**	**3,438**	**$983,271,800**	**1,421**	**$21,594,771**	**56**	**$65,341,500**	**172**	**$2,381,265**

Source: NFIP data, dated 6/30/2016 and 4/8/2021.

FEMA Repetitive Loss and Severe Repetitive Loss Properties

Nationwide, repetitive loss (RL) properties constitute 2% of all NFIP insured properties but are responsible for 40% of all NFIP claims. Mitigation for RL properties is a high priority for FEMA, and the areas in which these properties are located typically represent the most floodprone areas of a community.

The identification of RL properties is an important element in assessing local flood risk because the inherent characteristics of properties with multiple flood losses strongly suggest that they will be threatened by continual losses. RL properties are also important to the NFIP, since structures that flood frequently put a strain on NFIP funds. The NFIP defines an RL as any insurable building for which two or more claims of more than $1,000 were paid by the NFIP within any rolling 10-year period, since 1978.[7] A primary goal of FEMA is to reduce the numbers of structures that meet these criteria, whether through elevation, acquisition, relocation, or a flood control project that lessens the potential for continual losses.

According to FEMA, there are currently 158 RL properties within the Richmond-Crater region accounting for 468 losses. The specific addresses of the properties are maintained by FEMA, VDEM, and local jurisdictions, but are deliberately not included in this plan in accordance with the Privacy Act of 1974. More than $13.8 million has been paid in total repetitive losses, with an average claim of $30,000. **Table 5.7** shows the total number of properties, total number of losses experienced, and losses paid for all of the communities within the planning region. Historically, the majority of the RL properties are residential; however, a breakdown by property type was not provided by FEMA for this plan update.

A severe repetitive loss (SRL) property has: a) at least four NFIP claims payments of more than $5,000 each, with the cumulative amount of such claims payments exceeding $20,000; or b) at least two separate claims payments with the cumulative amount exceeding the market value of the building. As shown in Table 5.7, Chesterfield and Henrico Counties have the most SRL properties in the study area.

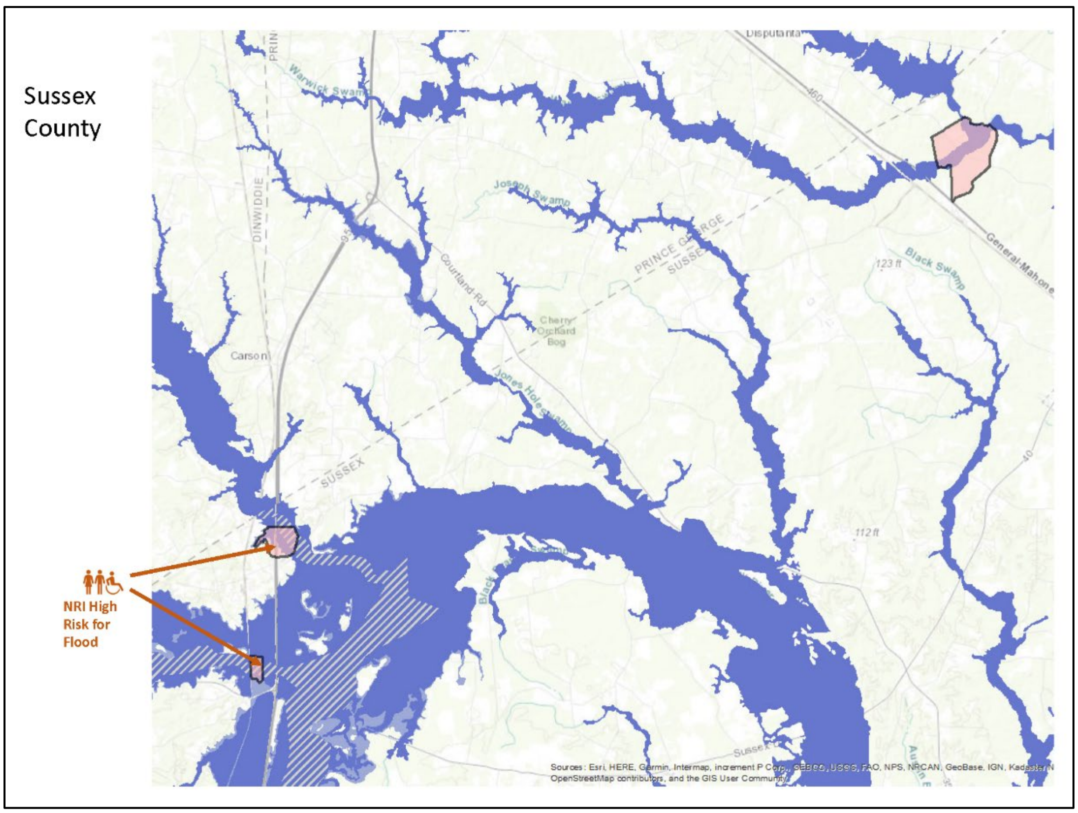
[7] The FEMA Hazard Mitigation Assistance Program defines RL as having incurred flood-related damage on 2 occasions, in which the cost of the repair, on the average, equaled or exceeded 25 percent of the market value of the structure at the time of each such flood event; and, at the time of the second incidence of flood-related damage, the contract for flood insurance contains increased cost of compliance coverage.

Table 5.7 Repetitive Flood Losses and Severe Repetitive Flood Losses				
Community	**Repetitive Flood Loss Detailed Data**			
Chesterfield County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	25	$1,359,017.04	77	$17,649.57
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	7	$691,300.59	33	$20,948.50
Claremont Town	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	4	$400,805.50	14	$28,628.97
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	3	$374,116.60	12	$31,176.38
Colonial Heights City	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	12	$912,220.30	37	$24,654.60
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	3	$324,780.80	14	$23,198.63
Dinwiddie County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	1	$67,506.04	4	$16,876.51
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	1	$67,506.04	4	$16,876.51
Emporia City	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	1	$15,358.28	3	$5,119.43
Goochland County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	1	$94,689.86	3	$31,563.29
Hanover County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	1	$134,119.83	2	$67,059.92

Table 5.7 Repetitive Flood Losses and Severe Repetitive Flood Losses				
Community	**Repetitive Flood Loss Detailed Data**			
Henrico County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	25	$1,765,976.35	99	$17,838.14
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	5	$717,634.39	40	$17,940.86
Hopewell City	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	1	$38,658.56	2	$19,329.28
New Kent County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	3	$272,374.43	10	$27,237.44
Petersburg City	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	11	$530,383.70	31	$17,109.15
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	2	$101,438.10	9	$11,270.89
Prince George County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	3	$179,261.10	10	$17,926.11
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	2	$144,808.10	8	$18,101.02
Richmond City	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	63	$8,019,552.70	162	$49,503.41
	Severe Repetitive Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	1	$1,386,405.53	13	$106,646.58
Stony Creek Town	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	4	$47,479.36	8	$5,934.92
Sussex County	Repetitive Flood Losses			
	Number of Properties	Value of Losses	Number of Losses	Avg Payment Per Claim
	3	$31,120.50	6	$5,186.75

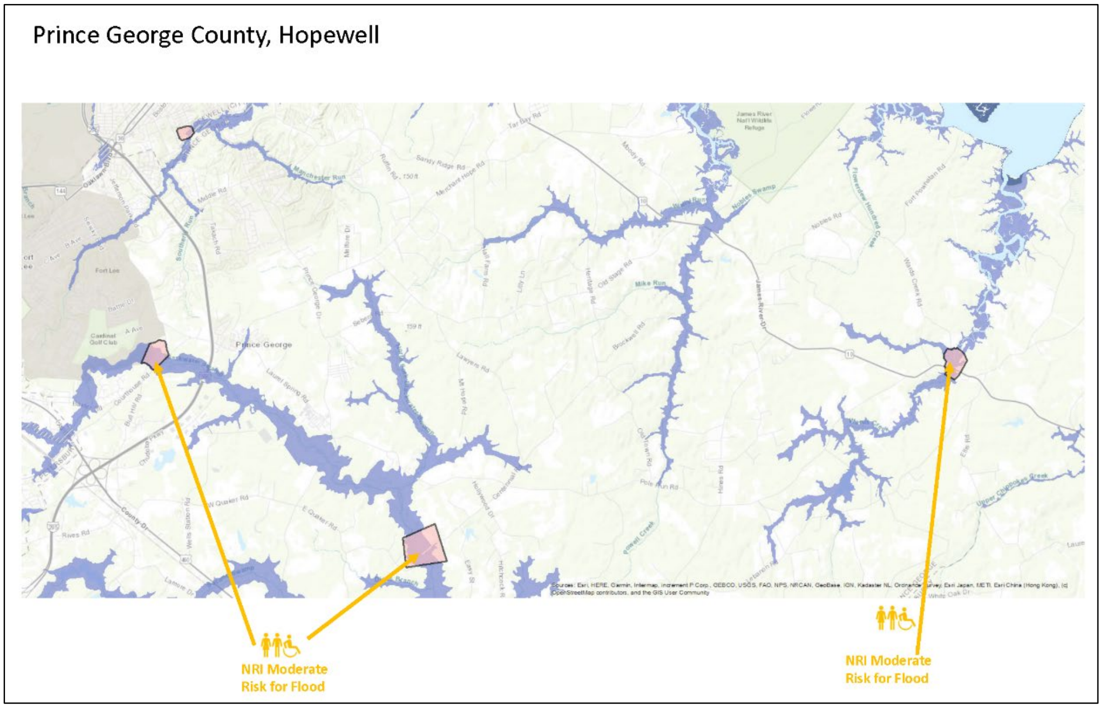
Figures 5.5a through 5.5j contain maps of the region's 59 repetitive loss areas. Each designated area shown in pink was identified by referencing maps of all historical NFIP flood claims, NFIP RL lists, the SRL list and, in some cases, Hazus results regarding predicted flood damages from a 100-year flood for individual structures. As shown in **Table 5.8**, there are 158 properties on FEMA's repetitive loss list and an additional 6,097 parcels identified as being within those repetitive loss areas. Other structures near the ones listed by the NFIP may have been uninsured during the floods, may have had single flood insurance claims, may be privately insured against flood, or may have had multiple claims under different policies that the claims system did not recognize as being the same repetitively flooded address. The NRI category for social vulnerability is noted for RL areas designated as "Relatively High" or "Relatively Moderate." There were no tracts in the Richmond-Crater region designated as "Very High" for social vulnerability to flood.

Figure 5.5a. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk



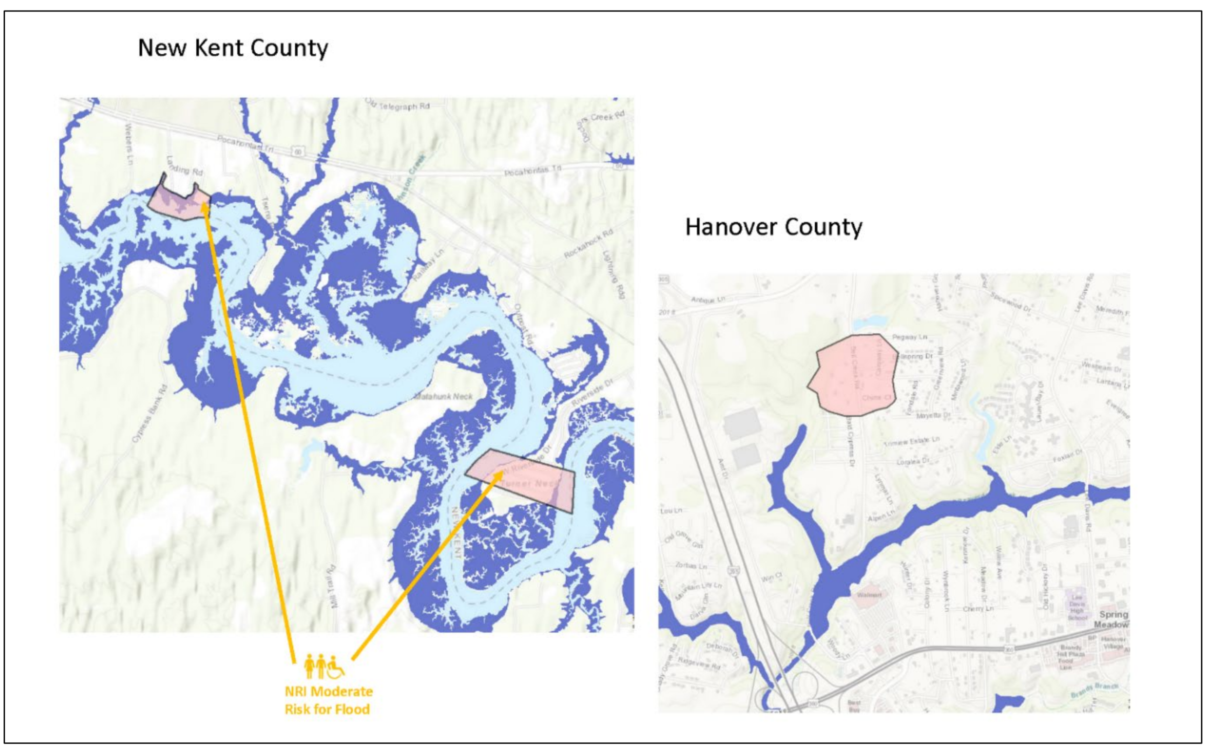
2021

Figure 5.5b. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk



2021

Figure 5.5c. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk



2021

Figure 5.5d. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk

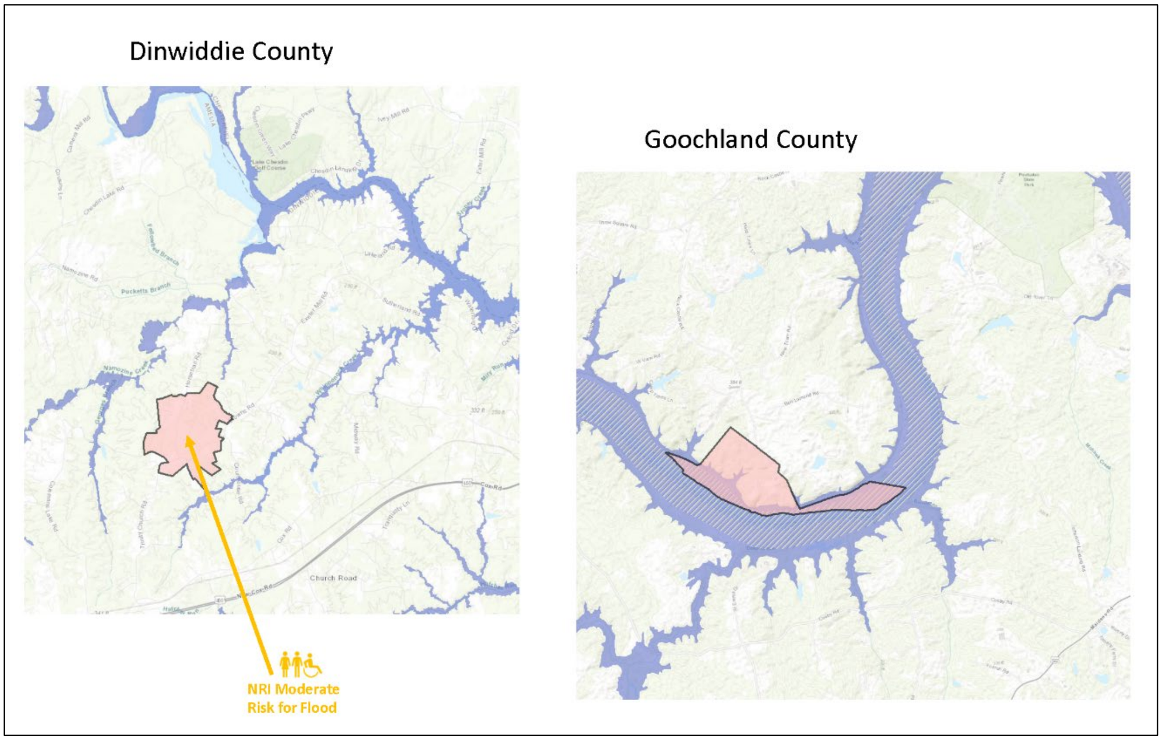


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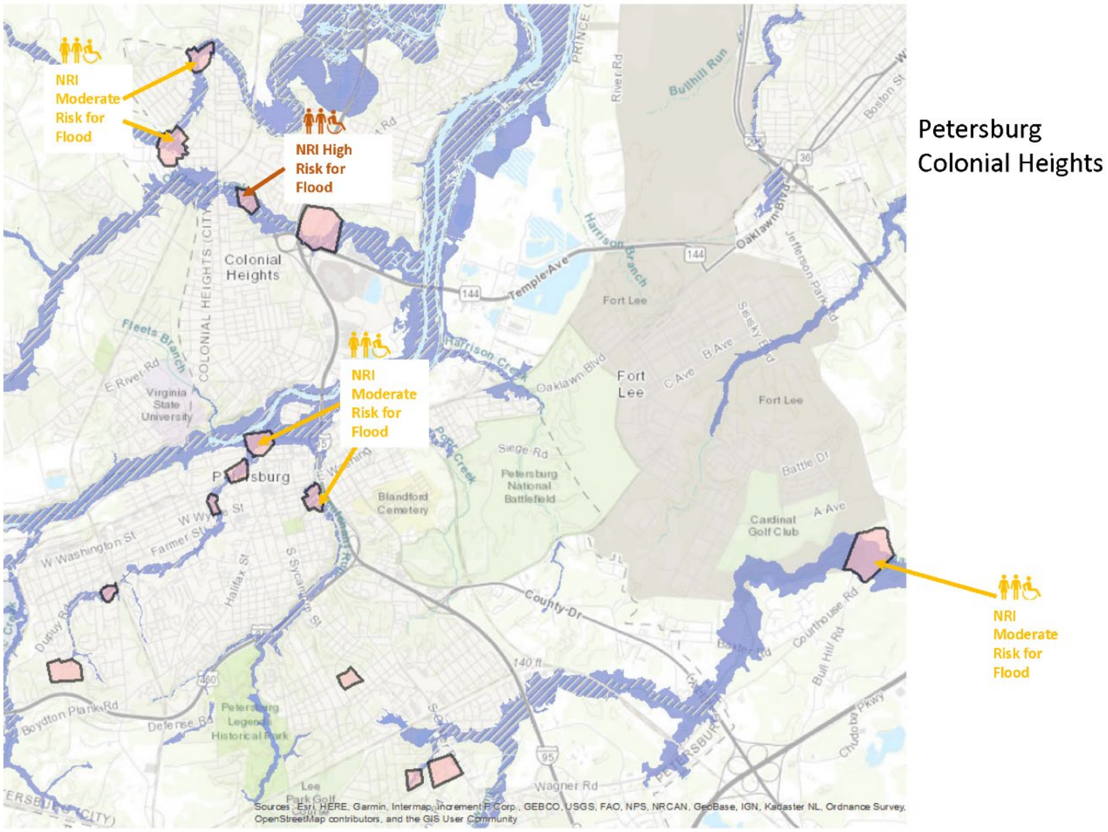
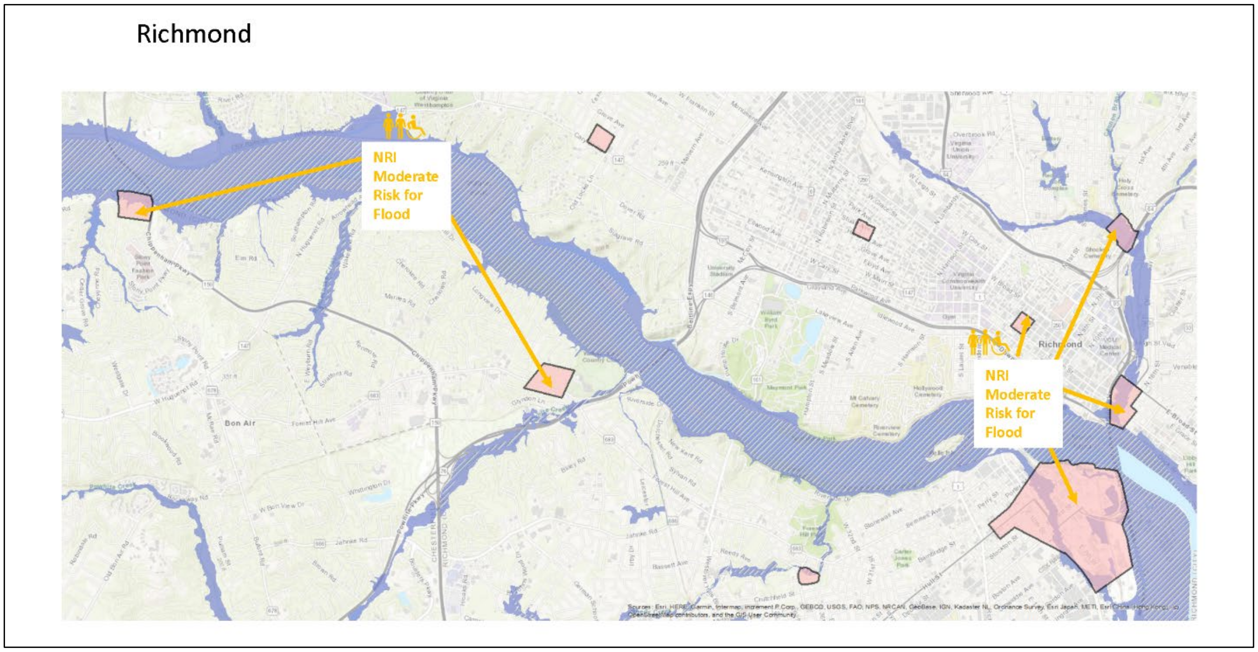
Figure 5.5e. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk



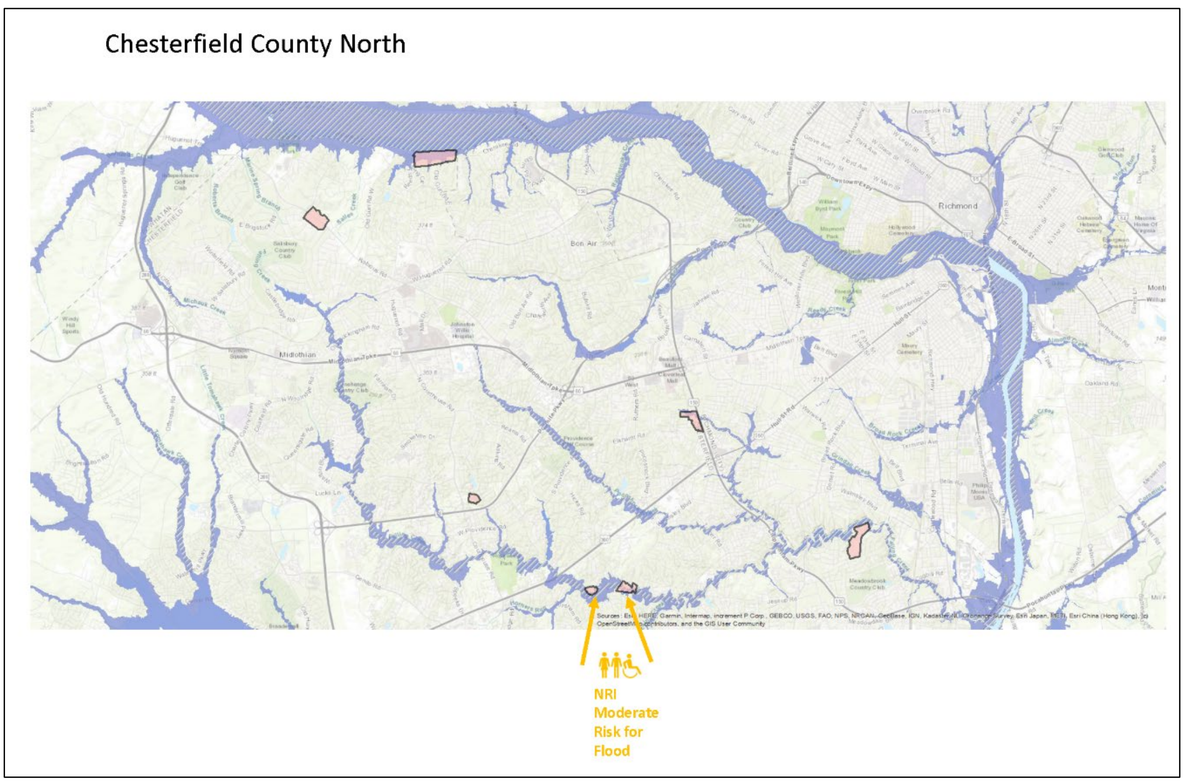
2021

Figure 5.5f. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk



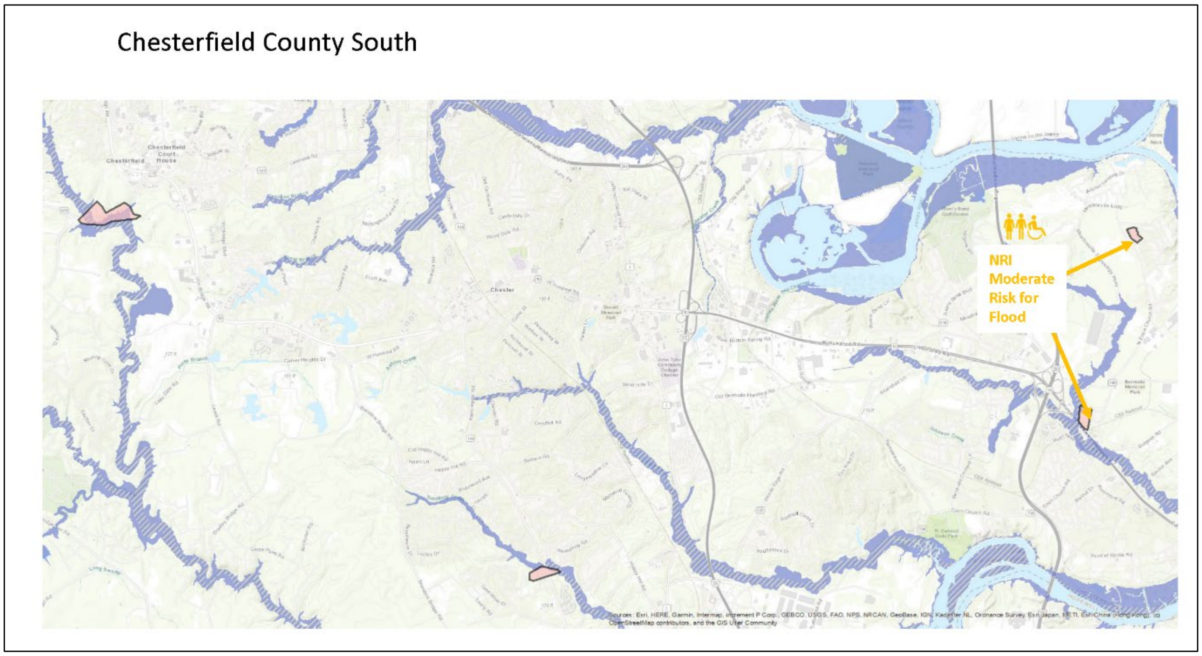
2021

Figure 5.5g. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk



2021

Figure 5.5h. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk

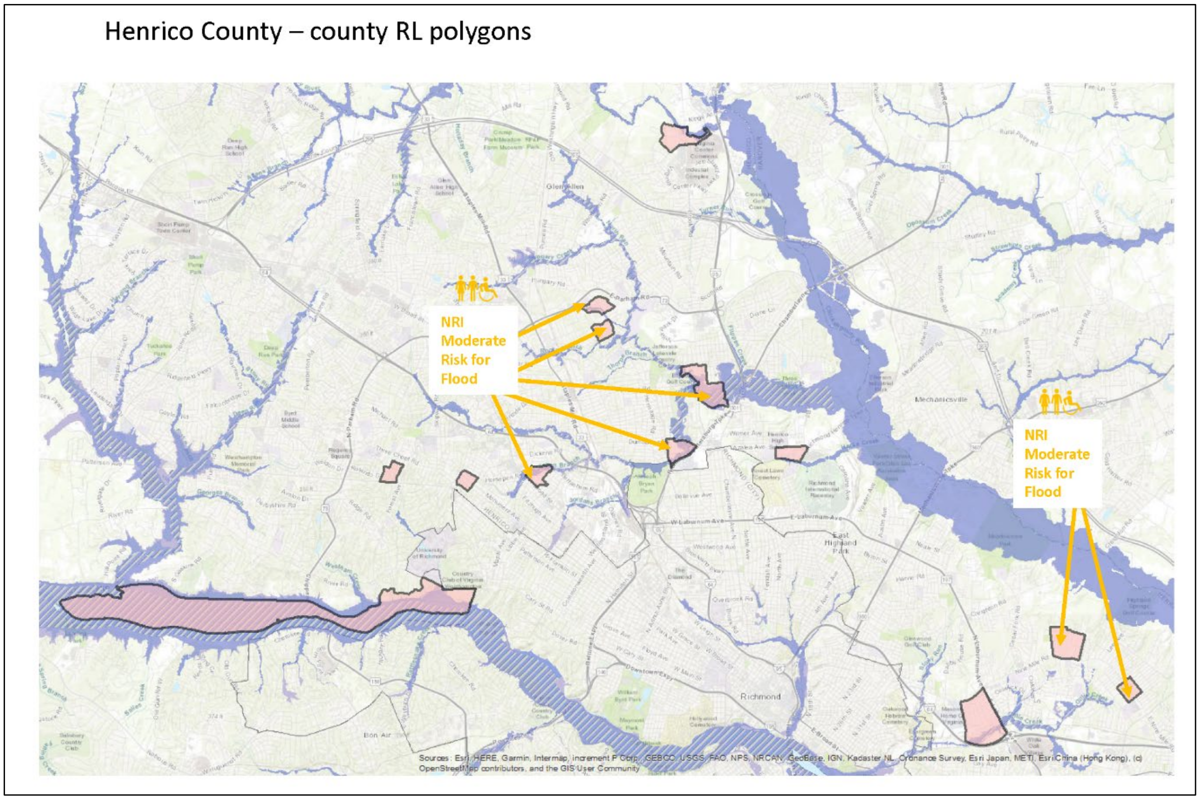


2021

Figure 5.5i. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk

2021

Figure 5.5j. Repetitive Loss Areas and National Risk Index Ratings of High or Moderate Risk



2021

Table 5.8: Repetitive Flood Loss Area Descriptions				
Community	Total Number of RL Areas	Number of High or Moderate Risk RL Areas	Estimated Number of Structures	Sources of Flooding
Goochland County	1	0	4	Overland flow of the James River in a large meander bend with broad floodplain on the north bank.
Hanover County	1	0	66	Area is outside the 100-year floodplain but lies between two tributaries to Beaverdam Creek.
Henrico County – from County RL polygons	13	7 Moderate	4,189	The northernmost RL area contains the 100-year floodplain of the Chickahominy River. In the western part of the county, a RL area lies outside the 100-year floodplain, near the headwaters of Little Westham Creek. One area is within the 100-year floodplain along Horespen Branch, with another area near the headwaters of Horsepen Branch. A large RL area lies along the northern bank of the James River, with the majority of the polygon within the 100-year floodplain. In the central part of the county, there are five areas with 100-year floodplain in the North Run and Upham Brook watersheds, with two along North Run Tributary 2, one at the confluence of North Run and Upham Brook, and one near the confluence of Upham Brook and Jordans Branch. Another nearby area is located in the upper portion of the Horse Swamp Creek 100-year floodplain. There are three eastern RL areas: one within the Gillies Creek 100-year floodplain, along Gillies Creek Tributary 9, near the confluence of Gillies Creek Tributary 2 and Gillies Creek Tributary 8; one area is outside of the floodplain but upstream of Tributary A to Gillies Creek Tributary 1; and one area is outside of the floodplain but upstream to Chickahominy River Tributary 17.
New Kent County	2	2 Moderate	175	Both areas are low-lying groups of residential structures in the meander bends of the Chickahominy River. The Chickahominy Shores neighborhood is on an oxbow named Turner Neck, with houses outside the 100-year floodplain, but within the storm surge zones for most hurricane categories.
Richmond	9	6 Moderate	774	The largest RL area is South Richmond, on the south side of the James River, across from Downtown. Two other areas are in the 100-year floodplain of Cannon Branch that flows between Downtown Richmond and Church Hill before entering the James River. An RL area exists along the Reedy Creek floodplain and floodway, south of Forest Hill Park, while another is in the 100-year floodplain of the James River, east of downtown near Chippenham Parkway. The remaining four areas are outside the 100-year floodplain and have stormwater-related causes.
Chesterfield County	11	4 Moderate	377	Four RL areas are along Falling Creek, or an unnamed tributary of Falling Creek near Chippenham Mall. Structures in the northernmost RL area are primarily in the 100-year floodplain of the James River, near the intersection of Old Gun Road and Cherokee Road. There are 41 structures in an RL area downstream of the Swift

Table 5.8: Repetitive Flood Loss Area Descriptions				
Community	Total Number of RL Areas	Number of High or Moderate Risk RL Areas	Estimated Number of Structures	Sources of Flooding
				Creek Lake Dam, while two other RL areas are on Timsbury Creek and an unnamed tributary of Johnson Creek. Three of the RL areas are outside the 100-year floodplain.
Colonial Heights	4	1 High, 2 Moderate	102	All four RL areas contain 100-year flood and designated floodway segments. The waterway sources are: Swift Creek (2 areas); and Oldtown Creek. The flooding to 2 apartment buildings in one area was due creek flooding during Hurricane Isabel in 2003. The flood waters rose above the 1st floor onto the 2nd floor. In 2004 the City did debris cleanup in the creek to remediate the problem. Since that time there has been little to no flooding.
Dinwiddie County	1	1 Moderate	32	Area is outside the 100-year floodplain but lies between Whipponock Creek to the south and Georges Branch to the west. Georges Branch is a tributary to Namozine Creek.
Emporia	1	1 Moderate	12	Suspected backwater flow from the Rt 58 bridge over a tributary to Metcalf Branch. Part of the RL area is designated Zone A, but no detailed study appears to have been done.
Hopewell	1	0	51	Structures are in an area outside the detailed-study 100-year floodplain and floodway of Bailey Creek, a tributary of the James River. Bailey Creek, in general, has a relatively flat watershed; the lower reaches are swampy, and flow is very sluggish.
Petersburg	9	3 Moderate	295	Five of the RL areas are along Brickhouse Run, a tributary to the Appomattox River with its headwaters in southern Petersburg. Lieutenant Run has a large backwater floodplain with designated floodway south of Washington Street that has repetitive flood losses. Poor drainage near Blackwater Swamp in the southeastern region of the City has resulted in 2 RL areas, and another RL area is not associated with any water bodies near Walnut Hill at Weyanoke Street and Arch Street.
Prince George County	2	2 Moderate	36	A low-lying part of Blackwater Swamp just north of the confluence with Dicks Branch contains over half the structures and lies within the 100-year floodplain of Blackwater Swamp. The remaining structures appear to be flooded by Wards Creek, downstream of the Rt 10 crossing and within the 100-year floodplain
Claremont	1	0	45	The single RL area is outside the 100-year floodplain as mapped by FEMA. Source of flooding suspected to be stormwater-related.
Stony Creek	1	1 High	69	The RL area is part of the floodway and 100-year floodplain of Stony Creek, east of Main Street, south of Crowder Lane toward Lee Ave on the south.
Sussex County	2	1 High	28	The westernmost area is within the 100-year floodplain of the tributaries that feed the Nottoway River near Stony Creek. The eastern RL area is along Warwick Swamp at its confluence with the Blackwater Swamp.

Estimates of Potential Losses

For the updated flood vulnerability analysis, participating communities were asked to share as much information as possible about individual structures in their communities, including:

- address;
- year built;
- number of stories;
- building cost;
- content cost;
- building type;
- square footage;
- construction class;
- foundation type;
- occupancy/use code; and/or
- Elevation Certificate data or lowest floor elevation.

As part of the flood hazard vulnerability assessments, analysts used the datasets provided by each community to construct the necessary base datasets required by Hazus to conduct a detailed, Level 2 hazard assessment wherever there are detailed FEMA flood studies. The following highlights the data source and processing methodology for each of the input datasets required by Hazus:

Flood Hazard Data and Depth Rasters

Geospatial analysts obtained the most recent effective Digital Flood Insurance Rate Map databases from the FEMA Map Service Center for the region. The 100-year floodplain boundary and associated Base Flood Elevations (BFE) were used as the flooding source input to Hazus for calculating the loss estimations.

User Defined Facilities (Building Data)

Communities provided building data in the form of either parcels, building footprints or address points. The datasets were inconsistent across the communities, but from each dataset, analysts were able to determine the basic structural attributes (i.e., value, foundation type, occupancy class, etc.) required by Hazus to perform a loss estimation. In some cases, Hazus appears to have counted structures as impacted or flooded when the parcel intersected the 100-year floodplain, but not necessarily the structure footprint, which may have artificially inflated some of the impacts.

Because of either a lack of structure-specific data or a lack of FEMA-determined BFEs in the community, the following communities were studied using a Level 1 analysis only: Charles City County, Colonial Heights, Greensville County, New Kent County, Prince George County and Sussex County. The Level 2 studies for Dinwiddie County and Powhatan County were supplemented with Level 1 analyses in areas where detailed BFEs were not available.

First Floor Elevations (FFE)

Each structure was assigned a relative FFE according to the guidelines listed in the Hazus Flood Model Technical Manual. These values were neither surveyed nor field verified but were instead algorithmic estimates provided by Hazus and subsequently adjusted for the region. This data input is identified as a potential area for increasing the accuracy of the model output in future updates to the plan. By collecting and using real-world data on FFEs, the model will provide more accurate results for individual structures.

Using the depth rasters and building data listed above, a building level 100-year flood vulnerability analysis was conducted. Hazus uses the associated 100-year depth at each structure and compares that to the assigned FFE to determine the predicted depth of flooding at each structure. Then, using depth damage curves, Hazus determines the building and content damage percentage for each structure, which corresponds to a dollar figure based on the assessed value of each structure.

Table 5.9 provides a detailed listing of the number of structures expected to be damaged, and the dollar losses predicted. In the previous regional hazard mitigation plan, the flood vulnerability results were run using a vastly different methodology, thus comparing the results and outcomes is not meaningful.

Table 5.9: Hazus 100-Year Flood Damage Vulnerability Results						
Analysis Type	**Community**	**Number of Buildings Moderately Damaged (41-50% of Value)**	**Number of Buildings Substantially Damaged (>50% of Value)**	**Building Losses**	**Content Losses**	**Inventory Losses**
Hazus Level 1	**Charles City County -** Residential	0	0	$820,000	$410,000	$0
	Commercial	0	0	$50,000	$130,000	$0
	Industrial	0	0	$10,000	$10,000	$0
	Other	0	0	$60,000	$290,000	$20,000
	Total	0	0	$940,000	$840,000	$20,000
	Colonial Heights – Residential	10	9	$21,290,000	$12,270,000	$0
	Commercial	0	0	$3,790,000	$9,130,000	$150,000
	Industrial	0	0	$270,000	$440,000	$70,000
	Other	0	0	$380,000	$1,710,000	$10,000
	Total	10	9	$25,730,000	$23,560,000	$23,0000
	Greensville County - Residential	0	0	$1,420,000	$690,000	$0
	Commercial	0	0	$100,000	$360,000	$0
	Industrial	0	0	$80,000	$180,000	$20,000
	Other	0	0	$20,000	$140,000	$0
	Total	0	0	$1,630,000	$1,360,000	$20,000
	New Kent County – Residential	1	2	$4,980,000	$257,000	$0
	Commercial	0	0	$170,000	$470,000	$20,000
	Industrial	0	0	$70,000	$100,000	$10,000
	Other	0	0	$20,000	$150,000	$0
	Total	1	2	$5,240,000	$3,290,000	$30,000
	Prince George County - Residential	2	2	$7,090,000	$370,000	$0

Table 5.9: Hazus 100-Year Flood Damage Vulnerability Results						
Analysis Type	**Community**	**Number of Buildings Moderately Damaged (41-50% of Value)**	**Number of Buildings Substantially Damaged (>50% of Value)**	**Building Losses**	**Content Losses**	**Inventory Losses**
	Commercial	0	0	$660,000	$1,470,000	$30,000
	Industrial	0	0	$190,000	$420,000	$70,000
	Other	0	0	$40,000	$3,320,000	$0
	Total	2	2	$7,980,000	$5,910,000	$90,000
	Sussex County – Residential	0	0	$1,710,000	$810,000	$0
	Commercial	0	0	$530,000	$1,730,000	$50,000
	Industrial	0	0	$80,000	$130,000	$30,000
	Other	0	0	$150,000	$780,000	$40,000
	Total	0	0	$2,470,000	$3,440,000	$110,000
Hazus Level 2	**Chesterfield County –** Residential	302	898	$419,240,000	$177,100,000	$0
	Commercial	10	4	$54,300,000	$99,560,000	$8,000,000
	Industrial	2	4	$17,250,000	$40,510,000	$5,190,000
	Other	0	7	$79,260,000	$411,960,000	$630,000
	Total	314	913	$570,061,000	$729,134,000	$13,820,000
	Dinwiddie County – Residential	1	6	$835,000	$285,000	<$500
	Commercial	0	0	$0	$0	$0
	Industrial	0	0	$0	$0	$0
	Other	0	0	$0	$0	$0
	Total	1	6	$835,000	$285,000	<$500
	Emporia – Residential	15	26	$8,930,000	$4,520,000	$0
	Commercial	0	0	$410,000	$800,000	$330,000
	Industrial	0	0	$0	$0	$0

Table 5.9: Hazus 100-Year Flood Damage Vulnerability Results						
Analysis Type	**Community**	**Number of Buildings Moderately Damaged (41-50% of Value)**	**Number of Buildings Substantially Damaged (>50% of Value)**	**Building Losses**	**Content Losses**	**Inventory Losses**
	Other	0	0	$0	$0	$0
	Total	15	26	$9,339,000	$5,326,000	$333,000
	Goochland County – Residential	10	61	$59,094,000	$23,816,000	$0
	Commercial	0	1	$1,180,000	$4,390,000	$18,000
	Industrial	1	0	$984,000	$1,918,000	$214,000
	Other	0	0	$490,000	$2,130,000	$0
	Total	11	62	$61,751,000	$32,256,000	$231,000
	Hanover County – Residential	72	215	$140,154,000	$58,688,000	$0
	Commercial	0	0	$3,610,000	$12,918,000	$4,455,000
	Industrial	0	0	$8,066,000	$23,534,000	$3,669,000
	Other	90	164	$126,577,000	$221,005,000	$170,576,000
	Total	162	379	$278,407,431	$316,143,853	$178,700,249
	Henrico County – FEMA SFHA only – Residential	197	383	$196,010,000	$109,085,000	$0
	Commercial	4	5	$78,984,000	$132,874,000	$193,000
	Industrial	2	0	$14,976,000	$36,655,000	$756,000
	Other	2	2	$30,138,000	$109,468,000	$0
	Total	205	390	$320,109,000	$388,081,000	$949,000
	Hopewell – Residential	16	15	$83,036,000	$39,785,000	$0
	Commercial	0	0	$5,765,000	$18,917,000	<$500
	Industrial	0	0	$29,104,862	$93,067,919	<$500
	Other	0	0	$0	$0	$0
	Total	16	16	$117,906,000	$151,770,000	<$500

Table 5.9: Hazus 100-Year Flood Damage Vulnerability Results						
Analysis Type	**Community**	**Number of Buildings Moderately Damaged (41-50% of Value)**	**Number of Buildings Substantially Damaged (>50% of Value)**	**Building Losses**	**Content Losses**	**Inventory Losses**
	Petersburg – Residential	7	23	$20,988,000	$11,738,000	$0
	Commercial	2	1	$2,267,000	$7,500,000	<$500
	Industrial	1	1	$5,826,000	$17,724,000	<$500
	Other	0	0	$0	$0	$0
	Total	10	25	$29,080,810	$36,961,004	<$500
	Powhatan County – Residential	3	62	$21,462,000	$7,014,000	<$500
	Commercial	0	0	$0	$0	$0
	Industrial	0	0	$0	$0	$0
	Other	0	0	$0	$0	$0
	Total	3	62	$21,462,000	$7,014,000	<$500
	Richmond – Residential	49	92	$79,071,000	$41,606,000	$0
	Commercial	2	6	$57,905,000	$82,338,000	<$500
	Industrial	7	12	$64,014,789	$146,556,947	<$500
	Other	0	3	$9,123,051	$19,266,061	$0
	Total	58	113	$210,114,000	$289,767,000	<$500
Supplementary Level 1 Analysis of Zone A areas	**Dinwiddie County –** Residential	0	0	$4,830,000	$3,580,000	$0
	Commercial	0	0	$120,000	$410,000	$0
	Industrial	0	0	$20,000	$40,000	$0
	Other	0	0	$50,000	$260,000	$0
	Total	0	0	$5,010,000	$4,290,000	<$500
	Powhatan County – Residential	0	0	$8,890,000	$4,770,000	$0

Table 5.9: Hazus 100-Year Flood Damage Vulnerability Results						
Analysis Type	**Community**	**Number of Buildings Moderately Damaged (41-50% of Value)**	**Number of Buildings Substantially Damaged (>50% of Value)**	**Building Losses**	**Content Losses**	**Inventory Losses**
	Commercial	0	0	$200,000	$610,000	$0
	Industrial	0	0	$100,000	$150,000	$10000
	Other	0	0	$120,000	$730,000	$10000
	Total	0	0	$9,310,000	$6,260,000	$30,000
Totals		**827**	**1987**	**$1,677,375,241**	**$2,005,687,857**	**$194,565,249**

Source: Hazus

Clearly, much of the Richmond-Crater region is susceptible to costly damage resulting from flood events and Figures 5.5a through 5.5j indicate where the flood risk is highest. The densely developed areas of the region (Chesterfield County, Hanover County, Henrico County and Richmond) have the highest numbers of repetitive losses and highest predicted number of structures expected to be damaged in a 100-year flood event based on the Hazus data.

The repetitive flood loss areas shown in Figures 5.5a through 5.5j indicate where within each community the flood damage has historically been highest and can be expected to continue into the future without large-scale mitigation measures to reduce flood vulnerability.

Vulnerability to stormwater flooding caused by precipitation and/or stormwater management infrastructure issues was not directly evaluated due to insufficient and inconsistent data across the study area. Although some municipalities have made progress in evaluating this specific type of flooding and have started collecting data to reflect historic occurrences and future vulnerabilities, data are not available to express quantitative risk in a meaningful way for the whole region.

Annualized NCEI Events and Damages

The NCEI flood events have been annualized and summarized in **Table 5.10**. Recurrence intervals can be estimated using the number of flood occurrences over a period of time. According to the NCEI database, there have been 259 recorded flood events for the region that have caused notable floods in the past 27 years, for a flood recurrence interval of approximately 9.6 events per year, with each event averaging about $91,000 in property and around $3,900 in crop damages, for a total of about $95,000 in average annual losses.

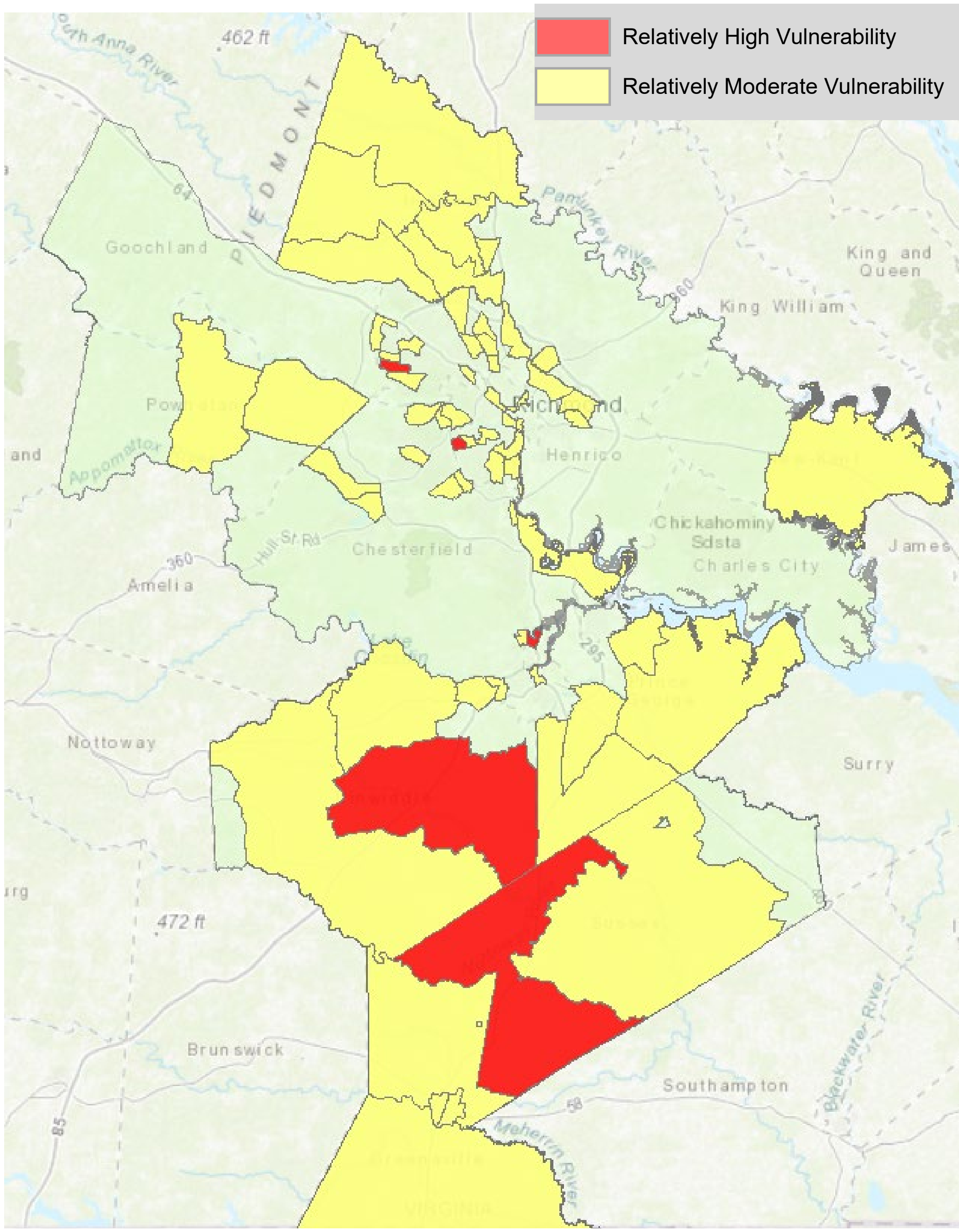
Table 5.10: Annualized Flood Events and Losses, 1993 - 2020				
Jurisdiction	**Annualized Number of Events**	**Annualized Property Losses**	**Annualized Crop Losses**	**Annualized Total Losses**
Charles City County	0.52	$0	$0	$0
Chesterfield County	1.52	$10,647	$111	$10,757
City of Colonial Heights	0.30	$2,654	$0	$2,654
Dinwiddie County (inc. Town of McKenney)	0.41	$453	$122	$574
City of Emporia	0.11	$0	$0	$0
Goochland County	0.26	$1,438	$442	$1,880
Greensville County (inc. Town of Jarratt)	0.48	$39,451	$0	$39,451
Hanover County (inc. Town of Ashland)	0.85	$6,074	$929	$7,003
Henrico County	1.11	$0	$0	$0
City of Hopewell	0.33	$2,654	$0	$2,654
New Kent County	0.78	$4,050	$0	$4,050
City of Petersburg	0.63	$5,240	$0	$5,240
Powhatan County	0.48	$1,443	$0	$1,443
Prince George County	0.56	$0	$0	$0
City of Richmond	0.59	$3,508	$0	$3,508
Surry County (inc. Towns of Claremont, Dendron, Surry)	0.81	$54,074	$27,778	$81,852
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	0.67	$13,545	$2,303	$15,849
Totals	**9.59**	**$91,156**	**$3,907**	**$95,063**

Source: NCEI

Social Vulnerability

Social vulnerability to flood hazard for the Richmond Crater region is shown in **Figure 5.6**, categorized by Census tract. For legibility and simplicity, only areas designated “Relatively High” or “Relatively Moderate” are shown. There were no areas of “Very High” social vulnerability to flood in the Richmond-Crater region. The map shows two large tracts of relatively high social vulnerability to flood at the boundary between Dinwiddie and Sussex Counties, as well as another tract on the south shore of Swift Creek in Colonial Heights rated as relatively high. The tract at the northeast corner of the intersection of Chippenham Parkway and Midlothian Turnpike in Richmond is rated relatively high, as is another tract just north of Patterson Avenue in Henrico County, at the boundary with Goochland County.

Figure 5.6: Social Vulnerability to Flood Hazards



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has relatively moderate social vulnerability for flooding.

Future Vulnerability, Land Use and Climate Change Impacts

Future vulnerability will be determined, in part, by local officials. Flood hazard and SLOSH maps are available to indicate what areas of the region are most vulnerable to flood and flood-related hazards. These planning tools are currently used to help guide development away from hazardous areas. Local officials are responsible for enforcing local floodplain management regulations, flood damage prevention ordinances, and other forms of development policies that restrict new development in flood hazard areas. Additional discussion of actions these communities have taken to guide land use and reduce future flood vulnerability is provided in Section 6, the Capability Assessment.

An unusual component of future flood vulnerability in the study area is the likelihood of mass evacuation (due to flooding and tropical storms from nearby coastal areas) *into* the Richmond-Crater region. Mass evacuations from urban areas can strain a community's resources and cause gridlock on major transportation routes, overcrowding of hospitals and shelters, and increased load on local utilities' infrastructures leading to potential failure.

A mass evacuation of significant proportions has not impacted the area in the past two decades. In anticipation of Hurricane Floyd in September 1999, more than three million people were evacuated from Florida to the North Carolina coastline, and to a lesser extent from the Virginia coast. Although the majority of these evacuations were from North and South Carolina coasts to inland areas of those states, some limited impact was experienced in the planning region.

The probability of a mass evacuation impacting the planning region includes factors such as the probability and location of the hazard that would make such an evacuation necessary, as well as sociological considerations. An influx of evacuees as a result of a mass evacuation has the potential to overload infrastructure and support systems. Impacted segments might include transportation, public safety, medical facilities and shelters, utilities, and depending on the duration of the evacuation, potentially the education sector. Jurisdictions located along major evacuation routes are more likely to be impacted.

In its June 2021 report entitled *The Impact of Climate Change on Virginia's Coastal Areas*, the Virginia Academy of Science, Engineering, and Medicine (VASEM), laid out the consequences of climate change for Virginians.[8] VASEM is a nonprofit organization consisting of members of the National Academies of Science, Engineering, and Medicine who reside or work in Virginia as well as other Virginians who are leaders in these fields. The most immediate consequence of climate change is sea level rise, caused primarily by melting ice and glaciers and thermal expansion. Additional consequences related to flooding include more recurrent flooding (higher frequency of occurrence for damaging floods), extreme rainfall and inundation of septic systems. The report projects that, particularly in urban areas, recurrent flooding will have a disproportional impact on racial and ethnic minorities, the poor, the elderly, renters, non-native English speakers, and those with mobility challenges. Exposure to a growing number of flood-prone facilities regulated

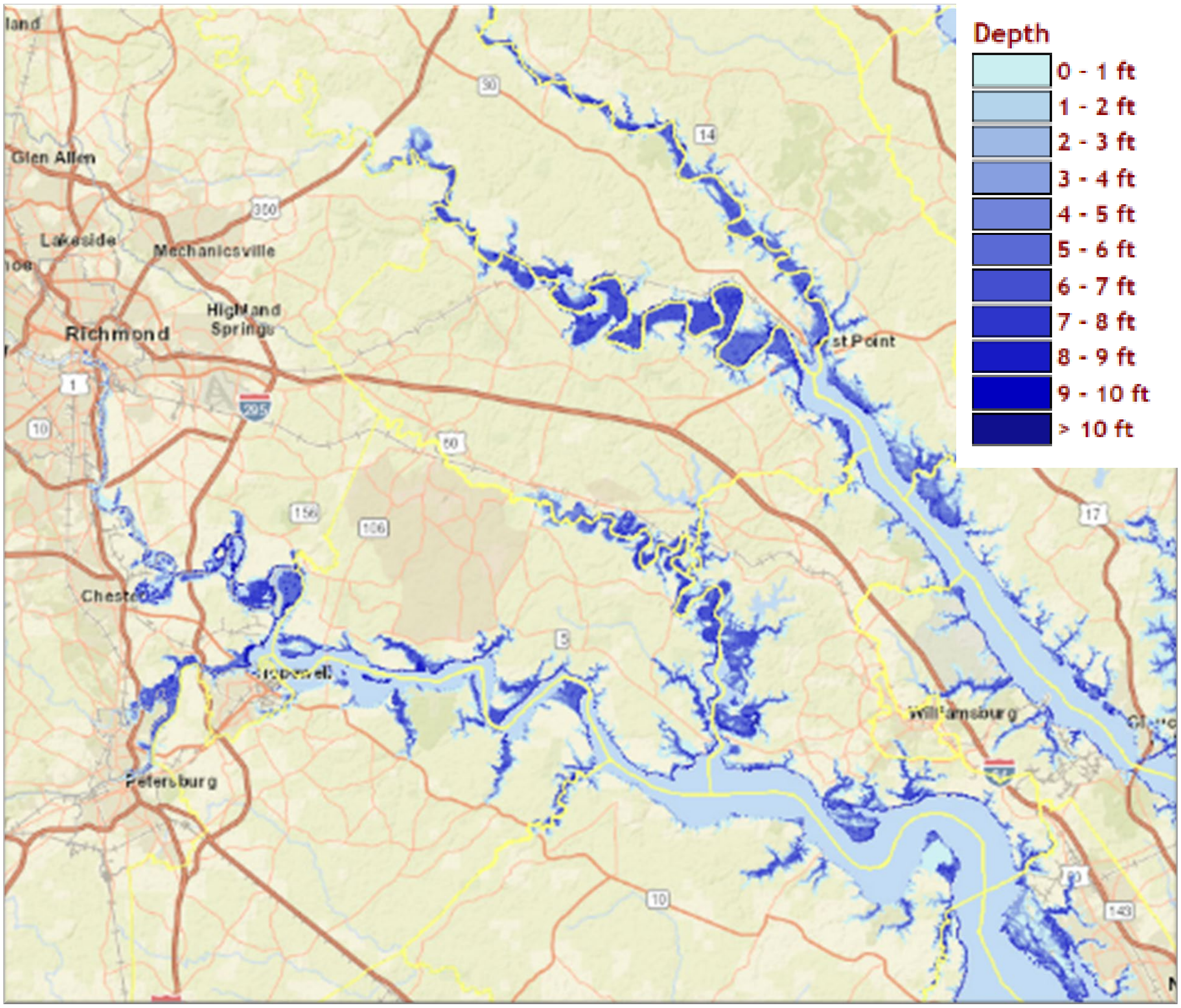
[8] http://www.vasem.org/wp-content/uploads/2021/08/VASEM_VirginiasCoastalAreasReport_FINAL.pdf

for toxic and hazardous substances as sea levels rise is another concern, particularly on the James River, between Richmond and Hampton Roads. Impacts in rural areas are more likely to be centered around soil quality, such as water-logged soils in flood-prone areas, increased salinity due to saltwater intrusion and septic system failures that affect public health.

The sea level rise curve chosen by the Commonwealth for planning purposes (NOAA's "intermediate-high" projection) is shown for each of the affected communities in the study area in **Figure 5.7**. This map is from the Virginia Institute of Marine Science (VIMS) Sea Level Rise Projection tool available online at:
http://cmap2.vims.edu/SeaLevelRise_Depth/SLRDepth_revised4.html.

Using this same projection for sea level rise, Old Dominion University and the Commonwealth Center for Recurrent Flooding Resiliency researchers have quantified their projections for impacts from sea level rise, categorized by the Commonwealth's planning districts. PlanRVA and Crater PDC combined are expected to see almost 5,000 parcels, 600 structures, and 14 miles of roadway flooded or otherwise impacted by sea level rise by 2080.

Figure 5.7: Sea Level Rise Projection for year 2100, Intermediate High Scenario



Source: VIMS Sea Level Rise Projection tool accessed online 2021 at:
http://cmap2.vims.edu/SeaLevelRise_Depth/SLRDepth_revised4.html

Increased levels of precipitation from storm events sometimes overwhelm existing municipal stormwater management systems in the region, which can result in roadway flooding, safety and access concerns, and issues with water quality and treatment capacity. As precipitation events become more intense and flashy, the ability of the existing stormwater management systems to collect, convey, treat, and discharge flow will be further reduced. In some parts of the study area, increased high tide levels due to sea level rise may impact or block the discharge points, creating further cause for storm flooding.

The average annual number of days with heavy precipitation is expected to increase in the future as a result of climate change. This increased precipitation will have an impact on the frequency of regional flooding, especially riverine flooding, but may also impact coastal flooding. Heavy precipitation events can easily overwhelm existing infrastructure, causing failure of stormwater culverts, bridge scour, and overland flooding affecting areas and structures that do not normally flood. Increased heavy precipitation can impact dams and, over time, influence flood frequency curves that are used for a variety of insurance, building safety and planning purposes.

According to 2022 data from the Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA)[9] , under a moderate emissions scenario, Glen Allen can expect that for the period 2066 to 2095, the average number of days per year with rainfall greater than 1 inch will be 7.8 days, which is 27% more than in the period between 1976 and 2005. Approximately the same percentage increase is expected across the PlanRVA portion of the region; the Crater PDC portion of the study area was not studied. On the other hand, the number of days with rainfall greater than 3 inches is 0.2, 63% more than in 1976-2005 for Glen Allen. The predictions for days with this severe rainfall are not uniform across the Plan RVA region and range from a low of 30-percent increase in parts of Prince George County, to an 83-percent increase in Richmond.

5.5 Flooding Due to Impoundment Failure

Hazard Profile

Flooding due to impoundment failure refers to a collapse, overtopping, breaching, or other failure that causes an uncontrolled release of water or sludge from an impoundment, resulting in downstream flooding. Dam or levee failures can occur with little warning. Intense storms may produce a flood in a few hours or even minutes from upstream locations. Flash floods can occur within six hours of the beginning of heavy rainfall, and impoundment failure may occur within hours of the first signs of breaching. Other failures and breeches can take much longer to occur, from days to weeks, because of debris jams or the accumulation of melting snow.

Dam risk can be categorized as either incremental, non-breach, or residual. Incremental risk is the risk (both likelihood and consequences) to the pool area and downstream floodplain occupants that can be attributed to the presence of the dam should the dam breach prior or subsequent to overtopping, or undergo component malfunction or misoperation, where the consequences considered are over and above those that would occur without dam breach. The consequences typically are due to downstream inundation, but loss of the pool can result in significant consequences in the pool area upstream of the dam. Non-breach risk refers to risk in the reservoir pool area and affected downstream floodplain due to 'normal' dam operation of the dam (e.g., large spillway flows within the design capacity that exceed channel capacity) or 'overtopping of the dam without breaching' scenarios. Residual risk is the risk that remains after all mitigation actions and risk reduction actions have been completed. With respect to dams, FEMA defines residual risk

[9] Mid-Atlantic Regional Integrated Sciences and Assessments: https://public.tableau.com/views/Climate_summary_rainfall_20181112_PUBS/3b?:embed=y&:toolbar=n&:embed_code_version=3&:loadOrderID=0&:display_count=y&:origin=viz_share_link

as "risk remaining at any time". It is the risk that remains after decisions related to a specific dam safety issue are made and prudent actions have been taken to address the risk. It is the remote risk associated with a condition that was judged to not be a credible dam safety issue.[10]

Hazard Profile: Dam Failure

Failure of dams may result in catastrophic localized damages. Vulnerability to dam failure is dependent on dam operations planning and the nature of downstream development. Depending on the elevation and storage volume of the impoundment, the impact of flooding due to dam failure may include loss of human life, economic losses such as property damage and infrastructure disruption, and environmental impacts such as destruction of habitat. Flooding following a dam failure may occur due to any one or a combination of the following causes:

- Prolonged periods of rainfall and flooding;
- Inadequate spillway capacity;
- Internal erosion caused by embankment or foundation leakage or piping, or earth movement resulting from an earthquake;
- Improper maintenance, including failure to remove trees, repair internal seepage problems, replace lost material from the cross section of the dam and abutments, or maintain gates, valves, or other operational components;
- Improper design, including the use of improper construction materials and construction practices;
- Negligent operation, including failure to remove or open gates or valves during high flow periods;
- Failure of upstream dams on the same waterway;
- High winds, which can cause significant wave action and result in substantial erosion; or
- Intentional criminal acts.

Dams are classified in Virginia by the DCR, with a hazard potential depending on the downstream losses estimated in event of failure. Hazard potential is not related to the structural integrity of a dam but strictly to the potential for adverse downstream effects if the dam were to fail. State regulatory requirements administered by DCR, such as the frequency of dam inspection, the standards for spillway design, and the extent of emergency operations plans, are dependent upon the dam classification. **Table 5.11** provides additional information on these classes and the possible effects on downstream areas if failure were to occur.

[10] FEMA, *Rehabilitation of High Hazard Potential Dams Grant Program Guidance*, June 2020.

Table 5.11: Virginia Dam Classification System		
Hazard Potential	**Description**	**Inspection**
High (Class I)	Failure will cause probable loss of life or serious economic damage (to buildings, facilities, major roadways, etc.)	Annual, with inspection by a professional engineer every 2 years.
Significant (Class II)	Failure may cause loss of human life or appreciable economic damage (to buildings, secondary roadways, etc.)	Annual, with inspection by a professional engineer every 3 years.
Low (Class III)	Failure would result in no expected loss of human life, and cause no more than minimal economic damage	Annual, with inspection by a professional engineer every 6 years.

Source: 2018 Commonwealth of Virginia Hazard Mitigation Plan

The owner of each regulated high, significant, or low hazard dam is required to apply to DCR for an Operation and Maintenance Certificate. The application must include an assessment of the dam by a licensed professional, an Emergency Action Plan, and the appropriate fee(s), submitted separately. An executed copy of the Emergency Action Plan or Emergency Preparedness Plan must be filed with the appropriate local emergency official and the Virginia Department of Emergency Management. The Virginia Soil and Water Conservation Board (VSWCB), a division of DCR, issues Regular Operation and Maintenance Certificates to the dam owner for a period of six years. If a dam has a deficiency but does not pose imminent danger, the board may issue a Conditional Operation and Maintenance Certificate, during which time the dam owner is to correct the deficiency. After a dam is certified by the board, annual inspections are required either by a professional engineer or the dam owner, and the Annual Inspection Report is submitted to the regional dam safety engineer.

Dam risk can be classified as incremental, non-breach or residual risk. Incremental risk is the risk (likelihood and consequences) to the pool area and downstream floodplain occupants that can be attributed to the presence of the dam should the dam breach prior or subsequent to overtopping, or undergo component malfunction or misoperation, where the consequences considered are over and above those that would occur without dam breach. The consequences typically are due to downstream inundation, but loss of the pool can result in significant consequences in the pool area upstream of the dam. Non-breach risk is the risk in the reservoir pool area and affected downstream floodplain due to 'normal' dam operation of the dam (e.g., large spillway flows within the design capacity that exceed channel capacity) or 'overtopping of the dam without breaching' scenarios. Residual risk is the risk that remains after all mitigation actions and risk reduction actions have been completed. With respect to dams, FEMA defines residual risk as "risk remaining at any time" (FEMA, 2015, p A-2). It is the risk that remains after decisions related to a specific dam safety issue are made and prudent actions have been taken to address the risk. It is the remote risk associated with a condition that was judged to not be a credible dam safety issue.[11]

At this time, limited information is available to conduct an analysis of incremental, non-breach and residual risk relative to the high hazard potential dams in the region. Please refer to Section 3.11: Flooding Due to Impoundment Failure of the *2018 Commonwealth of Virginia Hazard Mitigation Plan*, as amended, for additional information regarding the statewide approach to dam risk. That section of the state's plan is hereby incorporated by reference.

The Commonwealth of Virginia relies upon FEMA's definition of risk: "Risk is the product of the likelihood of a structure being loaded, adverse structural performance, and the magnitude of the resulting consequences." Risk data are compiled in the state's Dam Safety Inventory System (DSIS) for each high hazard dam. DCR, VDEM and local emergency and planning staff are given copies of emergency action plans and plans include detailed information on risk to the following:

- Dwellings
- Schools
- Hospitals
- Businesses
- Railroads:
- Utilities:
- Parks:
- Golf Course
- Public Trails
- Emergency Infrastructure.

The summary impacts shown in **Table 5.12** are drawn from the information in DSIS and the Emergency Action Plans (EAPs) for the high hazard potential dams, These data represent how Virginia summarizes significant economic, environmental and social impacts from a dam incident. Factors considered in risk assessment include the population at risk, land use, inspection condition assessment and any missing studies such as stability analyses under normal and extreme loading conditions (seismic and hydrologic), and any measures underway that affect the operational status, such as drawdowns or temporary pumps and siphons, when dams are compromised.

Owners of impounding structures are required to have dam break inundation zone maps that meet the standards of the Virginia Impounding Structure Regulations. The properties that are identified within the dam break zone are recorded in the dam safety emergency

[11] FEMA, Rehabilitation of High Hazard Potential Dams Grant Program Guidance, June 2020

action plan for that impoundment. DCR is pursuing efforts to make this information available in a digital form, but it is not currently available for all dams. The 2018 *Commonwealth of Virginia Hazard Mitigation Plan* indicates that such data would greatly improve ability to identify impact and vulnerability due to dam inundation.

Table 5.12 lists the high hazard dams in the study area from DCR's database and includes key details regarding each dam's basic characteristics, EAP status and a summary of expected impacts resulting from dam failure. The impacts are based on modeling requirements for high hazard dams that include two scenarios: 1) sunny day breach (incremental risk); and 2) probable maximum flood (non-breach risk). Appendix I provides a list of all dams in the study area from the DCR database, as well as the EAPs for each of the high hazard dams. The high hazard dams that have latitude and longitude characteristics identified in the U.S. Army Corps of Engineers' National Inventory of Dams are shown in Figure 5.8.

In addition to dams located within the study area, there are several high hazard dams upstream of the study area that could impact the region if the dam(s) were to fail or overtop, including:

Louisa County – Lake Anna Dam and Reservoir, Gordonsville Dam, South Anna Dam #22, South Anna Dam #6b, South Anna Dam #3, South Anna Dam #4, South Anna Dam #5;

Fluvanna County – Bremo Power Station Dam, Lake Monticello Dam, Fluvanna Ruritan Da, Bremo Power Station East Ash Pond Dam, Lake Monticello Settlement Pond Dam;

Cumberland County – Willis River Dam #6, Cobbs Creek Regional Water Supply Dam, Cobbs Creek Regional Water Supply Reservoir Saddle Dam, Cobbs Creek Regional Water Supply Reservoir Dam Perimeter Dam;

Amelia County – Bridgeforth Mill Dam;

Nottaway County – Nottoway Lake Dam.

Information on these dams is available through the State's DSIS program and the USACE NID.

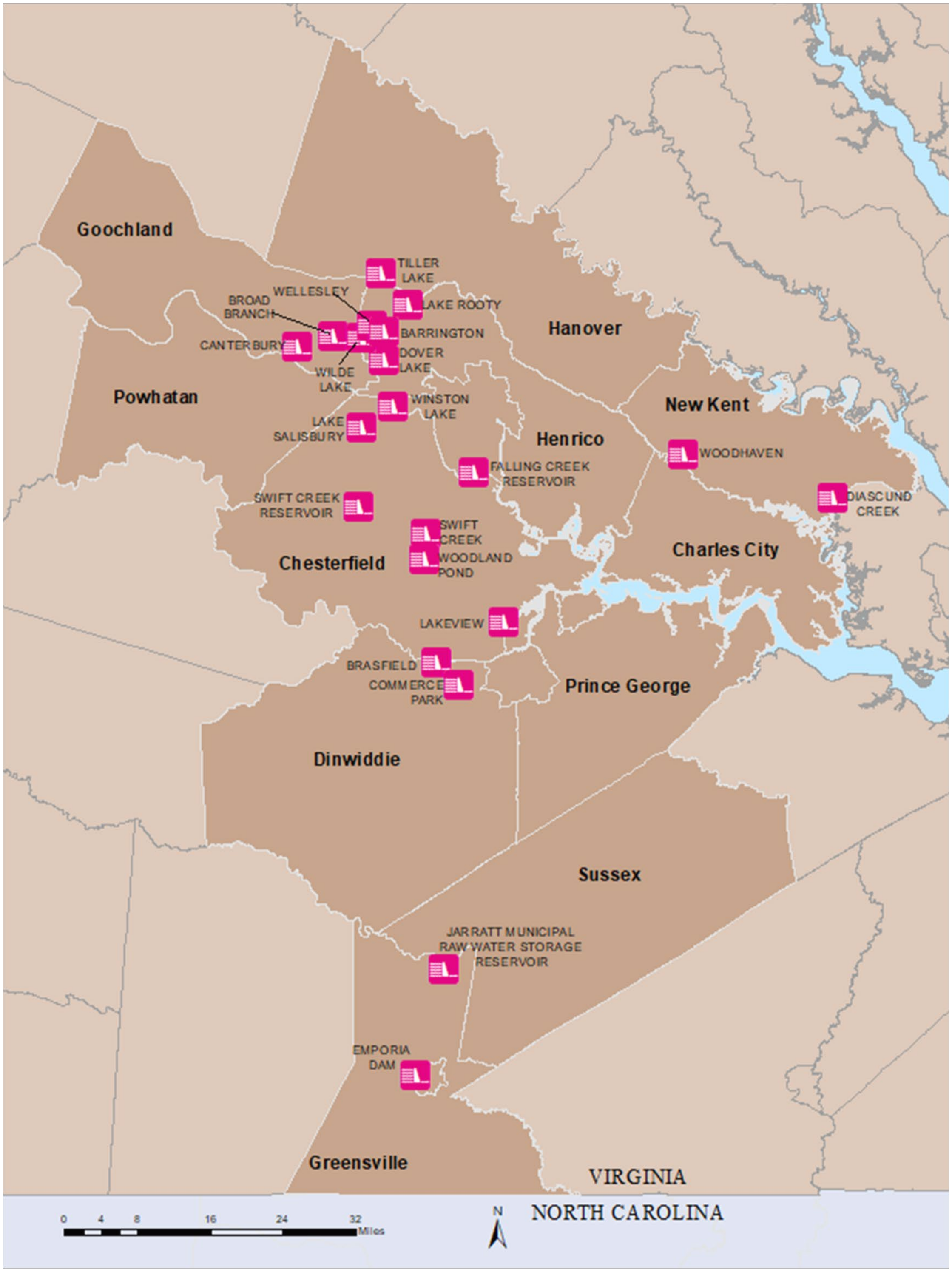
Table 5.12: High Hazard Dams in the Richmond-Crater Region								
Jurisdiction	**Dam Name**	**Dam Type**	**Year Built**	**Reservoir Purpose**	**Top Height (Feet)**	**Top Capacity (Acre-Feet)**	**EAP Status (Last Approval)**	**Downstream Impacts**
Chesterfield County	Cosby Dam	Gravity	1956	Recreation	17	85	Expired (11/15/2014)	Not provided
	Lake Crystal Dam				18	64		Not provided
	Lake Salisbury Dam	Earth	1973	Recreation	38	990	Expired (11/30/2010)	1,870 homes, 6 roads, 2 dams downstream
	Margaret Dam	Buttress	1961	Water Supply & Recreation	35	410	Expired (3/9/2007)	25 roadways, 208 homes
	Swift Creek Dam	Gravity	1936	Recreation	30.5	7,564	Current (1/3/2018)	32 homes, 1 business, 1 road
	Swift Creek Reservoir Dam	Earth	1965	Water Supply & Recreation	44	50,590	Current (4/8/2019)	2,000 homes, 400 businesses, 1 road
	Wake Lake Dam	Earth	2019	Recreation	15.5	88.71	Current (10/21/2019)	24 houses, 4 businesses, 1 golf course, 8 roads
	Woodland Pond	Earth	1970	Recreation	35	1,870	Current (8/23/2019)	9 homes, 1 golf course, 3 roads
Chesterfield County, City of Richmond	Falling Creek Reservoir Dam	Buttress	1952	Recreation	34	1,511	Current (3/31/2018)	Not provided
Chesterfield & Dinwiddie County	Brasfield Dam	Gravity	1968	Water Supply & Hydro-electric	55	79,500		Not provided
Dinwiddie County	Commerce Park Dam	Earth	1900	Recreation & Flood Control	12	149.4	Expired (1/9/2013)	52 homes, 1 business, 3 roads
Richmond	Winston Lake Dam	Earth	2008	Recreation	28	39	Current (12/15/2017)	2 homes, 2 roads
Goochland County	Broad Branch Dam	Earth	1992	Recreation	29	1,188	Current (5/26/2015)	5 homes, 4 roads
	Dover Lake Dam	Earth	1958	Irrigation & Recreation	41	4,198	Expired (6/1/2012)	3 homes, 1 railroad, 1 road

Table 5.12: High Hazard Dams in the Richmond-Crater Region								
Jurisdiction	**Dam Name**	**Dam Type**	**Year Built**	**Reservoir Purpose**	**Top Height (Feet)**	**Top Capacity (Acre-Feet)**	**EAP Status (Last Approval)**	**Downstream Impacts**
Hanover County, Henrico County	Tiller Lake Dam	Earth	2000	Irrigation	13	87.33	Expired (1/1/2010)	8 homes
Henrico County	Barrington Dam	Earth		Fire Protection & Recreation	16.5	100	Current (11/4/2014)	13 homes, 2 downstream dams
	Canterbury Dam	Earth	1965	Recreation	13	162	Current (5/18/2021)	200 homes, 5 businesses, 1 road
	Echo Dam	Earth	1900	Recreation	19	139	Current (5/5/2021)	73 homes, 1 park, 3 roads including I-295
	Lake Overton Dam	Earth	1970	Recreation	18	106	Expired (9/8/2005)	Not provided
	Lake Rooty Dam	Earth			22	142	Expired (5/15/2014)	8 homes
	Wellesley Dam	Earth	1987	Recreation	29	131.3	Expired (5/17/2021)	19 homes, 1 downstream dam
Petersburg	Wilcox Dam	Earth	1900	Recreation	18	200.29	Current (10/30/2020)	113 homes, 2 businesses, 1 hospital, 1 railroad, 10 roads, 1 downstream dam
Powhatan County	Mill Quarter Lake Dam	Earth	1974	Recreation	36	2,159	Expired (7/15/2012)	44 homes, 1 business, 1 road
	Upper Powhatan Dam	Earth	1810	Recreation	26.75	750	Expired (5/9/2008)	2 roads, 1 dam downstream
Colonial Heights	Lakeview Dam	Gravity	1920	Hydro-electric & Recreation	38.6	610	Current (1/1/2018)	Not provided
Emporia, Greensville County	Emporia Dam	Gravity	1908	Hydro-electric & Water Supply	42.5	9,500	Expired (1/31/2012)	Not provided
Greensville County	Jarratt Municipal Raw Water Storage Reservoir Dam	Earth	2018	Water Supply	51	3,682	Current (6/2/2020)	5 homes, 2 roads, 1 dam downstream

Table 5.12: High Hazard Dams in the Richmond-Crater Region								
Jurisdiction	**Dam Name**	**Dam Type**	**Year Built**	**Reservoir Purpose**	**Top Height (Feet)**	**Top Capacity (Acre-Feet)**	**EAP Status (Last Approval)**	**Downstream Impacts**
James City County, New Kent County	Diascund Creek Dam	Earth	1961	Water Supply & Recreation	35	29,093	Current (8/18/2016)	208 homes, 25 roads
New Kent County	Woodhaven Dam	Rockfill	1961	Recreation	23	1297	Current (8/7/2020)	10 homes, 1 railroad, 2 roads

Source: DCR, Dam Safety Inventory System, accessed April 2021

Figure 5.8: High Hazard Dams in the Richmond-Crater Region



Source: USACE National Inventory of Dams, 2021

Hazard Profile: Levee/Floodwall Failure

FEMA defines a levee as 'a man-made structure, usually an earthen embankment, designed and constructed in accordance with sound engineering practices to contain, control, or divert the flow of water to reduce the risk from temporary flooding.' Much like dams, levees and floodwalls require regular maintenance and inspection. Many of the causes and effects of levee failure are similar to dam failure. Though levees can reduce some flood risks, they do not eliminate risks. By creating a false sense of safety, communities may invest in development in levee-impacted areas and thus increase the flood risk. Flood risks associated with levees can change over time: if levees are not properly maintained, the risk of failure may increase, resulting in catastrophic flooding. Similarly, if flood hazards change or exceed design protection levels, overtopping of levels can be disastrous.

A levee designed to provide flood protection from at least the 1% annual chance flood is eligible for accreditation by FEMA. When accredited, the area protected by the levee will be mapped as a moderate risk zone instead of a high-risk zone on the FIRM.

The James River Levee System in Richmond secured FEMA levee accreditation in 2012. Other levees in Virginia have never been recognized as providing 100- year protection or have been de-accredited. De-accreditation does not necessarily mean the levee no longer can provide 100-year flood protection but may mean that the community or levee owner did not provide the necessary documentation to prove protection.

The James River Levee System (**Figure 5.9**) is a local system of flood protection with a total length of 17,327 feet (3.28 miles) and protects 750 acres valued at approximately $153 million. The line of protection extends across the mouth of Shockoe Valley to 12th Street. The wall is designed to protect those areas located behind it against a flood with an average recurrence interval of 280 years. The project was dedicated on October 21, 1994, at a cost of $143 million.

The line of protection extends from just west of the Manchester bridge, continues along the river's edge to the west side of Interstate 95, turns south, then west, crossing the CSX Railway mainline tracks, and tying into high ground at Goodes Street. The entire system consists of multiple components in addition to the levees and floodwall:

- A partially rip-rapped earthen levee;
- A concrete floodwall;
- Three overlooks (9th & Semmes, Hull & Mayo Bridge, and 12th & Byrd);
- Six roadway closures;
- Six railroad closures;
- Four personnel closure locations;
- Two combined roadway/railroad closures;
- Three pump stations; and
- Three designated ponding areas.

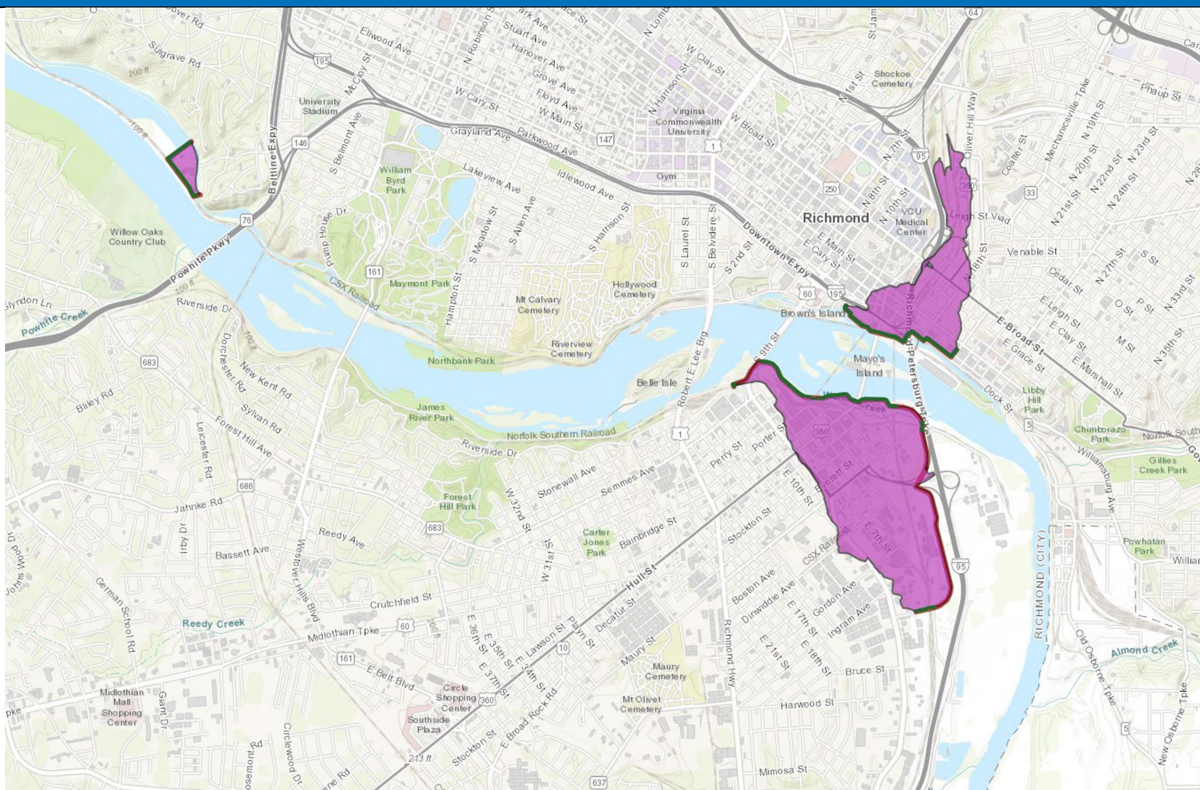
The northern alignment is comprised of one component – a concrete floodwall that is approximately 4,500 feet long with height variations from five to 29 feet. The southside alignment has three components:

- One earthen levee, approximately 9,000 feet long;
- A combination bin wall/levee, approximately 2,000 feet long; and
- A concrete floodwall, approximately 2,000 feet long.

Interior runoff from the watershed in excess of the capacity of the pump station during high river stages will be collected or backed up into the ponding areas. After the river recedes, all ponding areas will drain by gravity through their respective outlets.

Risk for the levee system is considered low. The south portion of the project protects a population of 1,271 people, 146 structures, and property valued at $397 million. The estimated population protected by the levee is 2,578 people, with 296 structures, and property valued at $501 million.

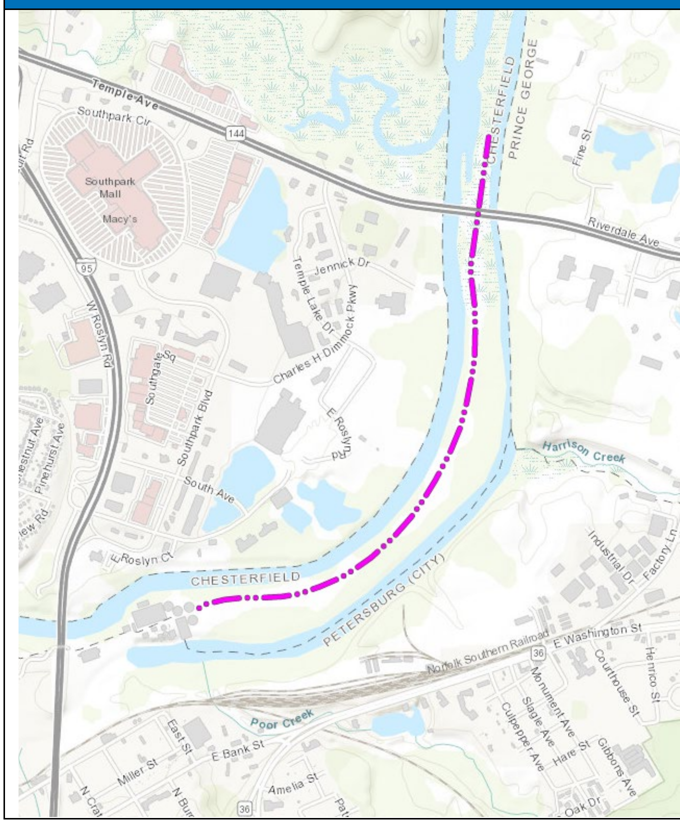
Figure 5.9: James River Levee System, Richmond



Source: U.S. Army Corps of Engineers, [National Levee Database] and the City of Richmond Department of Public Utilities, 2021

The Appomattox River Levee in Colonial Heights is not accredited by FEMA as providing 100-year flood protection. The embankment is 1.44 miles long, lying on a bend in the river as it exits the Petersburg area and turns north toward Back Creek and Gilliams Island (**Figure 5.10)**.

Figure 5.10: Appomattox River Levee, Colonial Heights



Source: U.S. Army Corps of Engineers, National Levee Database, *2021*

Hazard History

There are no comprehensive databases of historical dam failures or flooding following a dam failure or levee failure in Virginia. Most failures occur due to lack of maintenance of dams in combination with major precipitation events, such as hurricanes and thunderstorms. The 2018 *Commonwealth of Virginia Hazard Mitigation Plan* lists two notable events in the study area.

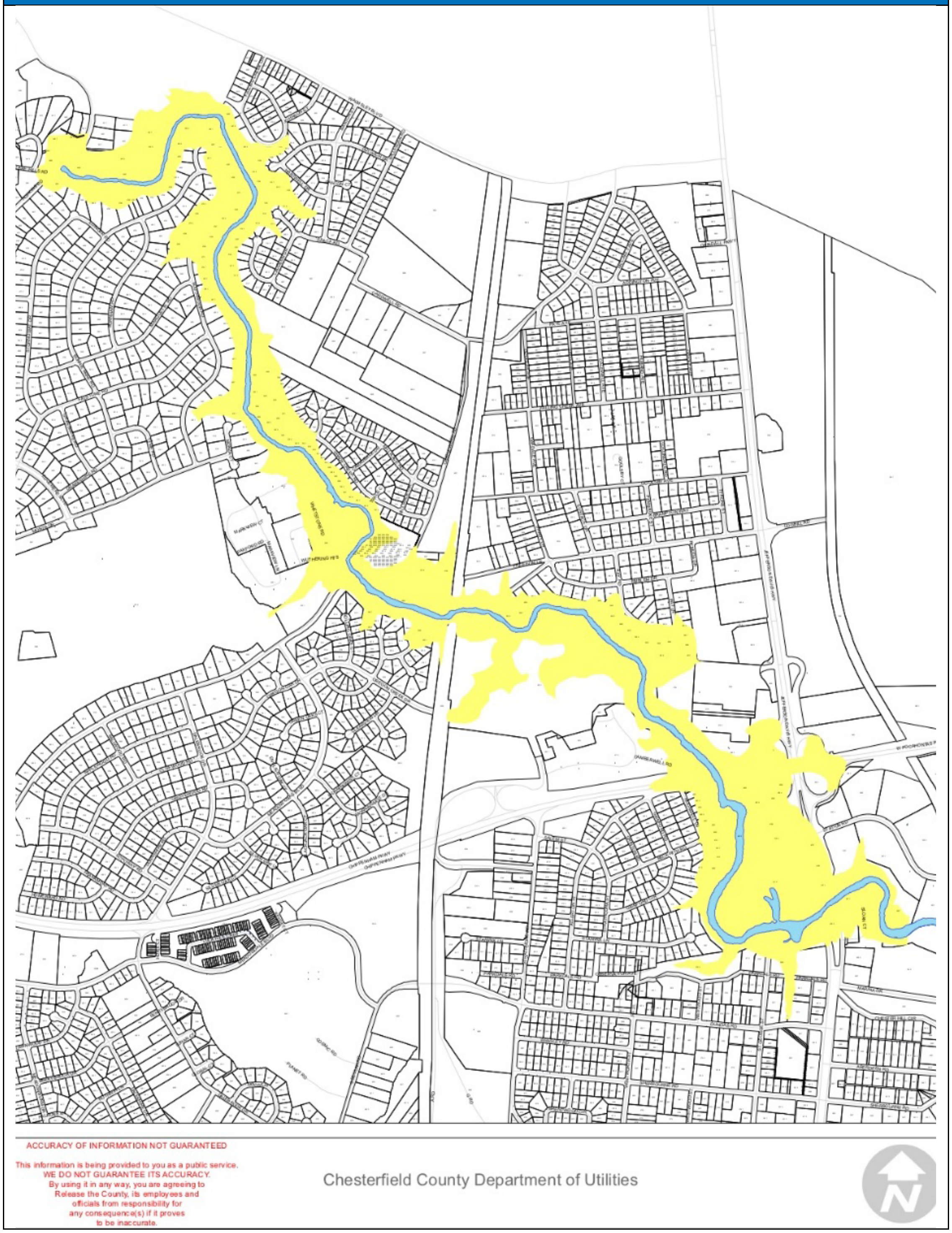
- The Powhatan Lakes Dam failed due to a heavy storm during June 2004 and caused over one million dollars in damage. The eventual breaching of the upper dam led to the subsequent chain-reaction breaching of the lower dam. According to the Virginia Department of Wildlife Resources, local news sources indicated that as much as five inches of rain may have fallen within a two-hour period.

- Falling Creek Dam in Chesterfield County was overtopped during Tropical Storm Gaston flooding in late summer 2004 with evacuations ordered for hundreds of families. Also, on the evening of August 15, 2020, officials issued an evacuation order for more than 150 residences in several neighborhoods near Falling Creek Dam and opened a shelter for evacuees. At 5:45pm that day, the dam was at a stage three flood advisory with a water level over 100 feet. By the next morning, the water levels had decreased, and the evacuation order was lifted. See **Figure 5.11** below that shows the dam inundation areas for this dam.
- Several dams in Virginia failed or were overtopped following Tropical Depression Ernesto in 2006.

In May 2018, Canterbury Dam in Henrico County overtopped after a rainfall event triggered severe flooding. The dam is an earthen dam along Deep Run Creek and impounds an approximately 12-acre recreational lake in the Short Pump neighborhood. The incident caused significant impacts, including Pump Road being shut down and damage to the downstream section of the dam. To prevent future damage from rainfall events, the county prioritized renovations to the dam. A detailed dam failure analysis to determine the downstream inundation area was conducted, as well as an alternatives analysis to determine renovation options. The county decided to spend roughly $1M to fix the dam and provide overtopping protection to protect the impoundment from failure during passage of the required spillway design storm event.

Installation of improvements to Canterbury Dam
Source: Timmons Group

Figure 5.11: Falling Creek Dam Inundation Areas, in Chesterfield County and Colonial Heights



Source: Chesterfield County Department of Utilities, undated

Social Vulnerability

The location of the study area high hazard dams was overlaid on the foundational social vulnerability map from the NRI. The analysis indicates that 5 dams are located in areas of relatively moderate or relatively high social vulnerability (no dams were in areas of Very High social vulnerability):

Emporia Dam – Relatively High;

Jarratt Municipal Raw Water Storage Reservoir, Brasfield Dam, Falling Creek Reservoir, Dover Lake – Relatively Moderate.

A small portion of the area protected the James River Levee System in Richmond is an area of relatively moderate social vulnerability. The Appomattox River Levee in Colonial Heights lies between an area of relatively high social vulnerability to the northwest near Southpark Mall, and an area of relatively moderate social vulnerability to the east in Petersburg.

According to DCR, social vulnerability is a factor in assessing grant applications prepared by dam owners in the region. Project engineers are also responsible for addressing impacts on historical and cultural impacts in accordance with state and federal regulations.

Future Vulnerability, Land Use and Climate Change

Based on historical experience and the fact that the dams in the study area are aging, precipitation patterns are increasingly more frequent and severe as a result of climate change, and the dams are categorized as High Hazard, there is a moderate probability of a future event involving a dam or levee failure in the study area. There is not expected to be a problem with mass evacuation due to a dam or levee failure, although evacuation on a smaller regional scale is likely and is capably managed by local emergency managers.

5.6 Severe Wind Events (including Tropical Storms, Derechos and Nor'easters)

Wind can be one of the most destructive forces of nature. Strong winds can erode mountains and shorelines, topple trees and buildings, and destroy a community's critical utilities and infrastructure. The analysis in this section focuses on hurricane and tropical storm winds as the most likely type of widespread wind hazards to occur in the region, though more localized damage from high winds also can be caused by straight-line wind events (*i.e.,* derechos), nor'easters, thunderstorms, and tornadoes. Thunderstorms, lightning and tornadoes are discussed in separate subsections of this HIRA.

Hazard Profile

A tropical cyclone is the generic term for a low pressure, non-frontal synoptic scale low-pressure system over tropical or sub-tropical waters with organized convection and definite cyclonic surface wind circulation. Tropical cyclones rotate counterclockwise throughout the Northern Hemisphere. Depending on strength, these weather systems are classified as hurricanes or tropical storms. They are called tropical depressions when wind speed is less than 39 mph, but become tropical storms when their wind speeds are between 39 mph and 73 mph. When wind speeds reach 74 mph the system is classified as a hurricane. Tropical cyclones involve both atmospheric and hydrologic characteristics, such as severe winds, storm surge flooding, high waves, coastal erosion, extreme rainfall, thunderstorms, lightning, and, in some cases, tornadoes. Storm surge flooding can push inland, and riverine flooding associated with heavy inland rains can be extensive. High winds are associated with hurricanes, with two significant effects: building damage and power outages due to airborne debris and downed trees.

The hurricane season in the North Atlantic runs from June 1 until November 30, with the peak season between August 15 and October 15. The average hurricane duration after landfall, is 12 to 18 hours. Wind speeds may be reduced by 50% within 12 hours after the storm reaches land.

Tropical storms are capable of producing great amounts of rain in a short period of time. For example, the Richmond-Crater region experienced more than 12 inches of rain during Tropical Depressions Camille, Isabel and Gaston over a short duration. These high rates of precipitation may cause flash floods and mudslides. The runoff eventually drains into the large rivers which may still be flooding for days after the storm has passed. To complicate matters, storm surge flooding can push inland as was experienced in Claremont and Sunset Beach in Surry County during Hurricane Isabel. Riverine and urban flooding associated with heavy inland rains can be extensive. Many areas of the Coastal Plain region are flat, and intense prolonged rainfall tends to accumulate without ready drainage paths. Storm surge or coastal flooding, and riverine flooding are discussed separately in this HIRA.

Typically occurring in the summer in the Northern Hemisphere, a *derecho* (from the Spanish, meaning "straight") is a wide, long-lived, straight-line windstorm. Derechos are often associated with a fast-moving group of severe thunderstorms forming a mesoscale convective system. Similar to a regular thunderstorm's gust front, a derecho's wind remains sustained for a greater period of time and may exceed hurricane force. The system may remain active for hours or even days as it moves over land.

Similar to hurricanes, nor'easters are coastal storms capable of causing substantial damage to coastal areas in the Eastern United States due to their strong winds and heavy surf. Nor'easters are named for the winds that blow in from the northeast and drive storms up the East Coast along the Gulf Stream, a band of warm water that lies off the Atlantic coast. They are caused by the interaction of the jet stream with horizontal temperature gradients and generally occur during the fall and winter months when moisture and cold air are plentiful.

Nor'easters are known for dumping heavy amounts of rain and snow, producing hurricane-force winds, and creating high surf that causes severe beach erosion and coastal flooding. There are two main components to a nor'easter: (1) a Gulf Stream low-pressure system (counterclockwise winds) generated off the southeastern U.S. coast, gathering warm air and moisture from the Atlantic, and pulled up the East Coast by strong northeasterly winds at the leading edge of the storm; and (2) an Arctic high-pressure system (clockwise winds) which meets the low-pressure system with cold, arctic air blowing down from Canada. When the two systems collide, the moisture and cold air produce a mix of precipitation and have the potential for creating dangerously high winds and heavy seas. As the low-pressure system deepens, the intensity of the winds and waves increase and can cause serious damage to coastal areas as the storm moves northeast. The coastal counties in the eastern portion of the study area are susceptible to the flooding and high wind impacts from nor'easters.

Extreme wind events pose a danger in the region because they can result in localized or widespread power outages, property damage, falling trees, toppled utility poles and damaged buildings. Mobile homes can be particularly vulnerable to high winds, especially if improperly installed. Injury or death to people can result from falling objects or flying debris. Communication and electricity may be lost for days, and roads can be impassable due to standing water, fallen trees and debris. Local businesses can be closed for extended periods of time due to building and content damage, loss of utilities, and transportation challenges. Extreme wind events can blow over tractor trailers on the highway and make driving difficult in a high-profile vehicle or lightweight vehicle. High winds can turn trash cans, lawn and patio furniture, and other property into projectiles resulting in further property damage.

Most deaths in extreme wind events (from wind) are caused by trees falling onto cars or homes. Dead trees or trees weakened by drought, disease, rotting, or pest infestations are the most susceptible to falling. Property owners using chainsaws to remove fallen debris or generators and grills for cooking when power outages occur also account for many deaths and injuries in the aftermath of severe wind events.

Magnitude or Severity

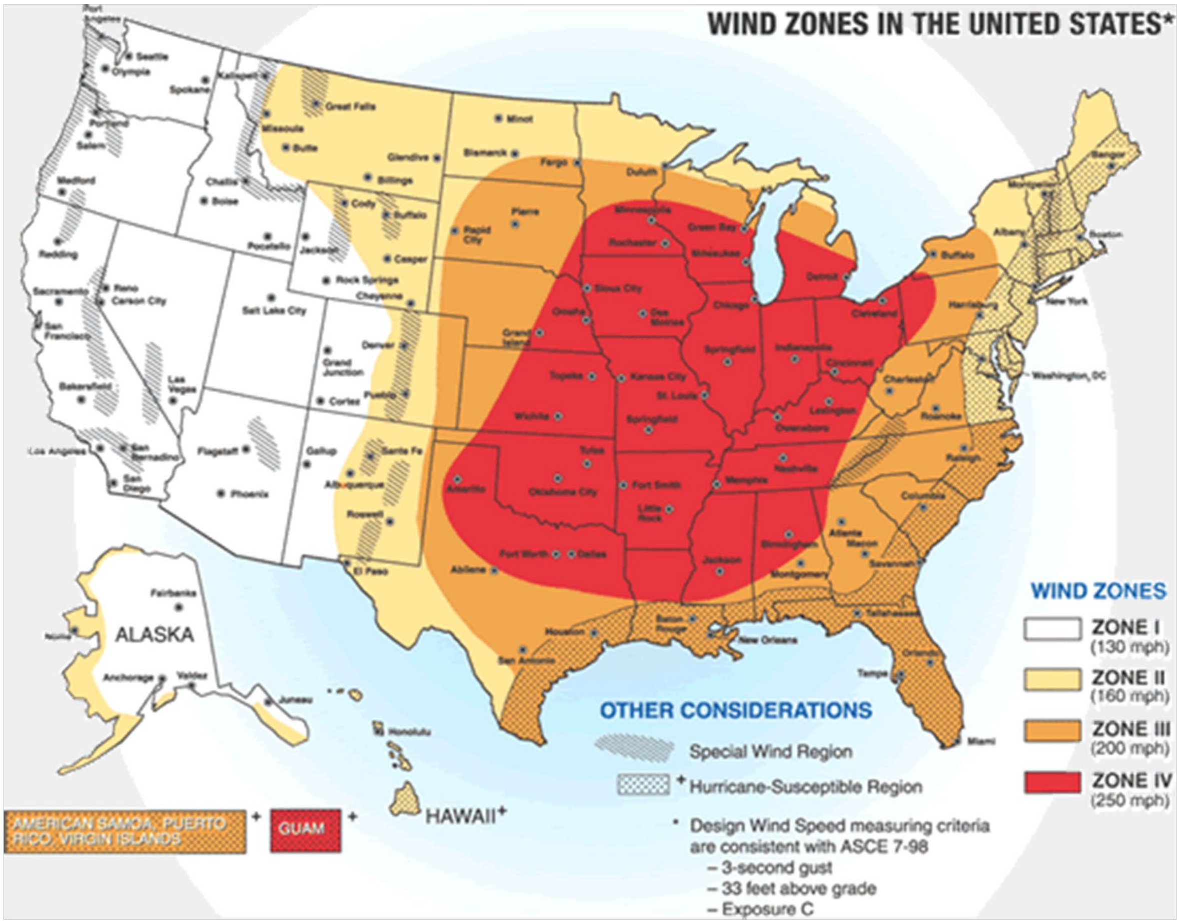
The strength of a hurricane is classified according to wind speed using the Saffir-Simpson Hurricane Damage Scale. This scale provides an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf in the landfall region. **Table 5.13** provides a description of typical damages associated with each hurricane category.

Table 5.13: Saffir-Simpson Hurricane Damage Scale			
Hurricane Category	**Sustained Winds (mph)**	**Damage Potential**	**Description**
1	74–95	Minimal	Minimal damage to unanchored mobile homes along with shrubbery and trees. There may be pier damage and coastal road flooding, with storm surge 4–5 feet above average.
2	96–110	Moderate	Moderate damage potential to mobile homes and piers, as well as significant damage to shrubbery and trees with some damages to roofs, doors, and windows. Impacts include flooding 2-4 hours before arrival of the hurricane in coastal and low-lying areas. Storm surge can be 6–8 feet above average.
3	111–130	Extensive	Extensive damage potential. There will be structural damage to small residences and utility buildings. Extensive damage to mobile homes and trees and shrubbery. Impacts include flooding 3-5 hours before the arrival of the hurricane cutting off the low-lying escape routes. Coastal flooding has the potential to destroy small structures, with significant damage to larger structures as a result of the floating debris. Land that is lower than 5 feet below mean sea level can be flooded 8 or more miles inland. Storm surge can be 6–12 feet above average.
4	131–155	Extreme	Extreme damage potential. Curtain wall failure as well as roof structure failure. Major damage to lower floors near the shoreline. Storm surge generally reaches 13–18 feet above average.
5	> 155	Catastrophic	Severe damage potential. Complete roof failure on residence and industrial structures, with complete destruction of mobile homes. All shrubs, trees, and utility lines blown down. Storm surge is generally greater than 18 feet above average.

Hazard History

Figure 5.12 shows how the frequency and strength of extreme wind events vary across the United States. The map was produced by FEMA and is based on 40 years of tornado history and more than 100 years of hurricane history. Zone IV, the darkest area on the map, has experienced both the greatest number of tornadoes and the strongest tornadoes. As shown by the map key, wind speeds in Zone IV can be as high as 250 mph. Most of the planning region falls within Zone II (winds up to 160 mph) and is considered to be susceptible to hurricanes.

Figure 5.12: Wind Zones in the United States



Source: FEMA, 2011

The Richmond-Crater region is categorized by the American Society of Civil Engineers in its *Minimum Design Loads for Buildings and Other Structures* (ASCE 7) as located in a 90-mph wind zone, based on a 50-year recurrence interval. Based on ASCE 7, the potential wind speed for an event with a 100-year recurrence interval was estimated to be 107% of the 50-year wind speed, or 96.3 mph. The Virginia Uniform Statewide Building Code (VUSBC) requires a 90 mph minimum design wind speed.

High wind events have occurred in every portion of the region. There are no proven indicators to predict specifically where high winds may occur, and wind events can be expansive enough to affect the entire area. The counties on the eastern side of the region are closer to the coast and might experience higher wind speeds from tropical storms or nor'easters that affect Virginia, North Carolina or the northeast United States.

Based on NCEI historical data dating back to the mid-1990s, there have been two deaths and 36 injuries in the region that have resulted from wind, and approximately eight deaths that have resulted from hurricanes. **Table 5.14** includes descriptions of damaging tropical storm and hurricane events in the region, of which there are several. Events have been broken down by the date of occurrence and when available, by individual community descriptions. When no community-specific description is available, the general description applies to the entire region. Although NCEI and VDEM were the primary source of general descriptions, other sources are referenced where more specific information was available.

Table 5.14: History of Wind Events and Damages, 2010–2020*

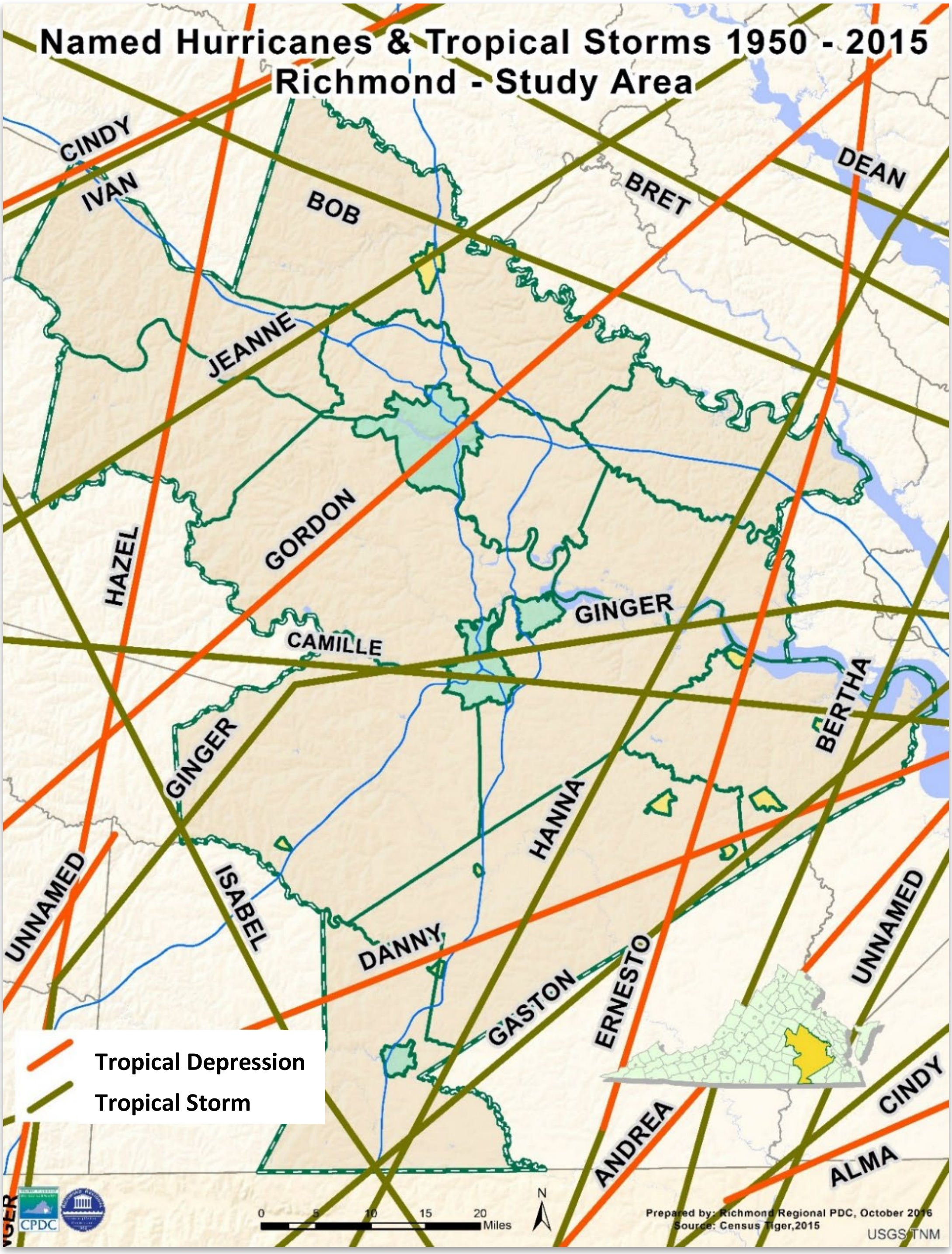
Date	Damages
June 28, 2010	Scattered severe thunderstorms in advance of a cold front produced damaging winds across portions of central Virginia. Trees were downed across eastern portions of Chesterfield County. Trees downed on a home caused the house to collapse in the Sherwood Ridge Subdivision. There was one minor injury. Property damage of $100,000 incurred.
August 27, 2011	Hurricane Irene – See full description in Flood section.
September 4, 2011	Hurricane Lee – See full description in Flood section.
June 29, 2012	A devastating line of thunderstorms known as a derecho moved east-southeast at 60 miles per hour (mph) from Indiana in the early afternoon to the Mid-Atlantic region around midnight. Winds were commonly above 60 mph with numerous reports of winds exceeding 80 mph. Some areas reported isolated pockets of winds greater than 100 mph. Nearly every county impacted by this convective system suffered damages and power outages. To make matters worse, the area affected was in the midst of a prolonged heat wave. Unlike many major tornado outbreaks in the recent past, this event was not forecast well in advance. Warm-season derechos, in particular, are often difficult to forecast and frequently result from subtle, small-scale forcing mechanisms that are difficult to resolve more than 12-24 hours in advance. (Source: http://www.nws.noaa.gov/os/assessments/pdfs/derecho12.pdf)
October 26, 2012	Hurricane Sandy made landfall along the southern New Jersey shore on October 29, 2012, causing historic devastation and substantial loss of life. The National Hurricane Center (NHC) Tropical Cyclone Report estimated the death count from Sandy at 147 direct deaths. In the United States, the storm was associated with 72 direct deaths in eight states: 2 in Virginia. The storm also resulted in at least 75 indirect deaths (i.e., related to unsafe or unhealthy conditions that existed during the evacuation phase, occurrence of the hurricane, or during the post-hurricane/clean-up phase). These numbers make Sandy the deadliest hurricane to hit the U.S. mainland since Hurricane Katrina in 2005, as well as the deadliest hurricane/post-tropical cyclone to hit the U.S. East Coast since Hurricane Agnes in 1972. (Source: http://www.nws.noaa.gov/os/assessments/pdfs/Sandy13.pdf)

Table 5.14: History of Wind Events and Damages, 2010–2020*	
Date	**Damages**
October 12, 2018	Michael was downgraded to extra-tropical shortly after the eye passed over the Virginia-North Carolina border. Winds were 45-50 knots in the region. Wind-related property damages of $19,000 were reported.
October 20, 2019	Nestor was extra-tropical by the time it passed through the region, with wind speeds of 40 knots. The slow-moving disorganized eye passed through the southern part of the study area, between Wakefield and Windsor, and then turned eastward and crossed the James River into Newport News. Wind-related property damages of $6,000 were reported.
August 4, 2020	Isaias was a tropical storm with wind speeds of 60 knots when passing through study area. Gusting winds caused power outages and torrential rains caused flooding that closed roads and bridges. According to the *Richmond Times-Dispatch*, 34 roads in the region were impassable. The paper also reported that the Richmond Metropolitan area had over 28,000 power outages. The storm spawned several tornados, but none reported in the study area. Tropical storm-related property damages of $100,000 were reported in Surry County.

**History from 1827-2010 in Appendix F-4*
Source: NCEI, 2021

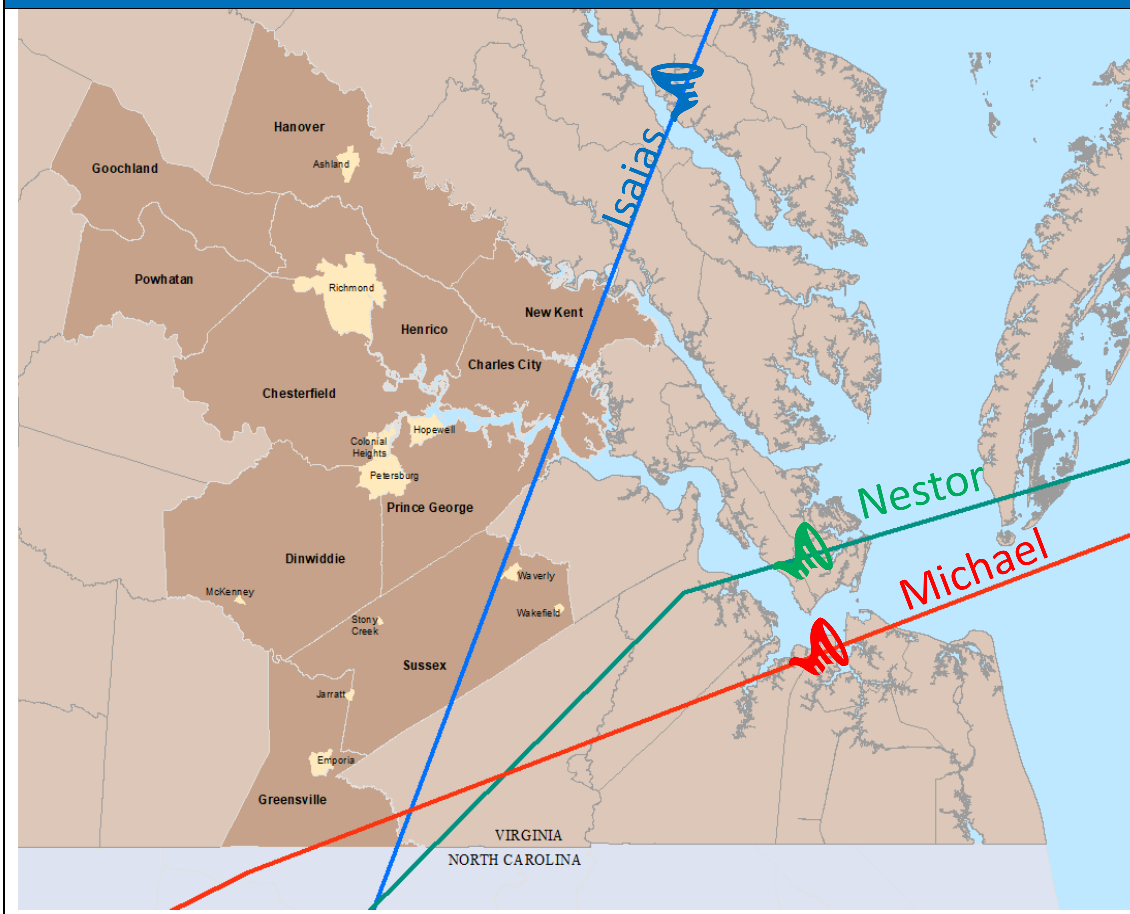
The NOAA Coastal Services Center maintains historical hurricane, tropical storm, and tropical depression track data dating back to the mid-1880s. **Figure 5.13** shows all tropical system and hurricane tracks through and near the region between 1950 and 2015. **Figure 5.14** provides a map of the most recent hurricane or tropical storm tracks between 2015 and 2020.

Figure 5.13: Named Hurricane and Tropical Cyclone Tracks, 1950–2015



Source: NOAA Coastal Services Center, 2021

Figure 5.14: Regionally Significant Hurricane and Tropical Cyclone Tracks, 2015- 2020



Source: NOAA Coastal Services Center, 2021

Vulnerability Analysis

Historical evidence shows that the Richmond-Crater region is vulnerable to damaging storm-force winds, whether associated with coastal storms like nor'easters, tropical storms such as hurricanes, or straight-line winds such those generated by a thunderstorm derecho. As shown in Figure 5.13 above, 36 hurricanes or tropical storms have passed within 75 miles of the region since the first unnamed hurricane in 1854. This equates to a 22-percent annual chance that a storm will similarly impact the region.

Table 5.15 analyzes the historical annual hurricane occurrences in the region with Prince George, Surry and Dinwiddie counties reporting the highest historical annual damages.

Table 5.15: Annualized Hurricane Events and Losses, 1993 - 2020				
Jurisdiction	**Annualized Number of Events**	**Annualized Property Losses**	**Annualized Crop Losses**	**Annualized Total Losses**
Charles City County	0.074	$3,296	$23,741	$27,037
Chesterfield County	-	-	-	-
City of Colonial Heights	-	-	-	-
City of Emporia	-	-	-	-
City of Hopewell	-	-	-	-
City of Petersburg	-	-	-	-
City of Richmond	-	-	-	-
Dinwiddie County	0.074	$214,074	$90,741	$304,815
Goochland County	0.037	$0	$10,481	$10,481
Greensville County	0.074	$8,111	$1,852	$9,963
Hanover County	0.074	$3,704	$14,815	$18,519
Henrico County	0.000	$0	$0	$0
New Kent County	0.074	$926	$4,519	$5,444
Powhatan County	0.037	$148,148	$13,296	$161,444
Prince George County	0.074	$314,815	$229,630	$544,444
Surry County	0.222	$232,111	$81,481	$313,593
Sussex County	0.111	$3,963	$37,037	$41,000
Totals	**0.852**	**$929,148**	**$507,593**	**$1,436,741**

Source: NCEI, 2020

Detailed loss estimates for the wind damage associated with the tropical storm hazard were developed based on probabilistic scenarios using Hazus (Level 1 analysis). **Table 5.16** shows estimates of potential building damage for the 100-year return period, and annualized total losses. In summary, the region may be susceptible to an estimated total of approximately $178 million in building damages from a 100-year wind event, equating to $9.7 million average annual damages.

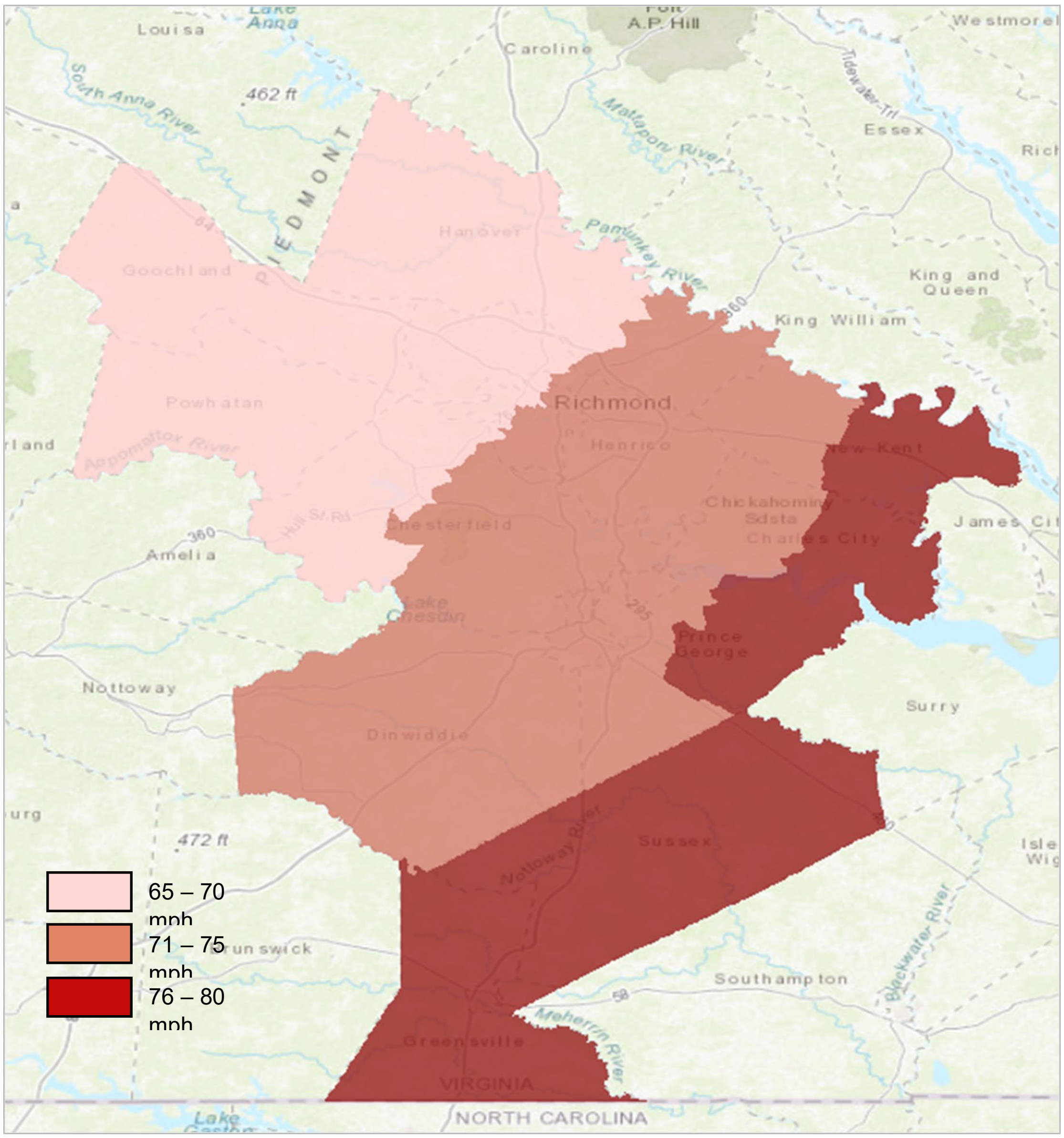
Table 5.16: Estimates of Potential Building Damage – 100-Year Wind Only Event					
Community	Building Damage	Contents & Inventory Damage	Income Losses	Total*	Annualized Total Losses
Charles City County	$969,000	$532,000	$0	$1,501,000	$125,000
Chesterfield County	$49,095,000	$7,696,000	$59,000	$56,850,000	$2,271,000
Colonial Heights	$3,645,000	$529,000	$24,000	$4,198,000	$174,000
Dinwiddie County	$8,111,000	$2,181,000	$194,000	$10,486,000	$252,000
Emporia	$953,000	$279,000	$11,000	$1,243,000	$90,000
Goochland County	$2,860,000	$1,297,000	$0	$4,157,000	$201,000
Greensville County	$1,562,000	$571,000	$1,000	$2,134,000	$137,000
Hanover County	$9,861,000	$5,123,000	$1,000	$14,985,000	$1,347,000
Henrico County	$24,076,000	$2,623,000	$58,000	$26,757,000	$2,059,000
Hopewell	$3,641,000	$843,000	$28,000	$4,512,000	$222,000
New Kent County	$2,337,000	$1,386,000	$0	$3,723,000	$441,000
Petersburg	$6,891,000	$1,429,000	$213,000	$8,533,000	$326,000
Powhatan County	$5,715,000	$3,128,000	$0	$8,843,000	$265,000
Prince George County	$8,093,000	$2,298,000	$24,000	$10,415,000	$412,000
Richmond	$14,589,000	$1,380,000	$140,000	$16,109,000	$1,235,000
Sussex County	$3,185,000	$1,012,000	$89,000	$4,286,000	$147,000
Totals	$145,583,000	$32,307,000	$842,000	$178,732,000	$9,704,000

** income losses from relocation, lost wages, and lost rental income*
Source: Hazus

Based on the data in Table 5.16, Chesterfield County, Hanover County, Henrico County and the City of Richmond have the highest annualized total losses from wind associated with a 100-year wind event. These communities are also the most vulnerable for flood, so these 3 communities are considered the most vulnerable to the combined wind and flooding effects of Tropical Storms. Prince George County, Dinwiddie County and Hanover County are also very vulnerable to wind effects from the 100-year wind event. Emporia, Charles City County and Greensville County are significantly further west, have less overall development, and are thus less likely to experience the devastating impacts of wind than the remainder of the Richmond-Crater region. Annualized losses for the region total just over $9.7 million, but vary remarkably throughout the area, with Emporia having annualized damages of $90,000 and Chesterfield County with over $2.2 million.

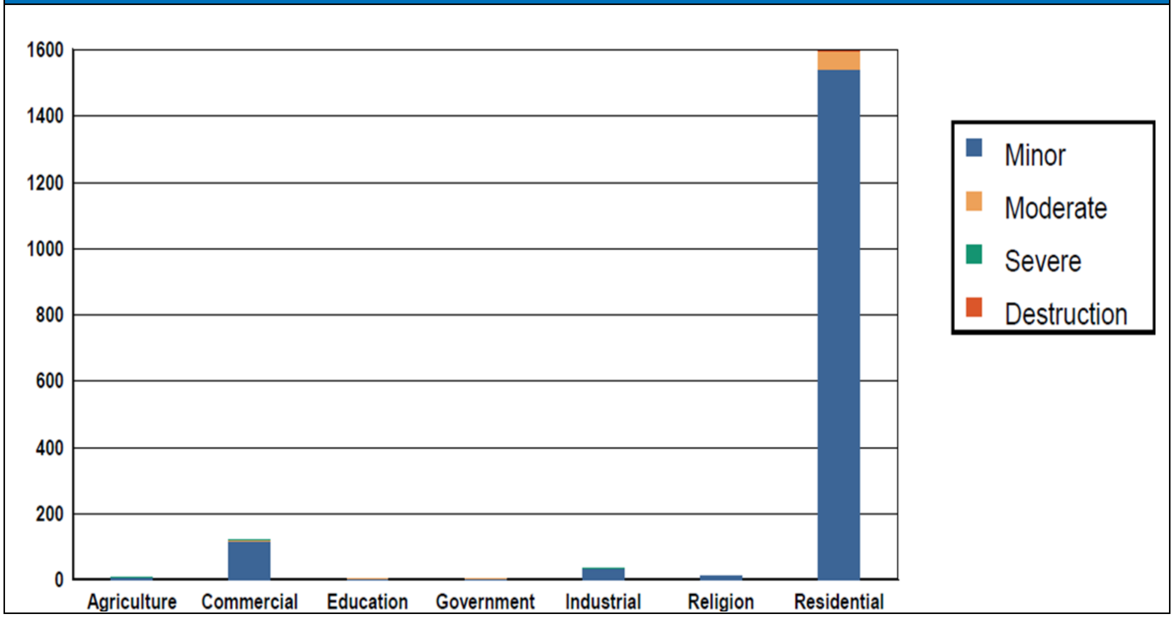
Figure 5.15 provides a map of winds expected from the 100-year event across the study area, also modeled through Hazus. Consistent with the expected exposure to hurricane force winds near the coast, the most vulnerable area to high winds is typically in the eastern portion of the study area. Areas west of Richmond and into the Virginia Piedmont region are less susceptible.

Figure 5.15: 100-year Return Period Peak Gusts (mph)



Source: Hazus, 2021

Figure 5.16: Expected Building Damage by Occupancy, 100-year Wind Event



Source: Hazus, 2021

Hazus was also used to model summary building damage estimates based on percentage of damage (by damage state) for the 100-year return period (**Figure 5.16**). These data can be useful when used in conjunction with Table 5.16 above because building wind damage can range from minor, easily repairable damage to gutters or roof features, to destruction of roofs and buildings from fallen trees, or structural failure.

For this update, Hazus was used to model a recurrence of Hurricane Hazel, which struck the Central Virginia region in 1954. The storm track was unique; it approached central Virginia from the south. On October 15, the storm made landfall near the North Carolina/South Carolina line and is estimated to have been a Category 4 storm at that time. As it moved north across North Carolina, Hazel became extratropical over Raleigh. Hazel rocketed north over Central Virginia at a forward speed of 50 miles per hour and brought with it wind gusts of 79 miles per hour in Richmond. But the speed of the storm kept the damage from being devastating. Many homes in Richmond lost roofs.

An examination of Hazel using modern building exposure data was possible through Hazus. **Table 5.17** provides a summary of the damage data for this "what-if" scenario, examining the damage caused if a storm similar to Hurricane Hazel struck the Richmond-Crater study area in the 21st century. Total estimated losses are over $2.3 billion, with most significant damages in Chesterfield County, Hanover County, Henrico County, and the City of Richmond.

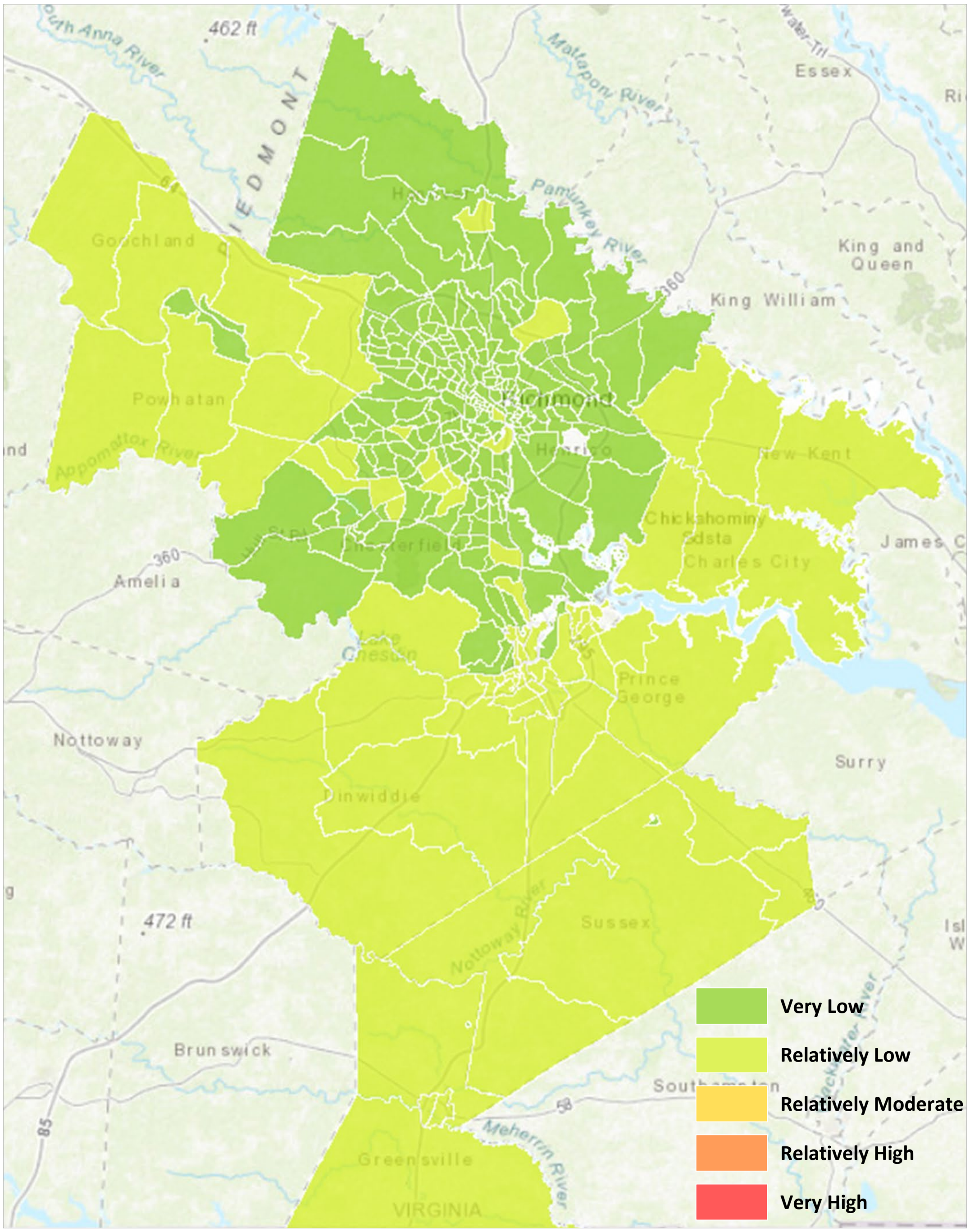
Table 5.17: Estimates of Potential Building Damage – Hurricane Hazel in 2021				
Community	**Building Damage**	**Contents & Inventory Damage**	**Income Losses**	**Total***
Charles City County	$6,537,000	$3,091,000	$190,000	$9,818,000
Chesterfield County	$504,598,000	$93,278,000	$36,964,000	$634,840,000
Colonial Heights	$23,552,000	$4,123,000	$2,858,000	$30,533,000
Dinwiddie County	$38,661,000	$11,292,000	$3,342,000	$53,295,000
Emporia	$8,258,000	$2,574,000	$1,239,000	$12,071,000
Goochland County	$27,418,000	$9,446,000	$1,175,000	$38,039,000
Greensville County	$12,319,000	$4,491,000	$1,150,000	$17,960,000
Hanover County	$209,059,000	$89,736,000	$10,711,000	$309,506,000
Henrico County	$513,786,000	$88,870,000	$50,033,000	$652,689,000
Hopewell	$22,906,000	$5,225,000	$2,076,000	$30,207,000
New Kent County	$20,972,000	$10,843,000	$462,000	$32,277,000
Petersburg	$41,072,000	$9,539,000	$5,277,000	$55,888,000
Powhatan County	$31,513,000	$14,209,000	$874,000	$46,596,000
Prince George County	$32,559,000	$9,329,000	$1,464,000	$43,352,000
Richmond	$302,153,000	$48,356,000	$45,582,000	$396,091,000
Sussex County	$7,234,000	$2,306,000	$415,000	$9,955,000
Totals	**$1,802,597,000**	**$406,708,000**	**$163,812,000**	**$2,373,117,000**

** Also includes income losses from relocation, lost wages, and lost rental income.*
Source: Hazus

Social Vulnerability

The NRI data for social vulnerability to hurricanes are shown in **Figure 5.17**. Most of the urbanized portion of the study area is shown as having very low social vulnerability, while the more rural land use areas are shown as having relatively low social vulnerability. This disparity could be a result of the lack of recorded hurricane or tropical storm losses for the cities in the region. Table 5.15 above (Annualized Hurricane Events and Losses, 1993 – 2020) shows that the NCEI database does not include any recorded events for any of the cities in the study area. Therefore, the modeling included a large number of no loss or low loss events.

Figure 5.17: National Risk Index, Hurricane Risk Rating



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has relatively moderate social vulnerability for hurricane.

Future Vulnerability, Land Use and Climate Change

The type of building construction has a significant impact on potential damages from high wind events in the future, as type of construction is also a key factor in determining the life of a structure. Basic building types in declining order of wind vulnerability are manufactured, non-engineered wood, non-engineered masonry, lightly engineered and fully engineered buildings. The primary residential construction type in the study area is wood framed, varying from single story to multiple stories, although some masonry and steel properties are present as well. With the prevalence of non-engineered, wood-framed structures throughout the Richmond-Crater region, a majority of structures in the area could be classified as having a high level of vulnerability to damages due to a high wind event in the future. Using Hazus, an analysis of the damage caused by a 100-year frequency wind event indicates that 815 wood-framed structures would have minor, moderate or severe damage, while 723 masonry structures would have minor, moderate or severe damage.

All future structures built in the Richmond-Crater region will likely be exposed to hurricane and tropical storm-force winds and may also experience damage not accounted for in the loss estimates presented in this section. The VUSBC continues to reduce vulnerability of newly constructed buildings to the wind hazard.

The VASEM 2021 report concludes that the research on climate change impacts in the study region is conflicted regarding increased frequency of Atlantic Coast hurricanes. However, the report indicates consensus that there will be an increase in average cyclone intensity, precipitation rates, and the number of strong storms. Strong storms combined with sea level rise are particularly alarming for the eastern region of the study area. Even in rural areas in the western portion of the study area, increasing storm intensity can damage crops and soil in addition to vulnerable agricultural structures.

Similar to the discussion in the subsection above regarding flooding, mass evacuations due to coastal wind events, particularly tropical storms, is a possibility. However, the last time a mass evacuation impacted the area was Hurricane Floyd in September 1999. Transportation disruptions and impacts on infrastructure are the most likely problems that communities in the study area may experience.

5.7 Tornadoes

Hazard Profile

A tornado is a violent windstorm characterized by a twisting, funnel-shaped cloud extending to the ground. Tornadoes are most often generated by thunderstorm activity when cool, dry air intersects and overrides a layer of warm, moist air forcing the warm air to rise rapidly. The damage caused by a tornado is a result of the high wind velocity and wind-blown debris, also accompanied by lightning or large hail. According to the NWS, tornado wind speeds normally range from 40 to more than 200 mph. The most violent tornadoes (EF5) have rotating winds of 200 mph or more and are capable of causing extreme destruction and turning normally harmless objects into deadly missiles.

Each year, an average of over 1,200 tornadoes is reported nationwide, resulting in an average of 80 deaths and 1,500 injuries. They are more likely to occur during the spring and early summer months of March through June and can occur at any time of day but are likely to form in the late afternoon and early evening. Most tornadoes are a few dozen yards wide and touch down briefly, but even small, short-lived tornadoes can inflict tremendous damage. Highly destructive tornadoes may carve out a path over a mile wide and tens of miles long.

Magnitude or Severity

The destruction caused by tornadoes ranges from light to devastating depending upon the intensity, size, and duration of the storm. Typically, tornadoes cause the greatest damages to structures of light or wood-framed construction such as residential homes (particularly mobile homes) and tend to remain localized in impact. The traditional Fujita Scale for tornadoes, introduced in 1971, was developed to measure tornado strength and associated damages. Starting in February of 2007, an "enhanced" Fujita (EF) Scale was implemented, with somewhat lower wind speeds at the higher F-numbers, and more thoroughly refined structural damage indicator definitions. **Table 5.18** provides a summary of the EF Scale. Assigning an EF Scale rating to a tornado involves the following steps:

- Conduct an aerial and ground survey over the entire length of the damage path;
- Locate and identify damage indicators in the damage path;
- Consider the wind speeds of all damage indicators and assign an EF Scale category for the highest wind speed consistent with wind speeds from the other damage indicators;
- Record the basis for assigning an EF scale rating to a tornado event; and
- Record other pertinent data related to the tornado event.

Table 5.18: Enhanced Fujita (EF) Scale for Tornadoes	
EF-Scale Number	**3 Second Gusts (mph)**
F0	65-85
F1	86-110
F2	111-135
F3	136-165
F4	166-200
F5	over 200

Source: NWS Storm Prediction Center

In Virginia, tornadoes primarily occur from April through September, although tornadoes have been observed in every month. Low-intensity tornadoes occur most frequently; tornadoes rated F2 or higher are very rare in Virginia, although F2, F3, and a few F4 storms have been observed. According to the *2013 Commonwealth of Virginia, Mitigation Plan*, Virginia ranks 28th in terms of the number of tornado touchdowns reported between 1950 and 2006. The 2018 update did not provide an updated ranking.

Tornadoes are high-impact, low-probability hazards. The net impact of a tornado depends on the storm intensity and the vulnerability of development in its path. Because the path of each tornado is unique to each event, general descriptions of impacts in the study area can be drawn from the impacts of previous storms (see also **Table 5.19** below). Communities rarely activate EOCs before tornadoes due to the short warning times, but after extreme events with catastrophic damage that displace a large number of residents, such activation may become necessary.

In the Richmond-Crater region, a high intensity tornado, while rare, can be expected to impact almost everything within the storm's path: homes, especially those constructed prior to the use of building codes; infrastructure, especially above-ground power lines in the commercial zones and bridges throughout the region; cars and personal property; landscape elements such as trees, fences and shrubs; and even human lives. Downed trees can block roadways, impeding traffic and blocking access and egress if any of the region's thoroughfares are impacted. Manufactured homes are particularly vulnerable to damage in the event of tornadoes, as well, particularly if they were placed outside of flood zones and before building codes were in effect requiring foundation tie-downs.

Tornadoes associated with tropical cyclones are somewhat more predictable. These tornadoes occur frequently in September and October when the incidence of tropical storm systems is greatest. They usually form around the perimeter of the storm, and most often to the right and ahead of the storm path or the storm center as it comes ashore. These tornadoes commonly occur as part of large outbreaks and generally move in an easterly direction. Tracking and prior notification by the National Weather Service and local news media helps save lives locally.

Most tornado strikes in the region have been F0 or F1 and the effects were somewhat less than as described above for severe storms. Critical damage to structures in the tornado's path is common, with indiscriminate damage to public-and privately-owned structures, some infrastructure, and downed trees that make transportation difficult. In areas adjacent to the path, minor damage, especially to roofs and windows from trees and flying debris, can also be expected. While downed trees may block transportation routes and result in power outages for some customers, these impacts are typically cleared within a few days.

Hazard History

Table 5.19 includes descriptions of major tornado events that have touched down and been recorded in the region since 2011. Prior events are included in Appendix F-5. Events have been broken down by the date of occurrence and, when available, by individual community descriptions. When no community description is available, the general description applies to the entire region. Although not comprehensive in terms of tornado fatalities and injuries, the NCEI database indicates that since 1950 there have been 11 deaths and 348 injuries in the region due to tornadoes.

Table 5.19: History of Tornado Events and Damages, 2011–2020*

Date	Description	Damages
April 16, 2011	**Dinwiddie County:** Tornado path started on Doyle Road west of Glebe Road and then tracked east-northeast to the Five Forks area of Dinwiddie County. Hundreds of trees were either downed or snapped off. Numerous power lines were also downed, and there were several homes and outbuildings with minor to moderate damage. Most significant damage was on Patillo Road at Wooded Lane, and on Wilkinson Road near Shannon Drive. EF-1	**$1,500,000 (property)** **5 injuries**
April 27, 2011	**Goochland County:** Scattered severe thunderstorms well in advance of a cold front produced damaging winds, large hail, and several tornadoes across portions of central Virginia. Tornado tracked from Bridgewater Bluff to Pony Farm Road, crossing Interstate 64. Numerous trees were downed or sheared off. The tornado tracked into Louisa County. EF1	**$25,000 (property)**
April 28, 2011	**Hanover County:** Scattered severe thunderstorms in advance of a cold front produced damaging winds and one tornado across portions of central and eastern Virginia. Tornado paralleled Old Ridge Road for 1.5 miles before crossing Coatesville Road. The tornado then tracked northeast approximately 1 mile and crossed Old Ridge Road. Numerous trees were downed or sheared off. A single tree fell on a house on Old Ridge Road causing minor roof damage. EF1	**$25,000 (property)**
October 13, 2011	**New Kent County:** Tornado first touched down along Emmaus Church Road or Route 609 just into New Kent County north of U.S. Route 60. The NWS Storm Survey rated the tornado as an EF1 with winds estimated at 95 mph as it reached the Woodhaven Shores Subdivision on both sides of Kent Lake. According to county emergency management, over 30 homes were damaged in the Woodhaven Shores Subdivision on both sides of Kent Lake, primarily due to trees falling on	**$1,000,000 (property)**

Table 5.19: History of Tornado Events and Damages, 2011–2020*		
Date	**Description**	**Damages**
	homes. Damage was most extensive along and adjacent to Lakeshore Drive which surrounds Kent Lake. EF1 damage extended just to the north of Kent Lake and included two barns that were destroyed along Ashland Farm Road. The tornado then weakened to a high-end EF0 and turned northeast as it crossed north of Interstate 64. Damage at GW Watkins Elementary School included aluminum roofing panels that were popped off along with a few busted windows. EF0 damage was observed farther northeast with several trees downed or snapped off along Talleysville Road near Old River Road. The tornado lifted just before entering King William County. EF-1	
June 1, 2012	Scattered severe thunderstorms in advance of a cold front produced damaging winds, large hail and several tornadoes across portions of central and eastern Virginia. **Petersburg:** The tornado tracked approximately 3 miles beginning on the western edge of Fort Hayes Common where a couple of trees were damaged. It then continued northeast through portions of the Battlefield Park, Oakhurst and East Walnut Hill sections of Petersburg. The tornado then crossed Interstate 95 causing minor damage, mainly windows blown out and signs damaged just east of the intersection of Route 460 and Hickory Hill Road. The last damage or debris was observed on the north side of the Petersburg National Battlefield. The tornado damage was characterized by trees, large limbs and power lines down. A number of trees fell on homes. The most significant damage occurred in the East Walnut Hill neighborhood and the northeast sections of the Oakhurst neighborhood. EF0 **Hanover County:** A brief tornado touched down just west of Highway 301 tracking southeast. The tornado knocked down numerous trees blocking roads including Highway 301. Tornado downed numerous trees and produced some minor structural damage in the Hadensville area of Goochland County. EF0	**$175,000 (property)** **5 injuries**
June 25, 2012	**Goochland County:** Scattered severe thunderstorms in advance of a cold front produced damaging winds, large hail and a tornado across portions of central and eastern Virginia. EF0	**$15,000 (property)**
June 30, 2012	**Hanover County:** The tornado downed numerous trees and produced some minor structural damage in the area. The tornado initially touched down near Williamsville Acres Lane, then tracked south southeast before lifting east of Mechanicsville near the intersection of Crown Hill Road and State Route 628. EF-0	**$15,000 (property)**
May 22, 2014	**Prince George County:** _ The tornado was confirmed near the city of Prince George. The storm intensified northwest of Richmond, then produced wind damage in the City of Richmond, with trained storm spotters periodically reporting a funnel cloud in the Metro as it raced southeast. At 5:45 p.m., a tornado touched down on Kurnas Lane, destroying a shed, snapping trees and causing minor damage to a home. The tornado was rated an EF-0, with winds of 70 mph. It was 25	**$50,000 (property)**

Table 5.19: History of Tornado Events and Damages, 2011–2020*		
Date	**Description**	**Damages**
	yards wide and was on the ground for 75 yards. No injuries were reported. EF-0 **Sussex County:** The tornado was confirmed near Waverly in Sussex County at 6:20 p.m. The tornado developed just north of Highway 460 and south of Petersburg Road, about mile northwest of Waverly. It moved south and crossed Highway 460 just north of Waverly. It struck an auto parts store, causing minor damage. Many large trees were uprooted along Highway 460, and the highway was closed due to trees on the road. The tornado tracked southward to North Church Street, causing minor damage to the First Baptist Church. Many large trees fell into the nearby cemetery, causing damage. The tornado moved across New Street, snapping trees and damaging homes. The tornado lifted shortly after crossing Highway 460 on the west side of Waverly. This tornado was classified as an EF-0 tornado, with winds of 75 mph. It was 100 yards wide and was on the ground for 1.5 miles. No injuries were reported. EF-0 (Source: http://wtvr.com/2014/05/23/two-tornadoes-confirmed-from-may-22-storm/)	
June 27, 2015	**Hanover County:** Scattered severe thunderstorms along a warm front and in advance of a cold front produced damaging winds, a weak tornado, and heavy rain across portions of central and eastern Virginia. A weak tornado touched down several times in Hanover County. It began just north and east of the Interstate 295 and Interstate 95 interchange. It then tracked east northeast for about 3.5 miles, crossing Route 301 before lifting and dissipating. Minor damage to tops of trees occurred. EF0	$2000 (property)
Feb 24, 2016	**Waverly:** NWS storm survey concluded that an EF1 tornado occurred near Waverly. The tornado began a few miles south southwest of Waverly, moved fast through the town of Waverly, then ended about five miles north northeast of Waverly in Surry County. Maximum winds were between 100 and 110 mph. Numerous trees were downed, with two mobile homes destroyed and several homes and businesses damaged. EF-1	$2,600,000 (property damage) 3 deaths, 8 injuries
May 5, 2017	**Mosely:** Tornado tracked from near the Norfolk Southern Railroad northeast to near the intersection of Bradbury Road (VA-672) and Moseley Road (VA-605). Many trees were found snapped or uprooted along this route, including several onto homes. EF-0 **McKenney:** Tornado tracked from Brunswick County into Dinwiddie County. The tornado continued north northeast into Dinwiddie County along Old White Oak Road. It crossed Old White Oak Road near Route 40, then continued north northeast before a visible damage path ended just north of Lew Jones Road. Numerous trees were uprooted or sheared off, and there was significant damage to a few homes and one large shed was destroyed. Also, there was extensive crop damage, as well as damage to farm equipment and land damage. EF-1	$578,000 (property) $40,000 (crops)

Table 5.19: History of Tornado Events and Damages, 2011–2020*		
Date	**Description**	**Damages**
	Dinwiddie County: Information obtained from the Dinwiddie County emergency manager and the Virginia Department of Forestry suggests a tornado touched down in timberland in northern Dinwiddie County. The tornado first touched down north of Route 460, to the west northwest of Sutherland, then tracked north northeast, ending near Namozine Road. Extensive damage to trees occurred along the path, with no damage to structures. EF-1	
September 17, 2018	**Rockville:** A brief EF1 tornado touched down just northwest of the intersection of Echo Meadows Road and Rockville Road in Hanover County. The storm then moved north northeast, causing numerous trees to be uprooted or snapped. In addition, an open shed was completely destroyed, with numerous round bales of hay moved into the field to the north. The tornado then lifted near Franklin Hills Drive. EF-1 **Hallsboro**: The tornado first crossed Beaver Bridge Road and then Beach Road. The bulk of the structural damage occurred in the Hampton Park Neighborhood. It then crossed Hull Street and entered Moseley, before dissipating near the Fox Club Parkway. EF-1 **Richmond:** An EF1 tornado touched down in the Stony Point area of the City of Richmond just south of West Huguenot Road. The tornado then tracked northward into Tuckahoe before lifting just south of Three Chopt Road. Numerous trees were downed or snapped with air conditioning units blown off the West End Church near West Parham Road. EF-1 **Bon Air:** Beginning in Winterpock, the tornado started as a weak EF1 before moving into a residential area north of River Road. The tornado reached peak intensity (EF2) when it crossed Hull Street Road. At this point, it took off the roof of Gabe's and damaged several other businesses. After crossing Hull Street Road, it destroyed the Old Dominion Warehouse, where one person was killed, and one was injured. It remained an EF2 until about Gregwood Drive, completely destroying trees and damaging other structures. It then quickly weakened to an EF0 as it reached Powhite Parkway and continued as an EF0 toward Route 60 in Bon Air. One death and one injury were reported. EF-2 **Pilkinton:** This was a weak tornado that uprooted a few trees and snapped some tree limbs. EF-0 **Richmond:** The tornado briefly touched down on New Kent Road where numerous trees were snapped. EF-0 **Richmond:** The tornado touched down on West Wood Avenue, then onto Confederate Avenue and Lamont Street where numerous trees and several power poles were snapped. EF-0 **Richmond:** The tornado touched down in the City of Richmond on the north side of the James River between Byrd Park and the Powhite Parkway. The tornado continued across the Powhite Parkway into the	$1,078,000 (property) 1 death, 1 injury

Table 5.19: History of Tornado Events and Damages, 2011–2020*		
Date	**Description**	**Damages**
	Windsor Farms section of the City of Richmond. The tornado mainly snapped and uprooted trees along its path. EF-0 **Atlee:** Public video of a tornado touchdown near Atlee High School. Tornado touched down briefly then lifted off the ground causing no damage. EF-0 **Richmond:** The tornado touched down near Stratford Road, then moved north across Chippenham Parkway, and ending near Cherokee Road where numerous trees and several power poles were snapped. EF-0	
October 11, 2018	**Lanexa:** A tornado touched down on Colony Trail in Lanexa where it downed several trees and damaged four homes before lifting near the intersection of Colony Trail and Waterside Drive. EF-0	$50,000 (property)
April 19, 2019	**Gaskins:** The tornado touched down approximately 1/2 mile west of Creek Road in rural southeast Greensville County. The tornado tracked north northeast over rural portions of Greensville County before finally lifting one mile north of Moores Lane. The tornado mostly snapped trees along its path. EF-0 **Dahlia:** The tornado tracked from Northampton County, NC, into Greensville County, VA. The tornado tracked across Skippers Road where additional trees were snapped. The tornado then briefly lifted while shifting its track slightly east, while remaining in Greensville County. EF-0 **Skippers:** The same tornado that started in Northampton County NC, shifted its track slightly east within Greensville County, VA and touched down again near Taylor`s Mill Road. From there, the tornado continued northeast crossing Caney Swamp and causing EF1 damage to numerous trees along Little Low Ground Road. The tornado then continued into extreme southwest Southampton County. EF-1 **Emporia:** The tornado touched down near the intersection of Brink Road and Collins Road, about 3 miles southwest of Emporia, VA in Greensville County. The tornado snapped trees and did damage to a couple of outbuildings along its path. Minor damage also occurred at a shopping center in Emporia. The tornado lifted just north of town. EF-0 **Newville:** The tornado touched down just south of Sussex Drive about 4 miles east of Stony Creek in Sussex County. It then traveled northeast and crossed Jerusalem Park Road near Courthouse Road, before continuing northeast across General Mahone Highway and lifting before reaching Centerville Road in Prince George County. The tornado mostly uprooted and snapped trees along its path. A garage was also destroyed from a tree falling on it. EF-0 **Burrowsville:** The tornado touched down near Fireside Drive in Disputanta causing some downed trees and a car port to be blown over, consistent with EF0 damage. The tornado continued moving north northeast across Webb Road and then Lebanon Road, Cedar Lane and Pole Run Road. Many trees were snapped or uprooted, and	$293,000 (property)

Table 5.19: History of Tornado Events and Damages, 2011–2020*		
Date	**Description**	**Damages**
	numerous sheds and outbuildings received significant damage or were destroyed between Lebanon Road and Pole Run Road. This area was where the EF1 damage occurred. The tornado lifted north of Pole Run Road before Route 10. There was additional tree damage along Hines Road just north of Newville. EF-1 **Ruthville:** The National Service in Wakefield confirmed an EF2 tornado just northeast of Charles City. The tornado touched down just east of The Glebe Lane about 1.7 miles northeast of Charles City causing some trees to be uprooted and snapped along Ruthville Road. Soon after crossing Ruthville Road, the tornado intensified to an EF2, causing extensive damage to Charles City Rod and Gun Club. The roof of the building was lifted off and blown partially off. In addition, the south facing exterior wall was blown in. The tornado continued tracking northeast, crossing Old Elam Cemetery Road and then The Glebe Lane, causing extensive tree damage including snapped and uprooted trees consistent with EF1 damage. The tornado then weakened to an EF0, before lifting just northeast of Sturgeon Point Road. EF-2	

**History from 1790-2010 in Appendix F-5*
Source: NOAA, NCEI data through 11/30/2020, accessed 3/18/21.

By far, the most memorable tornado in the region's history since 1950 occurred in the summer of 1993, affecting Petersburg, Colonial Heights, Prince George County and Hopewell. August 6, 1993, started out quietly for southeastern Virginia, with highs in the mid-70s and partly cloudy skies. However, as a warm front moved north across Richmond and Henrico County and an approaching low pressure center moved in, these clouds disappeared leading to intense warming throughout the day. Unfortunately, the mild temperatures and high humidity levels in place that day were two of the key ingredients that allowed a warm August afternoon to turn into an historical and deadly evening. (Source: https://www.weather.gov/akq/severe_Aug061993)

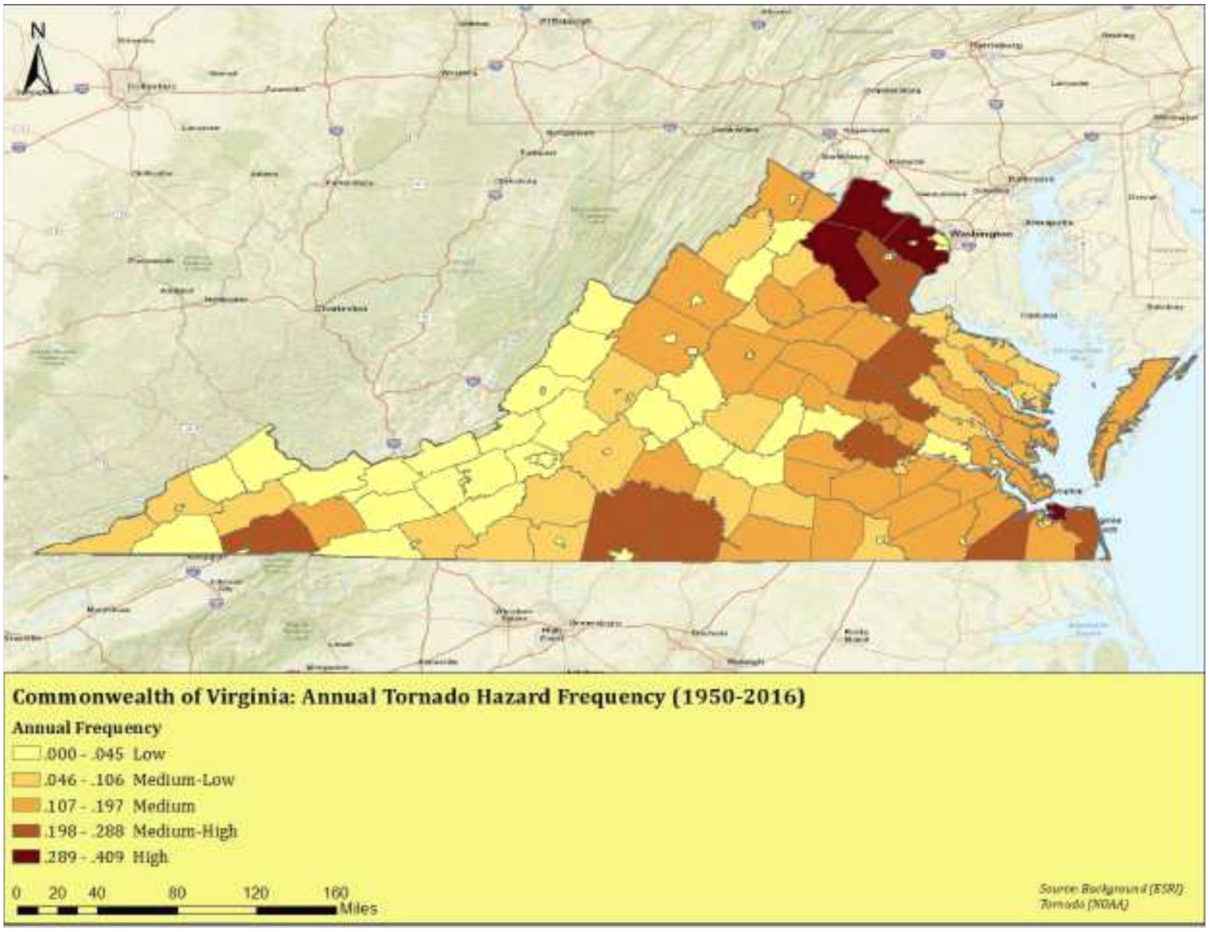
As pressures fell due to a low center developing along the front over southwest Virginia, an upper-level short-wave (disturbance) approached. Surface winds and winds aloft struggled against each other producing the ideal vertical wind shear needed for tornadic development that afternoon. The most devastating tornado of the day touched down one mile southwest of Petersburg at approximately 1:30 pm. This tornado rapidly grew in size and strength as it moved northeast into the commercial historic district of Petersburg. Numerous homes and businesses sustained major damage. Damage estimates for the area were $15 million. Forty people were injured.

Often called the “Tri-Cities Tornado”, the storm crossed the river into Colonial Heights and struck one of the area's shopping districts. It destroyed some buildings and did major damage to numerous other buildings including the Wal-Mart, where three people were killed and nearly 200 were injured. Total damage estimates in Colonial Heights were $29.5 million.

The tornado crossed the Appomattox River again into Prince George County where it struck a sand and gravel pit company. A block building collapsed, and numerous vehicles and other equipment were destroyed. One person was killed. Damage estimates were $750,000. It then moved into the northern section of Hopewell, where it ripped into the Riverside Park Apartment Complex, tearing the roofs off of several buildings. Minor damage was done to another 49 homes, major damage to 13 homes and destruction of 2 homes. The tornado weakened then dissipated near the confluence of the Appomattox and James Rivers. Final records indicate that the tornado caused 4 deaths, 246 injuries and approximately $50 million in damage. According to NCEI records, this tornado is one of only two F4 or greater tornadoes in Virginia history since 1950 and is by far the most destructive.

Figure 5.18 presents the results of a tornado frequency analysis performed as part of the *2018 Virginia State Hazard Mitigation Plan* update. The analysis suggests that relative to the entire Commonwealth of Virginia, the Richmond-Crater region is considered “Medium” to “Medium-High” in terms of tornado frequency. The State plan emphasizes that historical data may contain meteorological biases that should be considered when viewing the results of the probability analysis shown in **Figure 5.18**. Increased population and advanced technology have likely led to vastly higher numbers of low intensity tornadoes reported in recent decades, and more tornadoes are reported in areas of higher population because people are more likely to see and report the resultant damage. This map is also specific to Virginia, and “high frequency” in the Commonwealth is still relatively low frequency in parts of the Midwest and southern United States.

Figure 5.18: Historical Tornado Hazard Frequency Analysis



Source: 2018 Virginia State Hazard Mitigation Plan

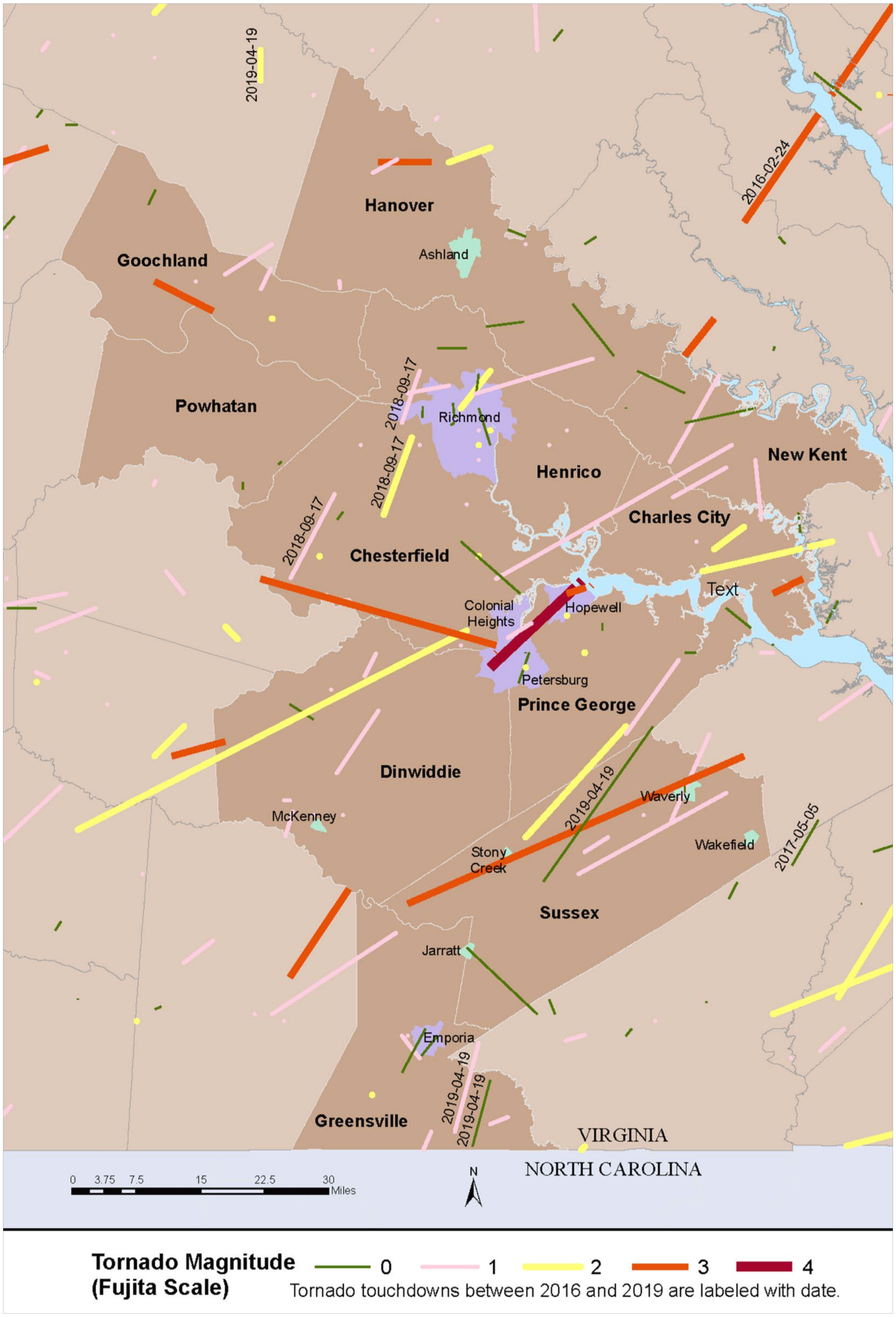
Table 5.20 presents summary data about the historical tornado events by jurisdiction and provides an estimate of annualized losses from tornadoes for each jurisdiction based on reports included in the NCEI database.

Table 5.20: Annualized Tornado Events and Losses, 1950 - 2020			
Jurisdiction	**Number of Events**	**Total Property Damages**	**Annualized Loss**
Charles City County	4	$700,000	$10,000
Chesterfield County	16	$7,073,250	$101,046
City of Colonial Heights	1	$2,000,000	$28,571
Dinwiddie County (inc. Town of McKenney)	11	$2,453,000	$35,043
City of Emporia	3	$125,000	$1,786
Goochland County	8	$553,500	$7,907
Greensville County (inc. Town of Jarratt)	8	$823,000	$11,757
Hanover County (inc. Town of Ashland)	16	$1,401,500	$20,021
Henrico County	11	$3,322,530	$47,465
City of Hopewell	2	$2,510,000	$35,857
New Kent County	6	$1,090,000	$15,571
City of Petersburg	7	$75,925,000	$1,084,643
Powhatan County	3	$103,000	$1,471
Prince George County	9	628000	$8,971
City of Richmond	14	$1,122,000	$16,029
Surry County (inc. Towns of Claremont (3), Dendron, Surry(2))	9	$696,000	$9,943
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	10	$3,692,000	$52,743
Total	**138**	**$104,217,780**	**$1,488,825**

Source: NOAA NCEI Database

Figure 5.19 graphically depicts tornado events in the region between 1950 and 2019, the latest year for which geographical data were available during the planning stage of this update. The thick burgundy swath across Petersburg and Hopewell represents the EF4 tornado from August 1993. The most recent events since the 2017 update to this plan are labeled with the date of occurrence.

Figure 5.19: Tornado Events, 1950 – 2019



Source: NOAA, 2021

Vulnerability Analysis

Human vulnerability to death or injury from tornado is based more on the availability, reception, and understanding of early warnings of tornadoes (e.g., tornado warnings issued by the NWS) and access to safe, substantial indoor shelter than it is on a person's location within the study area. While one might generalize that areas of high population are more vulnerable due to exposure of more people, property and infrastructure, Table 5.20 and Figure 5.19 demonstrate that tornadoes have struck both rural and urban jurisdictions of the study area. Access to technology (computers, radio, television, cell phones, outdoor sirens, etc.) that allows for receiving warnings, physical ability to relocate oneself safely to a tornado-safe space, and language comprehension that allows for suitable understanding of warnings are all factors affecting human vulnerability.

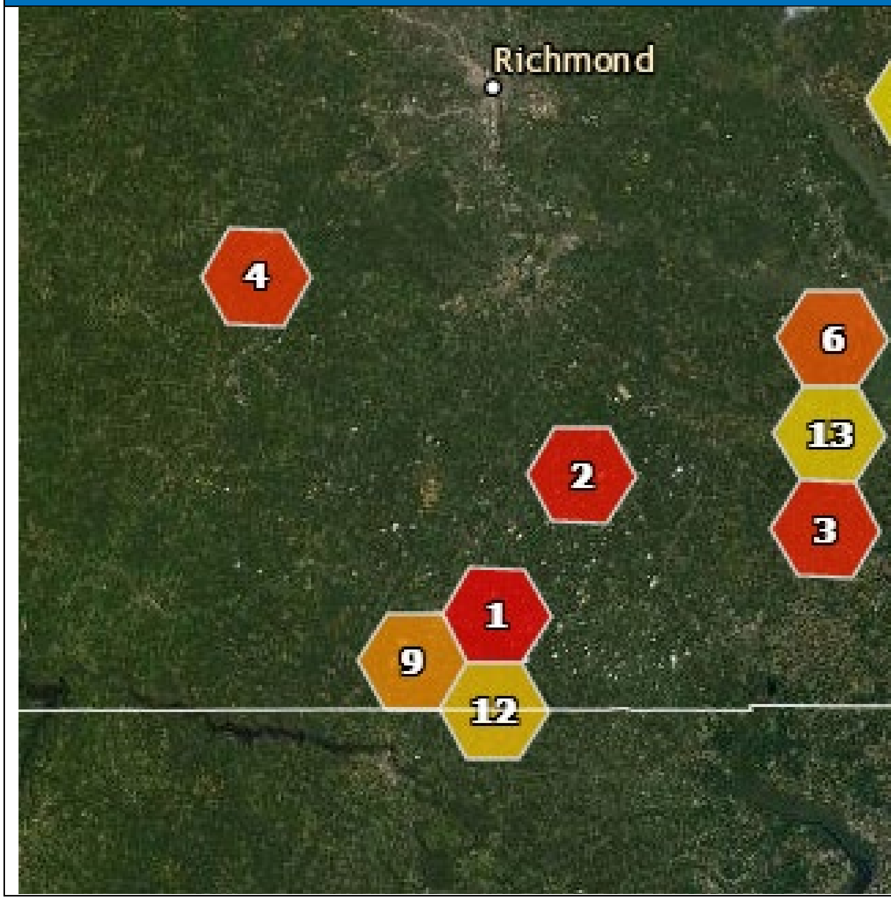
Low-intensity tornadoes may not completely destroy a well-constructed building, although even the most well-constructed buildings are vulnerable to the effects of a more intense (F2 or higher) tornado throughout the study area. A structure's tornado vulnerability is the same as that for other types of extreme wind events and is based in large part on building construction methods and design standards, as discussed in greater detail in Section 5.6 regarding Tropical Storm vulnerability. Other factors such as structure elevation, condition, and maintenance or location of trees and treelines also play a significant role in determining vulnerability to tornado damage. The statewide building code provides a reasonable level of protection for newly constructed buildings, while structures built before the code went into effect are most vulnerable to damage.

Although historical data indicate that there have been variations in the distribution of tornadoes across the region, the probability of experiencing a tornado is roughly equal for all of the jurisdictions. The vulnerability of critical facilities across the area is largely determined by construction type of each particular facility. Wood-framed structures are generally considered to be more vulnerable to tornado damage than steel, brick, or concrete structures. The population concentrations in the urbanized areas of Metropolitan Richmond and Petersburg may experience more damage as a result of a similar event than more rural areas of Greensville County or New Kent County, for example, but the vulnerability to tornado strike is characterized uniform throughout the study area.

Probably the most vulnerable type of structure with regard to tornado damage is a manufactured home. Proper anchoring of these structures can reduce damage exposure, but not entirely. Researchers at ODU have been documenting spatial variability and trends in tornado occurrence in the Commonwealth, and have overlaid areas of increased tornado activity with the highest percentage of manufactured homes in the state using data from the 2014-2018 American Community Survey.

Based on their analysis, there are several areas that have experienced an increased trend in number of tornadoes since 1950, and which have a high concentration of mobile homes, including the Richmond-Crater areas of: Emporia, Greensville County, Sussex County, and Surry County. **Figure 5.20** from the ODU study shows these areas in more detail.

Figure 5.20: Virginia Tornado Mobile Home Risk Index



#1 – (up trend since 1950 with 99% confidence), 23.52% mobile homes, Emporia, Greensville County, Sussex County, Southampton County

#2 – (up trend 95% confidence), 36.75% mobile homes, Sussex County

#6 – (up trend 95% confidence), 17.97% mobile homes, Surry County

#9 – (up trend 95% confidence), 15.25% mobile homes, Emporia, Greensville County

#12 – (up trend 95% confidence), 13.68% mobile homes, Greensville County

#13 – (up trend 95% confidence), 13.13% mobile homes, Isle of Wight County, Surry County

Source: Old Dominion University, accessed online at: https://odu-gis.maps.arcgis.com/apps/Cascade/index.html?appid=723e660c2c09447fa8a57d3186dc8d2a, 2021.

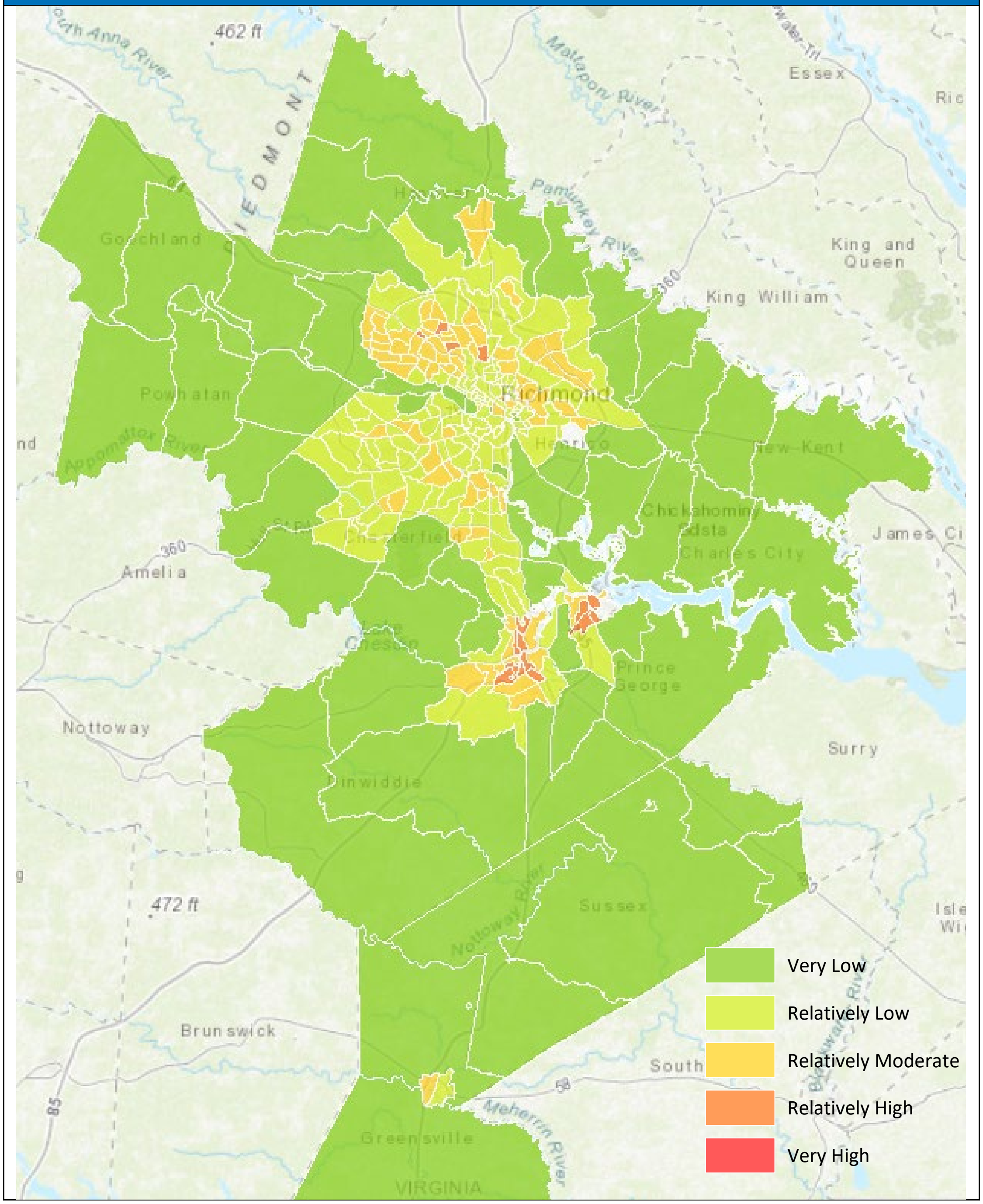
Because scientists and weather experts cannot predict exactly where a tornado may strike, there are no geographic boundaries for this hazard or methodology for modeling detailed loss estimates. Therefore, all buildings and contents within the region are considered to be exposed and could potentially be impacted on some level by the tornado hazard.

Based on historic property damages for the 70-year period of record between 1950 and 2020 as shown in Table 5.20, there were 138 tornado events with an annualized loss estimate of $1.48 million and a recurrence interval of .5 year, or frequency of 2.0 events per year.

Social Vulnerability

The NRI data for social vulnerability to tornadoes are shown in **Figure 5.21**. Despite the higher numbers of manufactured homes in the rural, southeastern portions of the study area, the damage history and built infrastructure exposure in the central part of the region result in higher social vulnerability in the Richmond and Petersburg regions.

Figure 5.21: National Risk Index, Tornado Risk Rating



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has very low social vulnerability for tornado.

Future Vulnerability, Land Use and Climate Change

The link between changing climate and tornado severity and frequency is currently unclear. One problem is that long-term trends are difficult to determine, as records only go back to the 1950s. Another issue is that as population centers have grown and shifted over time, the reporting of tornadoes has been inconsistent. Also, improved observation technology (such a Doppler radar) allows for detection of events that was not possible in earlier years.

Researchers are working to better understand how the fundamental elements required for tornado formation – atmospheric instability and wind shear – interacts with changing climate conditions. It is likely that a warmer, wetter climate will allow for more frequent atmospheric instability. However, it is also likely that a warmer climate will dampen the probability of wind shear. Recent trends observed in the Midwest are inconclusive. It is also possible that climate change would shift the traditional timing or expected locations for tornadoes and have less impact on the total number of tornado occurrences.

Mass evacuations as a result of a tornado or tornado outbreak are unlikely. Evacuations of damaged areas or damaged communities may be required, but would be expected to be within the scope of responsibilities for local emergency management, the community and its partners.

5.8 Wildfires

Hazard Profile

A wildfire is any fire occurring in a wildland area (i.e., grassland, forest, brush land) except for fire under prescription.[12] Wildfires are part of the natural management of the Earth's ecosystems but may also be caused by natural or human factors. Over 80% of forest fires are started by negligent human behavior such as smoking in wooded areas or improperly extinguishing campfires. The second most common cause for wildfire is lightning.

There are three classes of wildland fires: surface fire, ground fire, and crown fire. A surface fire is the most common of these three classes and burns along the floor of a forest, moving slowly and killing or damaging trees. A ground fire (muck fire) is usually started by lightning or human carelessness and burns on or below the forest floor. Crown fires spread rapidly by wind and move quickly by jumping along the tops of trees. Wildland fires are usually signaled by dense smoke that fills the area for miles around.

Fire probability depends on local weather conditions, outdoor activities such as camping, debris burning, and construction, and the degree of public cooperation with fire prevention measures. Drought conditions and other natural disasters (such as hurricanes, tornadoes and lightning) increase the probability of wildfires by producing fuel in both urban and rural settings. Forest damage from hurricanes and tornadoes may block interior access roads and fire breaks, pull down overhead power lines, or damage pavement and underground utilities.

[12] Prescription burning, or "controlled burn," undertaken by land management agencies is the process of igniting fires under selected conditions, in accordance with strict parameters.

The impacts of wildfire in the Richmond-Crater region are both economic and environmental. From an economic perspective, fires destroy most homes, businesses and infrastructure in their path. The population displacement and subsequent rebuilding consumes valuable resources of private and public entities. Communities in the region spend significant capital funds both fighting wildfires and training staff and preparing equipment and infrastructure to fight wildfire. Wildfire also endangers the lives and safety of firefighters and residents. Loss of life is a possible impact of severe wildfire in the region, especially where access roads are limited or impassable.

The region's air, water and soil environments are all altered by wildfire, and even wildfire in adjacent regions. Dense smoke and the fine particles and gases inside the smoke pose a risk to human health. Smoke irritates the eyes and respiratory system and can cause bronchitis or aggravate heart or lung disease even for residents hundreds of miles downwind. Wildfires raise the temperature of forest soils and potentially wipe away organic value of the soil. And although soils do eventually recover, the impact on watersheds in the interim can be detrimental to the region's water bodies. Burned organic matter in soils may negatively affect infiltration and percolation making soil surfaces water repellant. If water is unable to infiltrate, runoff quantity increases and infiltration to groundwater decreases. Both of these factors may negatively impact water quality downstream and could increase risk of flooding and landslides in the event of heavy rains.

Magnitude or Severity

A wildfire can range from a very localized and containable burn to an out-of-control blaze that can spread quickly and is capable of scorching thousands of acres of land over many days. The Virginia wildfire season is normally in the spring (March and April) and then again in the fall (October and November). During these months, relative humidity tends to be lower, and winds are higher. In addition, hardwood leaves are on the ground, providing more fuel and allowing the sunlight to directly reach the forest floor, warming and drying the surface fuels.

As fire activity fluctuates during the year from month to month, it also varies from year to year. Historically, extended periods of drought and hot weather can increase the risk of wildfires. Some years with adequate rain and snowfall amounts keep fire occurrences low; while other years with extended periods of warm, dry, and windy days exhibit increased fire activity.

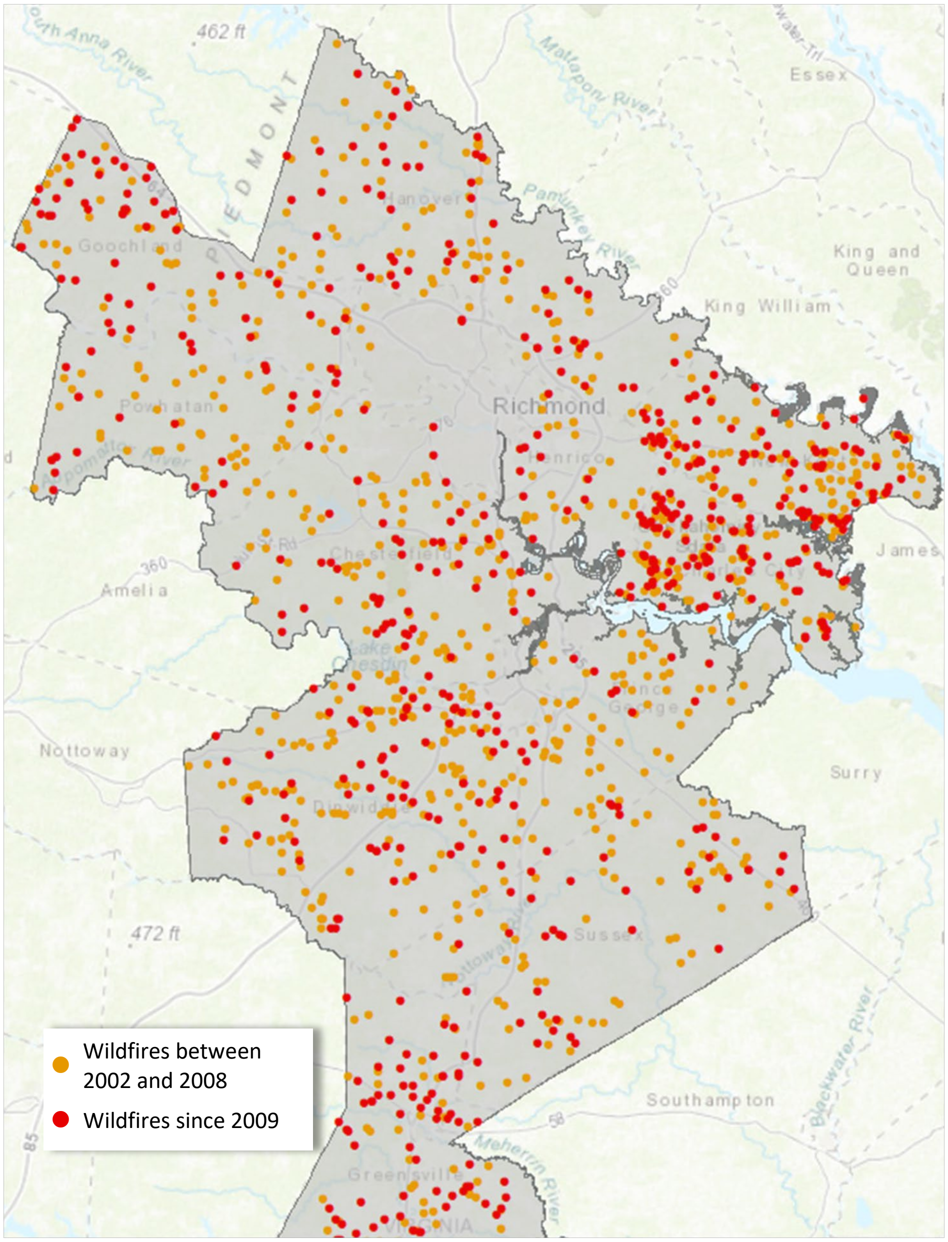
Long-term climate trends as well as short-term weather patterns play a major role in the risk of wildfires occurring. For instance, short-term heat waves along with periods of low humidity can increase the risk of fire, while high winds directed toward a fire can cause it to spread rapidly.

Hazard History

Due to the growth of the population of the commonwealth, there has been an increase in people living in the urban-wildland interface, as well as an increase in use of the forest for recreational purposes. Historical records of wildfire events specific to the study area are limited, not all wildfires are reported, and the records appear to contain some duplicate entries. Nevertheless, the data provide useful information from a planning perspective.

VDOF provided fire incidence data for the period 1995 to 2020, with detailed data for the period between 2005 and 2020. The fire incidence data provided from 1995 to 2004 were originally included in the *2011 Richmond-Crater Hazard Mitigation Plan*. The data from VDOF are summarized in **Table 5.21** showing the number of wildfires per jurisdiction per year, with acres burned and total damages for the latter periods. **Figure 5.22** indicates the location of VDOF-reported fires since 2002.

Figure 5.22: Wildfire History, 2002 - 2019



Source: VDOF, 2021

According to VDOF records from 1995 to 2020, there were 2,468 wildfires that burned approximately 9,170 acres and caused nearly $3.5 million in damages in the region. The most recent 5-year period, between 2015 and 2020, shows a dramatic reduction in the number of reported fires; from 722 fires in the period 1995 to 1999 down to just 244 fires between 2015 and 2020. In the most recent period, Charles City County shows the highest number of wildfires, while Sussex County experienced the most acres burned by wildfire.

Hanover County suffered the most damages in the most recent period, while Dinwiddie County has the highest annualized damages for the region.

One of the most damaging events in the period between 2000 and 2020 was the February 19, 2011, fire in Goochland County that burned approximately 273 acres and caused a reported $110,000 in damage. High winds exacerbated the brush fire on Cardwell Road that was caused by a limb falling on a power line. An abandoned home burned, as well.

Debris burning was the cause of another notable fire in the region on April 3, 2011, that burned an estimated 545 forested acres in Dinwiddie County, near McKenney. The value of the timber damaged was estimated at $200,000. A NOAA climate report issued in January 2012, indicated that "the overall [weather] pattern during 2011 created ideal wildfire conditions across most of the southern U.S. during the year."[13]

[13] National Centers for Environmental Information, Wildfires – Annual 2011 report, accessed online at: https://www.ncdc.noaa.gov/sotc/fire/201113.

Table 5.21: Wildfire Data, 1995–2020												
Jurisdiction Name	**# of Wildfires**		**2005-2009**			**2010-2014**			**2015-2020**			**Annualized Damages**
	1995-1999	**2000-2004**	**# OF FIRES**	**ACRES BURNED**	**TOTAL DAMAGES**	**# OF FIRES**	**ACRES BURNED**	**TOTAL DAMAGES**	**# OF FIRES**	**ACRES BURNED**	**TOTAL DAMAGES**	
Charles City	49	62	43	171.7	$67,600	52	78.7	$190,600	40	227.8	$65,950	$21,610
Chesterfield	130	36	65	137.8	$6,750	28	264.9	$80,635	19	58.5	$142,650	$15,336
Colonial Heights	0	1	0	0	$0	0	0	$0	0	0	$0	$0
Dinwiddie	54	93	91	3063.6	$780,500	48	826.7	$288,502	29	80.5	$64,950	$75,597
McKenney	0	0	0	0	$0	0	0	$0	0	0	$0	$0
Emporia	1	1	1	1	$0	1	2	$0	0	0	$0	$0
Goochland	76	40	31	153.2	$10,018	34	349.5	$307,330	18	110.1	$6,700	$21,603
Greensville	30	20	36	408.9	$80,900	37	151.2	$68,400	30	183	$77,900	$15,147
Jarratt	0	1	0	0	0	0	0	0	0	0	0	$0
Hanover	56	35	67	151.2	$113,410	30	126.8	$170,250	26	103.8	$207,215	$32,725
Ashland	0	0	2	2	$100	0	0	$0	0	0	$0	$7
Henrico	39	31	16	93.2	$12,000	8	39.7	$373,600	3	21.2	$17,000	$26,840
Hopewell	0	1	0	0	$0	0	0	$0	0	0	$0	$0
New Kent	47	19	58	43.8	$9,800	56	119.9	$118,251	35	92.9	$700	$8,583
Petersburg	0	71	2	26	$0	1	1	$0	1	2.5	$0	$0
Powhatan	99	32	24	38.6	$0	10	44.7	$42,100	11	59.1	$82,985	$8,339
Prince George	40	23	56	90.2	$4,250	8	91.5	$8,850	7	41.5	$2,600	$1,047
Richmond	1	60	0	0	$0	1	7	$0	2	28	$100	$7
Surry	0	0	0	0	$0	0	0	$0	0	0	$0	$0
Sussex	67	43	51	368.3	$21,150	21	228.2	$26,150	17	283.6	$28,550	$5,057
Jarratt	0	1	0	0	$0	0	0	$0	0	0	$0	$0
Stony Creek	0	0	0	0	$0	0	0	$0	0	0	$0	$0
Wakefield	0	1	0	0	$0	0	0	$0	0	0	$0	$0
Waverly	1	1	0	0	$0	0	0	$0	1	1	$0	$0
Totals	**722**	**572**	**543**	**4,749.5**	**$1,106,478**	**335**	**2,331.8**	**$1,674,668**	**239**	**1,293.5**	**$697,300**	**$231,896**

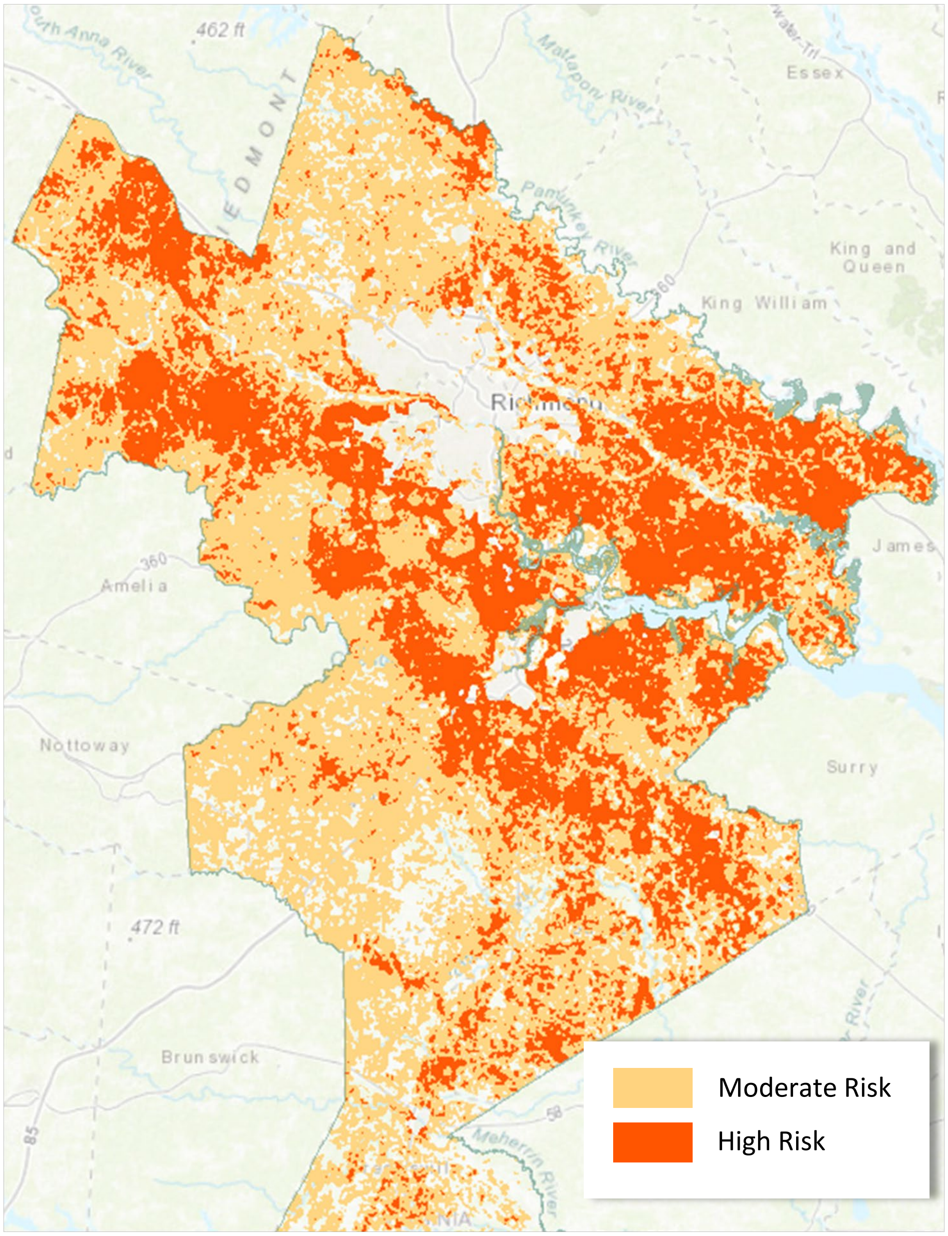
Vulnerability Analysis

The probability of wildfires is difficult to predict, constantly in flux over the short-term, and dependent on numerous factors, including the types of vegetative cover in a particular area, and weather conditions, including humidity, wind, and temperature. Analysis of VDOF data indicates that on an annual basis, approximately 99 wildfires impact the region.

In July 2003, VDOF developed and released a GIS-based wildfire risk assessment for the Commonwealth of Virginia. The data are now part of the Southern Foresters web site at www.southernwildfirerisk.com that serves as a portal for data from several southern states. While this assessment of wildfire risk is not recommended for site-specific determinations of wildfire vulnerability, the data were used in this plan as an indicator of general hazard exposure within the region, as shown in **Figure 5.23**. Risk assessment designation involved several inputs, including slope, aspect, land cover, distance to railroads, distance to roads, population density, and historical fire occurrence. Potential wildfire risk areas are graduated but presented in two overall categories indicating the relative level of threat to the area as high or moderate. Areas without a high or moderate designation are considered to be at low risk of wildfire.

Hurricanes Isabel and Irene downed thousands of trees in both New Kent and Charles City Counties in 2003 and 2011, respectively. While the counties removed the most hazardous trees from public facilities and many homeowners have removed trees from their property, thousands still remain. These trees provide an easy source of fuel for wildfires and create a high risk across these counties.

Figure 5.23: Wildfire Risk Assessment



Source: VDOF and www.southernwildfirerisk.com accessed online 2021

Certain groups of essential facilities were assessed to determine if their location was within a high risk area as determined by the Wildfire Risk Assessment. The analysis looked at facilities that could be particularly hazardous during a wildfire: electric power facilities, hazardous materials facilities, natural gas and oil facilities. All of the natural gas providers in the region have segments of their lines that traverse high wildfire risk areas. The analysis for other facilities shows the following facilities are located in high wildfire risk areas:

Electric Power Facilities:	Boydton Plan Road Cogen Plant, Petersburg Correctional Solar, Barhamsville Scott Solar Farm, Powhatan
Hazardous Materials Facilities:	Van Waters & Rogers, Inc, Richmond Industrial Chemicals, Inc, Richmond Rehrig International, Richmond Honeywell Tech Center, Chesterfield Carter-Wallace, Colonial Heights Super Radiator Coils, Richmond Chaparral, Petersburg Graphic Packaging Corp. of Virginia, Richmond Borden Chemical Inc., Waverly
Oil Facilities:	Atlantic Industrial Services, Chester

VDOF defines woodland home communities as clusters of homes located along forested areas at the wildland-urban interface that could possibly be damaged during a nearby wildfire incident. **Table 5.22** illustrates the number of woodland communities in each jurisdiction, broken down by wildfire risk zone, while **Table 5.23** illustrates the number of homes in woodland communities, also broken down by wildfire risk zone. The data indicate that approximately 46% of woodland home communities in the region are located in a high-wildfire-risk area. Of the 132,218 homes in woodland home communities, approximately 33% are located in a high-fire-risk area.

Table 5.22: Number of Woodland Communities by Fire Risk

Jurisdiction Name	Low	Moderate	High	Total	% High Risk
Charles City County	0	6	36	42	86%
Chesterfield County	82	140	189	411	46%
City of Colonial Heights	0	0	1	1	100%
Dinwiddie County	1	5	4	10	40%
Town of McKenney	1	0	0	1	0%
City of Emporia	5	0	0	5	0%
Goochland County	4	93	79	176	45%
Greensville County	1	5	0	6	0%
Town of Jarratt	0	0	2	2	100%
Hanover County	10	184	79	273	29%
Town of Ashland	2	3	1	6	17%
Henrico County	54	67	74	195	38%
City of Hopewell	1	0	0	1	0%

Table 5.22: Number of Woodland Communities by Fire Risk					
Jurisdiction Name	**Low**	**Moderate**	**High**	**Total**	**% High Risk**
New Kent County	0	8	47	55	85%
City of Petersburg	5	2	4	11	36%
Powhatan County	0	31	73	104	70%
Prince George County	2	7	24	33	73%
City of Richmond	23	2	4	29	14%
Town of Surry	0	0	0	0	0%
Sussex County	0	0	1	1	100%
Town of Jarratt	0	0	2	2	100%
Town of Stony Creek	0	0	0	0	0%
Town of Wakefield	0	0	0	0	0%
Town of Waverly	0	0	0	0	0%
Totals	**191**	**553**	**622**	**1,366**	**46%**

Source: VDOF

Table 5.23: Number of Homes in Woodland Communities by Fire Risk					
Jurisdiction Name	**Low**	**Moderate**	**High**	**Total**	**% High Risk**
Charles City County	0	136	855	991	86%
Chesterfield County	20,697	27,146	25,142	72,985	34%
City of Colonial Heights	0	0	75	75	100%
Dinwiddie County	135	144	253	532	48%
Town of McKenney	31	0	0	31	0%
City of Emporia	240	0	0	240	0%
Goochland County	138	3,099	2,720	5,957	46%
Greensville County	85	149	0	234	0%
Town of Jarratt	0	0	76	76	100%
Hanover County	981	7,278	3,342	11,601	29%
Town of Ashland	255	312	14	581	2%
Henrico County	13,700	4,409	3,761	21,870	17%
City of Hopewell	65	0	0	65	0%
New Kent County	0	293	1,829	2,122	86%
City of Petersburg	555	104	271	930	29%
Powhatan County	0	713	3,204	3,917	82%

Table 5.23: Number of Homes in Woodland Communities by Fire Risk					
Jurisdiction Name	**Low**	**Moderate**	**High**	**Total**	**% High Risk**
Prince George County	415	199	1,397	2,011	69%
City of Richmond	7,595	65	185	7,845	2%
Town of Surry	0	0	0	0	0%
Sussex County	0	0	43	43	100%
Town of Jarratt	0	0	76	76	100%
Town of Stony Creek	0	0	0	0	0%
Town of Wakefield	0	0	0	0	0%
Town of Waverly	0	0	0	0	0%
Totals	**44,892**	**44,047**	**43,279**	**132,218**	**33%**

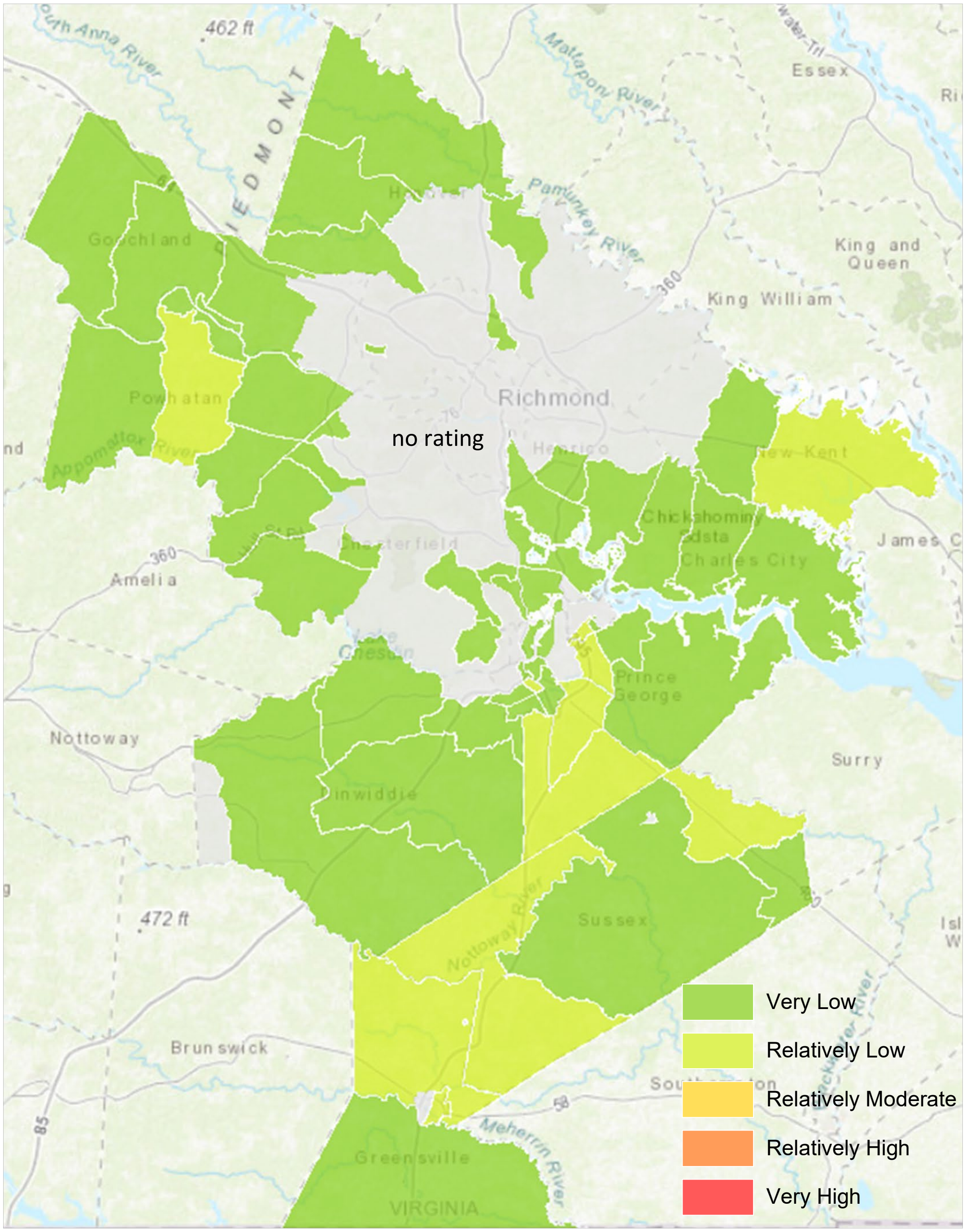
Source: Virginia Department of Forestry, 2010 dataset.

Based on the VDOF historical record from 1995 to 2020, the region experiences approximately 96 fires per year that result in approximately $231,896 in annualized damages.

Social Vulnerability

The NRI data for social vulnerability to wildfire are shown in **Figure 5.24**. Where data and historical events are sufficient to calculate a rating for wildfire, the risk is determined to be very low or relatively low throughout the study area.

Figure 5.24: National Risk Index Rating, Wildfire



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has very low social vulnerability for wildfire south of Route 10 and relatively low social vulnerability for wildfire north of Route 10.

Future Vulnerability, Land Use and Climate Change

The region is expected to continue to incur wildfires, particularly during extended periods of dry and windy weather. The region's zoning ordinances do not generally guide new development away from the Wildland Urban Interface, but the wildfire threat is not as severe as in the western United States.

Climate change increases the risk of the hot, dry weather that is likely to fuel wildfires. Also, because climate change is also a factor in higher intensity windstorms, there is a likelihood of increased fuel for wildfire when downed trees from storms are not removed. For site specific information on historic wildfire ignition density, property owners and planners can visit: www.southernwildfirerisk.com.

While evacuations may be required as a result of wildfire in the Richmond-Crater region, these evacuations would likely be of a locality-manageable scale and are not expected to be considered "mass evacuations". Should larger-scale evacuations be required, adjacent jurisdictions can assist.

A VDOT snowplow plows I-64 East. (Photo by Tom Saunders, VDOT)

5.9 Severe Winter Weather

Hazard Profile

A winter storm can range from a moderate snow over a period of a few hours to blizzard conditions with blinding wind-driven snow that lasts for several days. Some winter storms may be large enough to affect several states, while others may affect only a single community. Many winter storms are accompanied by low temperatures and heavy and/or blowing snow, which can severely impair visibility.

In the Richmond-Crater region, winter storms typically include snow, sleet, freezing rain, or a mix of these wintry forms of precipitation. Sleet—raindrops that freeze into ice pellets before reaching the ground—usually bounce when hitting a surface and do not stick to objects; however, sleet can accumulate like snow and cause a hazard to motorists. Freezing rain is rain that falls onto a surface with a temperature below freezing, forming a glaze of ice. Even small accumulations of ice can cause a significant hazard, especially on roads, power lines and trees. Ice storms have also occurred in the region, when freezing rain falls and freezes immediately upon impact.

Communications and power in the region can be disrupted for days, and even small accumulations of ice may cause extreme hazards to motorists and pedestrians. Perhaps one of the most common impacts of winter storms in the region is vehicle accidents and stranded, disabled vehicles. Unaccustomed to driving in snow and ice much of the year, drivers attempt to drive at normal speeds despite deteriorated road conditions. Lacking the large fleets of snowplows of some counties and municipalities further north, the region's secondary roads are not cleared as often or as quickly, and roads may remain unplowed or untreated for days. This impacts special needs populations and others who may become housebound by severe winter storms. Airports in the region also shut down for some time until the runways can be cleared.

Recent winter storms in the region have caused severe economic disruption with lengthy school and business closures, damage to vehicles and reduced community services for extended periods. In agricultural portions of the study area such as Greensville County, freezing temperatures may affect agricultural production, depending on when the event occurs relative to the growing periods of certain crops. Nor'easters can cause winter storms in the region, so the impacts of coastal flooding and shoreline erosion can also be associated with winter storm events, especially in New Kent and Charles City Counties.

The impacts of winter storms are usually minimal in terms of property damage and long-term effects. The most notable impact from winter storms is the damage to power distribution networks and utilities. Severe winter storms have the potential to inhibit normal functions of the community. Governmental costs for winter storms accumulate due to personnel and equipment needed for clearing streets. Private sector losses are attributed to lost work when employees are unable to travel. Occasionally, buildings may be damaged when snow loads exceed the design capacity of their roofs or when trees fall due to excessive ice accumulation on branches.

The water content of snow can vary significantly from one storm to another and can significantly impact the degree to which damage might occur. In snow events that occur at temperatures at or even above freezing, the water content of the snowfall is generally higher. Higher water content translates into a heavier, 'wet' snowfall that more readily adheres to power lines and trees, increasing the risk for their failure. Roof collapse is also more of a concern with wetter, heavier snowfall. On the other hand, clearing roadways and sidewalks is considerably easier for a drier, more powdery snow. A dry, fluffy snow is less likely to accumulate on power lines and trees. This type of snow generally occurs in temperatures below freezing with water content decreasing with temperature. The primary impact of excessive cold is increased potential for frostbite, and potentially death as a result of over-exposure to extreme cold.

Homes and businesses suffer damage when electric service is interrupted for long periods of time. Six utility companies provide service to the region, which can make power restoration complicated. Threats to personal health can intensify when frozen precipitation makes roadways and walkways slippery and when prolonged power outages and fuel supplies are combined.

Another challenge with winter weather in the region is the amount of ice that often accompanies the winter season. Even small accumulations of ice from sleet or freezing rain can cause significant hazards to people, especially to pedestrians and motorists, as well as to property. Ice from freezing rain can accumulate on trees, power lines, and communication towers causing damage and leading to power and communication outages that can last for days or weeks. Even small accumulations of ice can be severely dangerous to motorists and pedestrians. Bridges and overpasses are particularly dangerous because they freeze before other surfaces.

Some of the secondary effects presented by winter storms and extreme or excessive cold temperatures are threats to the health of livestock and pets, and frozen water pipes in homes and businesses that may burst and flood indoor areas. Debris created by the trees can also blocks roadways and impact emergency services. Clean-up of the debris is often complicated because responsibility is shared by the Virginia Department of Transportation (VDOT) and private utility companies.

Magnitude or Severity

NOAA's NCEI is now producing the Regional Snowfall Index (RSI) to evaluate significant snowstorms that impact the eastern two-thirds of the United States. The RSI is a regional snowfall impact scale that uses the area of snowfall, the amount of snowfall, and the number of people living within a snowstorm. Since the index uses population information, it attempts to quantify the societal impacts of a snowstorm. RSI has been calculated for large snowstorms back to 1900 and therefore the index puts a particular event into a century scale historical perspective (**Table 5.24**). A Category 5 snowstorm is a very rare event while Category 0 and 1 snowstorms are quite typical.

Table 5.24: Regional Snowfall Index (RSI)

Category	RSI Raw Score	Approximate Percent of Storms	Description
5	>18	1%	Extreme
4	10-18	2%	Crippling
3	6-10	5%	Major
2	3-6	13%	Significant
1	1-3	25%	Notable
0	0-1	54%	

Source: NOAA NCEI

RSI is calculated for specific regions. Only the snowfall within a particular region is used to calculate the index for that region. The Richmond-Crater study area is within the Southeast study region for the RSI. The RSI differs from other indices because it includes population, which ties the index to societal impacts. Currently, the index uses population based on the 2000 Census. Where available, the RSI value for specific storms is provided in the History section below.

Table 5.25 provides a summary of the most severe winter weather events to strike the Richmond-Crater region.

Table 5.25: History of Winter Storm Events and Damages, 2010–2021		
Date	**Damages**	**RSI Category**
December 25-28, 2010	A 4- to 10-inch snowfall blanketed the region with the heaviest amounts falling over the south and eastern sections. Amounts ranged from 4 inches northwest of the City of Richmond, 6 to 7 inches in the Cities of Petersburg and Emporia, and around a foot near the Town of Wakefield.	2
February 11-14, 2014	This was a major ice and snowstorm that affected the entire region and elsewhere in the Eastern United States. This event produced devastating amounts of freezing rain and snow along and east of Interstate 95 all the way down to the coast. Overall temperatures throughout the winter were much colder in 2014. A Presidential Disaster event was declared in Chesterfield. (Source: http://www.weather.gov/phi/02132014)	4
January 22-24, 2016	What transpired was reasonably close to what was forecast, with a major snowstorm for our entire region, which also included a mix of some sleet across portions of the area as well as small amounts of freezing rain. NOAA ranks Northeast U.S. storms according to overall impact, part of which is dependent on societal and economic factors, thus population density is a key component. This particular storm was ranked as a 4 on the "NESIS" scale of 1-5, or "crippling". It is now 4th on the list of historic storms that have been ranked on the NESIS scale, with only two storms ever ranked as a 5 ("extreme). Presidential Disasters for this study region were declared for Sussex and Henrico Counties. (Source: http://www.weather.gov/media/rnk/past_events/2017_01_2223_Winter.pdf)	4
January 5-8, 2017	Low pressure tracking northeast just off the Southeast and Mid Atlantic Coasts produced between three inches and twelve inches of snow across central, south central, and interior southeast Virginia. Laurel reported 2.5 inches of snow. Ginter Park and Glen Allen reported 2.0 inches of snow.	2
December 8-10, 2017	Low pressure tracking northeast just off the Southeast and Mid Atlantic Coasts produced between three inches and twelve inches of snow across central, south central, and interior southeast Virginia. Reports ranged from 7 to 12 inches across the study area.	2
January 3-5, 2018	Strong low pressure tracking northward just off the East Coast produced between one inch and four inches of snow across central and south central Virginia.	1

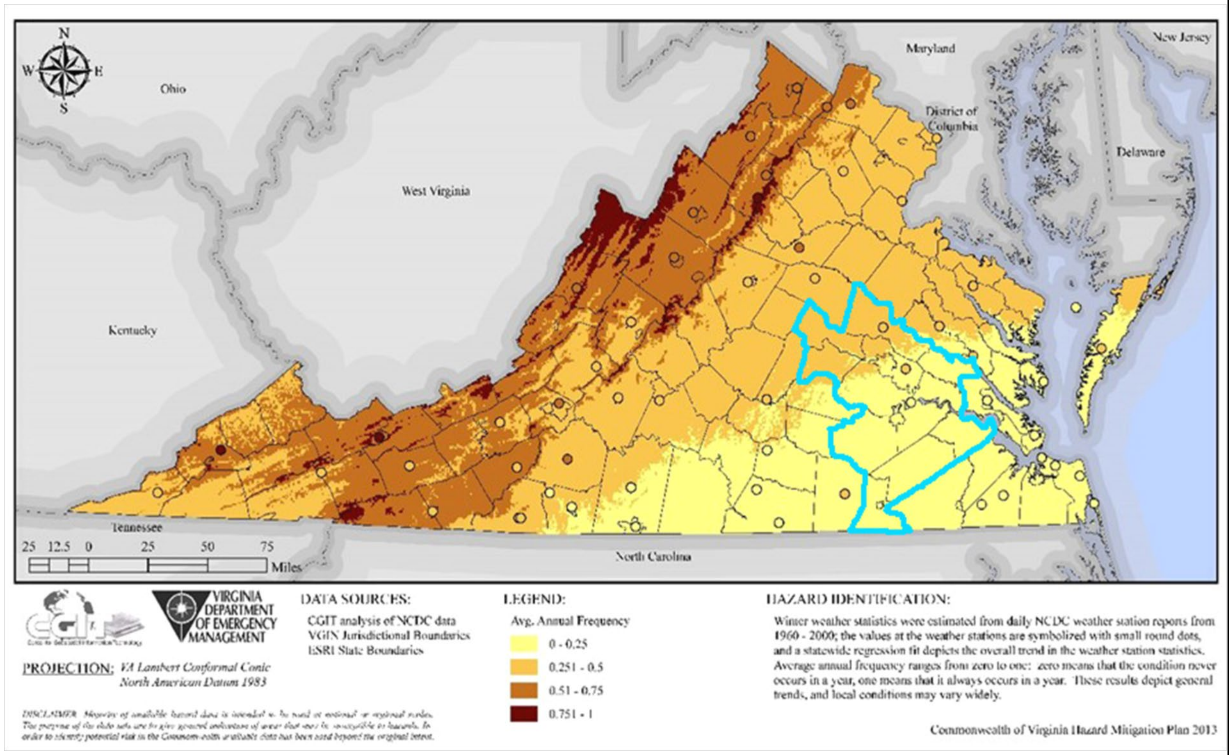
Table 5.25: History of Winter Storm Events and Damages, 2010–2021		
Date	**Damages**	**RSI Category**
March 11-15, 2018	Snowfall totals ranged from one to three inches across the Richmond-Crater region.	1
March 20-22, 2018	Low pressure tracking east northeast off the Mid Atlantic Coast produced between one inch and four inches of snow across portions of central and south central Virginia, and the Middle Peninsula. Snow totals ranged from 1 to five inches in the region.	1
December 7-10, 2018	An area of low pressure became centered over Florida Panhandle as a cold air damming regime set up across interior parts of Virginia and the Carolinas, with winds out of the NNE. A large area of precipitation was impacting the Carolinas and was approaching southern VA by sunrise on the 9th. By Sunday morning, there was snow in most areas except for coastal SE VA/NE NC, where NE winds ushered in milder air. Bands of heavy snow (rates of 1-2"/hour) set up over far southwestern portions of Wakefield area. Snow started changing to sleet then rain over SE VA/northern NC Sunday afternoon. Snow became heavy over Richmond metro area in afternoon, with temperatures slightly below freezing. Moderate to heavy snow continued through afternoon from Richmond metro to Virginia Piedmont, with widespread 9 to 14 inches of snow. Numerous flight cancellations at area airports. Interstates became snow covered and numerous accidents were reported. The 11.5 inches of snow at Richmond International Airport ranks as the 2nd largest December snowstorm on record.	3
January 30 – February 3, 2021	Powhatan County and Oilville in Goochland County had snow totals between 1 to 4 inches, but snow accumulation elsewhere in the region was between .5 inch to 3 inches.	1
February 18 – 19, 2021	Strong surface high pressure centered from the Midwest into New England helped to supply low level cold air into the area, as a prolonged Classic Cold Air Damming regime was in place throughout the duration of the event. With warmer air present aloft, precipitation fell in the form of freezing rain and sleet across central and south central Virginia, and the Virginia Northern Neck, as a couple of weak low pressure areas tracked northeast along and off the Southeast and Mid Atlantic Coasts. There were two distinct waves of precipitation that moved across the area. One that occurred during the early morning-midday on the 18th, and a second wave of light to moderate precipitation that moved across the region during the early to mid morning on the 19^{th}. This resulted in significant ice accretion between 0.20 inch and 0.40 inch, along with sleet accumulations between 0.5 inch and 1.5 inches. Several trees and power lines were downed, with	3

Table 5.25: History of Winter Storm Events and Damages, 2010–2021		
Date	**Damages**	**RSI Category**
	numerous power outages reported. Ice accretions between 0.20 inch and 0.25 inch, along with sleet accumulations between 0.5 inch and 1.0 inch were reported. Damages estimated at $390,000 throughout the region.	

**History from 1940-2010 in Appendix F-6*
Source: NCEI

The Virginia Tech Center for Geospatial Information and Technology performed analyses of weather station daily snowfall data for the Commonwealth of Virginia's *2013 Hazard Mitigation Plan Update*. Station-specific statistics were used as the basis for a seamless statewide estimate based on multiple linear regressions between the weather statistics (dependent variable) and elevation and latitude (independent variables). **Figure 5.25** shows that the average number of days with at least 3 inches of snowfall ranges from 1.51 to 2 days over northwestern portions of the region, including portions of Hanover, Goochland, Powhatan, and Henrico Counties to 1.5 days or fewer over the remainder of the area. A similar analysis was not conducted in the most recent state hazard mitigation plan.

Figure 5.25: Average Annual Frequency of Days with at Least 3 Inches of Snowfall

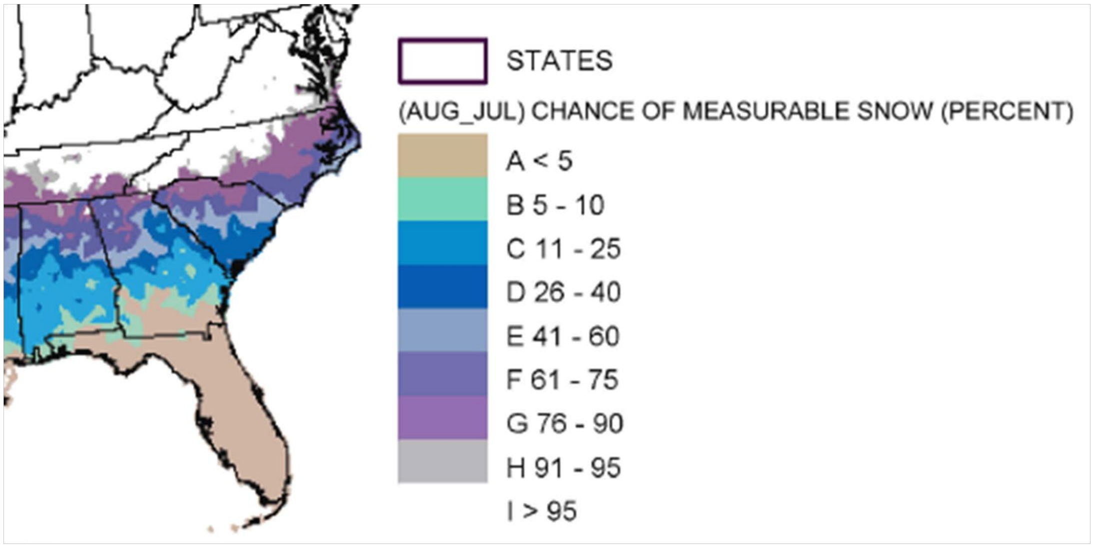


Source: 2013 Commonwealth of Virginia Hazard Mitigation Plan

Vulnerability Analysis

Historical evidence indicates that the region has been impacted by varying degrees of snowstorms and ice storms over the last century. **Figure 5.26** provides graphic evidence that the chance of snow annually is close to or equal to 100 percent in the study area.

Figure 5.26: Annual Percent Chance of Measurable Snow



Source: North Carolina State University, Climate Education web page: [http://climate.ncsu.edu/edu/k12/.SEPrecip, undated](http://climate.ncsu.edu/edu/k12/.SEPrecip)

To determine the geographic distribution and frequency with which major snow or ice events impact the region, the Iowa Environmental Mesonet (IEM) obtains data from cooperating members that have observing networks. Watch, Warning, and Advisory events were collected and examined between 1986 and 2021 (see **Table 5.26**). The events were sorted into the following categories: Freeze, Freezing Fog, Freezing Rain, Frost, Heavy Snow, Snow, Winter Storm, and Winter Weather. (Data were collected from: http://mesonet.agron.iastate.edu/vtec/search.php)

The most alerts between 1986 and 2021 were for Dinwiddie County, followed by Goochland and Hanover Counties. The fewest alerts were issued for Charles City, Surry County, and Prince George Counties. The most common type of events for all counties were the Winter Weather, Winter Storm, Freeze, and Frost type events.

Table 5.26: National Weather Service Winter Alerts, 1986 - 2021

Jurisdiction	Watch Events	Warning Events	Advisory Events	Total Events	Annualized Events
Charles City County	20	36	59	115	3.3
Chesterfield County	21	38	63	122	3.5
City of Colonial Heights	-	-	-	-	
Dinwiddie County	31	48	88	167	4.8
City of Emporia	-	-	-	-	

Table 5.26: National Weather Service Winter Alerts, 1986 - 2021					
Jurisdiction	**Watch Events**	**Warning Events**	**Advisory Events**	**Total Events**	**Annualized Events**
Goochland County	33	45	73	151	4.3
Greensville County	21	37	62	120	3.4
Hanover County	26	41	77	144	4.1
Henrico County	22	38	64	124	3.5
City of Hopewell	-	-	-	-	
New Kent County	22	34	65	121	3.5
City of Petersburg	-	-	-	-	
Powhatan County	32	46	65	143	4.1
Prince George County	19	38	62	119	3.4
City of Richmond	-	-	-	-	
Surry County	22	34	62	118	3.4
Sussex County	22	37	65	124	3.5
Totals	**291**	**472**	**805**	**1,568**	

**county data includes towns*

Source: Iowa State University, Iowa Environmental Mesonet, accessed 2021 online at: https://mesonet.agron.iastate.edu/vtec/search.php

Winter storm vulnerability can be expressed by impacts to people, property, and societal function. For example, exposure of individuals to extreme cold, falls on ice-covered walkways, carbon monoxide poisoning from generators and automobile accidents is heightened during winter weather events. **Table 5.27** summarizes NCEI historical impacts of winter weather events since 1993. Based on this information, on average, the region experiences approximately one and a half winter weather events annually, of which some rare winter storms have historically included significant accumulations of ice (due to freezing rain). In terms of annualized damages, roughly $40,411 per year in losses is attributed to winter weather events.

Property damage due to winter storms includes damage done by and to trees, water pipe breakage, structural failure due to snow loads, and injury to livestock and other animals. The average amount of total damages due to winter events is $40,400 per year (1993-2017) for the region. The counties most affected from winter events are Prince George ($9,089/yr.), Henrico ($8,948/yr.), and Chesterfield ($7,962/yr.). Disruption of utilities and transportation systems, as well as lost business and decreased productivity represent societal vulnerability.

Table 5.27: NCEI Annualized Winter Weather Events, 1993 - 2020				
Jurisdiction	**Annualized Number of Winter Weather Events**	**Annualized Property Damages**	**Annualized Crop Damages**	**Annualized Total Losses**
Charles City County	2.4	$1,304	-	$1,444
Chesterfield County	5.5	$7,962	-	$7,962
City of Colonial Heights	-	-	-	-
City of Emporia	-	-	-	-
City of Hopewell	-	-	-	-
City of Petersburg	-	-	-	-
City of Richmond	-	-	-	-
Dinwiddie County	2.4	$2,600	-	$2,600
Goochland County	3.3	$3,004	-	$3,004
Greensville County	3.9	-	-	-
Hanover County	3.4	$3,030	-	$3,030
Henrico County	5.6	$8,948	-	$8,948
New Kent County	2.5	$1,444	-	$1,444
Powhatan County	2.9	$2,889	-	$2,889
Prince George County	7.0	$9,089	-	$9,089
Surry County	1.0	-	-	-
Sussex County	2.2	-	-	-
Total		**$40,411**	**$0**	**$40,411**

Source: NOAA NCEI

According to NCEI records dating back to 1993, one fatality was officially recorded resulting from a winter storm event in the area. NCEI storm event records typically do not contain traffic fatalities blamed on wintry weather, and although details were not provided, the fatality reportedly occurred during a severe snowstorm on January 25, 2000.

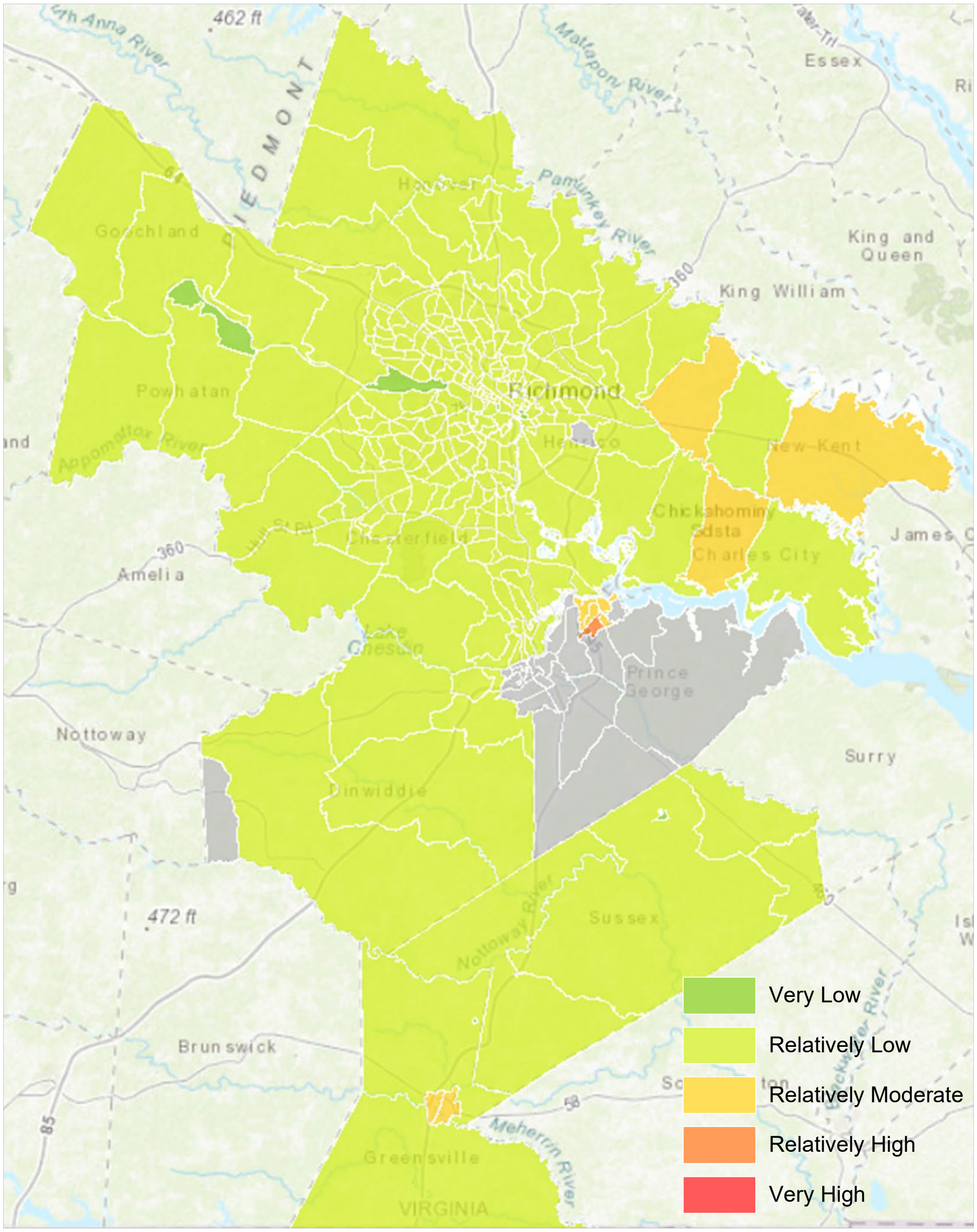
The number of reported events from the IEM (Table 5.26) and NCEI (Table 5.27) were slightly different. With the number of annual IEM events being 44.8 and the NCEI annual winter events being 46.9. Because of the difference in collection criteria, agencies, and time frames of the reported events, the difference between the two annualized events reported was not significant.

A quantitative assessment of critical facilities for winter storm risk was not feasible for this plan update. Transportation structures and natural gas transmission lines are at great risk from winter storms. In addition, building construction variables, particularly roof span and construction method, are factors that determine the ability of a building to perform under severe stress weights from snow. Finally, critical facilities do not always have redundant power sources, and many are not wired to accept a generator for auxiliary power.

Social Vulnerability

The NRI data for social vulnerability to winter weather are shown in **Figure 5.27**. Most of the region is rated as Relatively Low, with some moderate areas found in New Kent and Charles City counties, and a Relatively High area in Petersburg. The social vulnerability map does not appear to reflect the disparity between the historically higher impacted areas of Henrico, Prince George and Chesterfield counties and the southern and eastern portions of the study area with fewer reported winter storms. Technical documentation for the NRI indicates that the Iowa Environmental Mesonet data were used for historical occurrences; however, the historic loss ratios were derived from NCEI data which show relatively low dollar value losses for the region. Total reported losses from winter storms for the 27-year period between 1993 and 2020 were just under $1 million.

Figure 5.27: National Risk Index Rating, Winter Weather



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has relatively moderate social vulnerability for winter weather.

Notwithstanding the above, severe winter weather can be problematic for socially vulnerable populations, especially people living in substandard housing or without alternative arrangements when power goes down. Transportation impacts are especially severe when vulnerable people rely on public transportation and those routes are interrupted by snow or ice accumulation.

Future Vulnerability, Land Use and Climate Change

Winter storms remain a likely occurrence for the region. While storms will be more likely to produce small amounts of snow, sleet or freezing rain, larger storms, though less frequent in occurrence, are also expected to impact the region. The *2018 Commonwealth of Virginia Hazard Mitigation Plan* suggests that the southern and southeastern portions of the state are likely to receive significant winter weather approximately once a decade. Local zoning and comprehensive plans are not focused on winter storm planning in the study area; however, the statewide building code does address snow loads and newer buildings are expected to better withstand roof snow loads, in particular.

As the earth's climate changes, heavy seasonal snow years have begun to occur with greater frequency. According to NOAA's NCEI, the frequency of extreme snowstorms in the eastern US has increased over the past century, with approximately twice as many extreme snowstorms occurring in the last half of the 20th century as in the first half. Conditions that influence snowstorm severity including warmer ocean surface temperatures in the Atlantic. These increased temperatures can lead to exceptionally high amounts of moisture feeding into a storm and contribute to storm intensification.

Global ocean surface temperatures have increased at a rate of +.18 degrees Fahrenheit each decade since 1950. Natural variability can affect surface ocean temperatures, but as global surface temperatures increase, the temperature is higher at any time than it would have been if the climate were not changing. Some research has shown that increasing ocean surface temperature and reductions in Arctic sea ice may produce atmospheric circulation patterns that are favorable for winter storm development in the eastern United States. Notably, a greater prevalence of high pressure blocking patterns over the North Atlantic that result in cold outbreaks in the eastern US, along with slow moving systems can further exacerbate the longevity and severity of a snowstorm.

Studies have shown that natural variability associated with El Niño conditions has a strong relationship and influence on the incidence of severe snowstorms in the eastern US. An analysis of 100 storms in six regions east of the Rocky Mountains found that severe snowstorms are approximately twice as likely to occur in the eastern US – north and south – during years when a moderate to strong El Niño is present as compared to years when more neutral conditions are present.

Mass evacuations are not expected in relation to severe winter weather, including evacuations into the Richmond-Crater region from other areas.

5.10 Thunderstorms (including Hail and Lightning)

Hazard Profile

Thunderstorms are caused when air masses of varying temperatures and moisture content meet. All thunderstorms produce lightning. Droplets of water in a thunderstorm may get picked up in the storm's updraft, a column of rising air. The updraft can carry the droplets to levels of the atmosphere where temperatures are below freezing. The frozen droplets, now hail, may then fall due to gravity injuring people, property and animals. In Virginia, thunderstorms can occur at any time during any season, but are most common in the late afternoon and evening hours of the summer months.

Magnitude or Severity

A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning can remain in-cloud or can contact the ground or other surfaces. A cloud-to-ground bolt of lightning can sometimes strike locations 10 or more miles away from the parent thunderstorm, producing the effect that the lightning came from 'out of the blue' or without warning. Lightning kills an average of 49 people each year in the United States and hundreds more are injured. Some survivors suffer lifelong neurological damage.[14]

In addition to flooding rainfall, damaging winds, and sometimes tornadoes, thunderstorms might also produce large hail and deadly lightning. Hail can be smaller than a pea, or as large as a softball or grapefruit, and can be very destructive to automobiles, glass surfaces such as skylights and windows, roofs, siding, trees, and crops. The amount of damage to crops can be a factor of crop growth stage, amount of hail and how hard it falls, size of the hail (smaller does not necessarily lead to less damage), and concurrent wind speeds and temperatures.

Hazard History

Virginia averages 40 to 50 thunderstorm days per year.[15] Past occurrences of thunderstorm events that produced damage, injuries, or fatalities as a result of hail or lightning since 2010 are listed in **Table 5.28**. The NCEI database shows that at least two people in the region have been killed and three others injured as a result of lightning since 1993 (see **Appendix F-7**). The database did not indicate any deaths or injuries in the region during this period as a result of hail.

[14] https://www.weather.gov/safety/lightning, NWS, accessed September 16, 2021.

[15] Sammler, William. Personal interview, September 15, 2005. (National Weather Service, Warning Coordination Meteorologist, Wakefield, Virginia office.)

Table 5.28: History of Hail/Lightning Events and Damages, 2010–2020	
Date	**Damages**
August 12, 2010	**Hanover County:** Hail, two inches in diameter, damaged vehicles in the county east of Old Cold Harbor.
June 29, 2012	The June 2012 Mid-Atlantic and Midwest derecho was one of the most destructive and deadly fast-moving severe thunderstorm complexes in North American history. The progressive derecho tracked across a large section of the Midwestern United States and across the central Appalachians into the mid-Atlantic states on the afternoon and evening of June 29, 2012, and into the early morning of June 30, 2012. It resulted in 20 deaths, widespread damage and millions of power outages across the study region. (Source: https://en.wikipedia.org/wiki/June_2012_North_American_derecho)
June 13, 2013	On the morning of the 13, another linear complex of severe storms developed along a line near the southern border of Ohio. The storms eventually strengthened into a powerful derecho and raced to the south and east. Fatalities and injuries occurred as a result of falling trees and power lines as the storms ripped through Virginia, along with numerous reports of damaging winds and power outages. The derecho downed numerous tress and damaged structures winds up to 80 mph (130 km/h) in some areas. (Source: https://en.wikipedia.org/wiki/June_12%E2%80%9313,_2013_derecho_series)
May 22, 2014	A large Hail and Thunderstorm event came through the region. Some hail was reported to be as large as ping pong balls. Several areas were affected from fallen electric lines. The NCEI data reports that 12 direct deaths in the study region resulted from this event. (Source: NCEI data & http://www.nbcwashington.com/news/local/Severe-Thunderstorms-DC-Area-May-22-260300391.html)
February 24, 2016	This storm started in the northeastern states and traveled down through Virginia and south. During the thunderstorm, hail in some parts of the region were as large as 3 inches in diameter. (Source: http://www.weather.gov/akq/Feb24-2017TOR)
July 19, 2016	Scattered severe thunderstorms associated with a cold front produced damaging winds and large hail across portions of Henrico, Chesterfield, Sussex and Greensville Counties. Reports of hail size varied from quarter size to hen's egg size in Sussex County, where a corn field was stripped by the large hail on Beaverdam Road near Harrels Mill Pond causing $3000 crop damage.
February 25, 2017	Thunderstorms caused large hail and damaging winds of 50-60 mph throughout the study area. Hail was generally small or quarter size. Minor roof damage of $1000 reported in Bon Air section of Chesterfield County.
May 27, 2017	A low pressure system and warm front produced scattered thunderstorms, causing large hail and damaging winds in Hanover, Henrico, Dinwiddie and Chesterfield Counties. Hail was very large in the Beach area of Chesterfield County, reportedly as large as teacups, with $2000 damage reported.
July 19, 2017	Chesterfield County, Ampt Hill: A lightning strike associated with severe thunderstorms in advance of a cold front caused a small structural fire. There was

Table 5.28: History of Hail/Lightning Events and Damages, 2010–2020	
Date	**Damages**
	also lightning strike on utilities and an adjacent shed on Dulwich Lane. Damages reported at $15,000.
June 22, 2018	Lightning from a thunderstorm produced by a warm frontal boundary caused a house fire in the New Bohemia section of Prince George County. Damage was reported at $10,000.
August 15, 2019	Damaging lightning strikes caused damage in Chesterfield County and Henrico County. Lightning struck a house on Shepherds Drive in Chesterfield causing $5000 damage to the house. In Henrico County, lightning caused a house fire on Linstead Road, with $3000 reported.
August 23, 2019	A house was struck by lightning on Hunnicut Road in Dinwiddie causing $3000 damage.
June 19, 2020	Lightning strike caused a house fire on North Oaks Drive in Hanover with a reported $5000 in damage.

Source: NOAA NCEI

Vulnerability Analysis

Although most frequent in the Southeast and parts of the Midwest, thunderstorms are a relatively common occurrence across the region and have been known to occur in all calendar months. All of the central Virginia region is deemed equally likely to experience severe thunderstorms and associated damages from hail or lightning. **Table 5.29** indicates the annualized number of hail and damaging lightning events by jurisdiction based on NCEI data.

Table 5.29: Annualized Hail and Lightning Events and Losses, 1956 - 2020				
Jurisdiction	**Annualized Hail/Lightning Events**	**Annualized Property Losses**	**Annualized Crop Damages**	**Annualized Total Losses**
Charles City County	0.14	$78	-	$78
Chesterfield County	1.67	$1,773	-	$1,773
City of Colonial Heights	0.19	$31	-	$31
Dinwiddie County (inc. Town of McKenney)	0.36	$516	$1	$517
City of Emporia	0.08	$156	-	$156
Goochland County	0.45	$78	-	$78
Greensville County (inc. Town of Jarratt)	0.13	$0	-	$0
Hanover County (inc. Town of Ashland)	0.95	$2,046		$2,046
Henrico County	1.53	$11,781	-	$11,781

Table 5.29: Annualized Hail and Lightning Events and Losses, 1956 - 2020				
Jurisdiction	**Annualized Hail/Lightning Events**	**Annualized Property Losses**	**Annualized Crop Damages**	**Annualized Total Losses**
City of Hopewell	0.25	$78	-	$78
New Kent County	0.23	$78	-	$78
City of Petersburg	0.11	$187	-	$187
Powhatan County	0.45	$16	-	$16
Prince George County	0.63	$344	-	$344
City of Richmond	0.36	$78	-	$78
Surry County (inc. Town of Surry)	0.16	-	-	-
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	0.31	$313	$47	$360
Total	**0.31**	**$17,553**	**$48**	**$17,601**

Source: NOAA NCEI (events categorized as hail and lightning only)

Table 5.29 is based on NCEI historical data for the 64-year period of record between 1956 and 2020. On average, the region experiences approximately seven to eight hailstorms annually and one damaging lightning event every two years. In terms of damages, roughly $1,200 in losses is attributed to hail and about $16,400 to lightning annually.

Electrical utilities and communications infrastructure are vulnerable to lightning. Damage to power lines or communication towers from direct lightning strikes can cause power and communication outages for residents, businesses, and critical facilities. In addition to lost revenues, downed power lines present a threat to personal safety. Downed wires and lightning strikes have also sparked fires in the past.

A structure's thunderstorm vulnerability is based in large part on building construction and design standards. Other factors, such as location, condition, and maintenance of trees also plays a significant role in determining vulnerability. Windows, roofs, and siding are most vulnerable to the impacts of large hail.

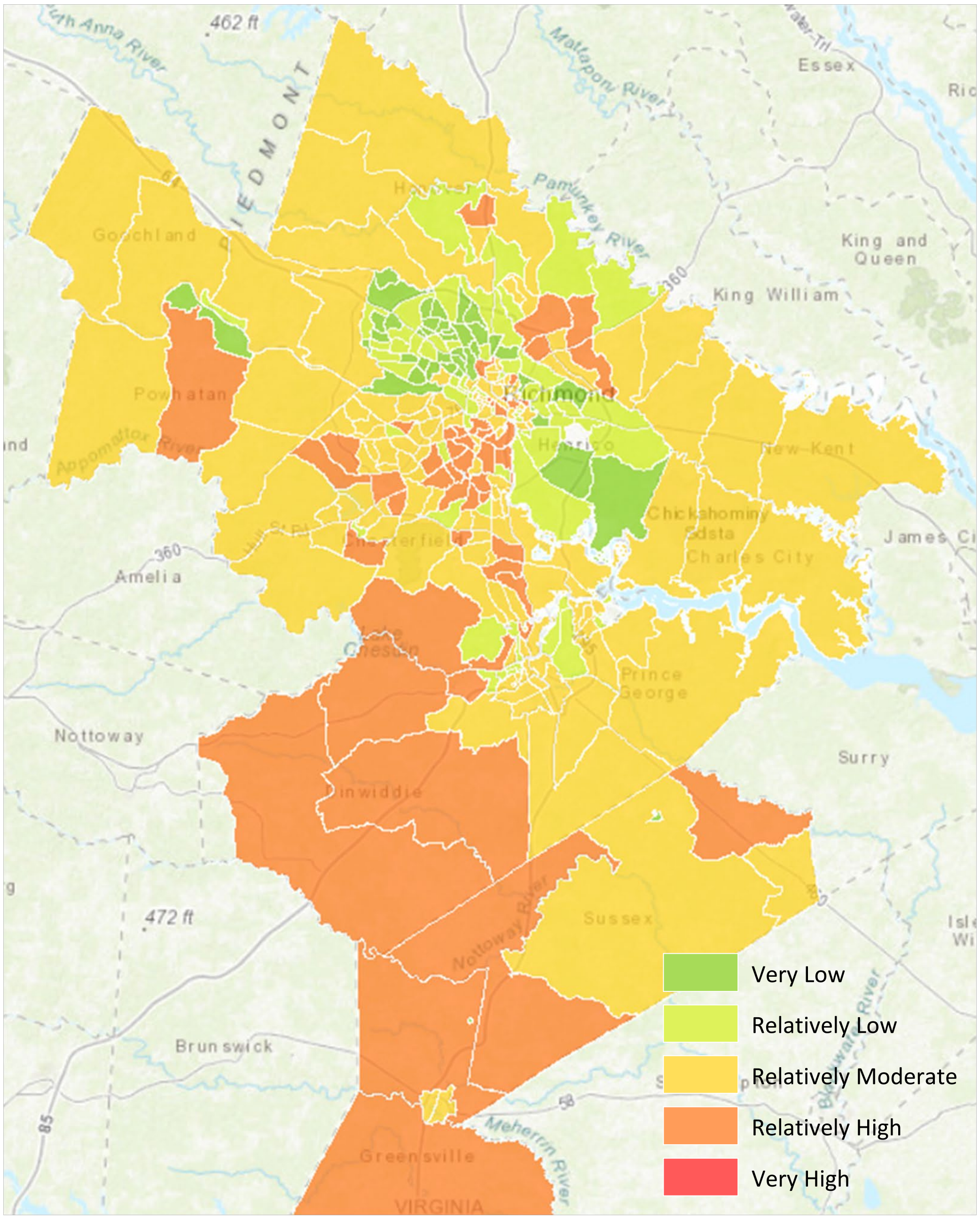
Human vulnerability is based on the availability and reception of early warnings of significant thunderstorm events (i.e., Severe Thunderstorm Warning issued by the NWS) and access to substantial indoor shelter. Seeking shelter indoors on the lowest floor of a substantial building away from windows is recommended as the best protection against thunderstorm-related hazards.

All critical facilities in the study area are at risk for hail and lightning damage, but recent history does not include mention of significant previous damage to these facilities. Critical facilities with generators for auxiliary power are better prepared in the event of power outages caused by thunderstorms and associated wind, hail and lightning.

Social Vulnerability

The NRI data for social vulnerability to lightning and hail are shown in **Figure 5.28** and **Figure 5.29, respectively**.

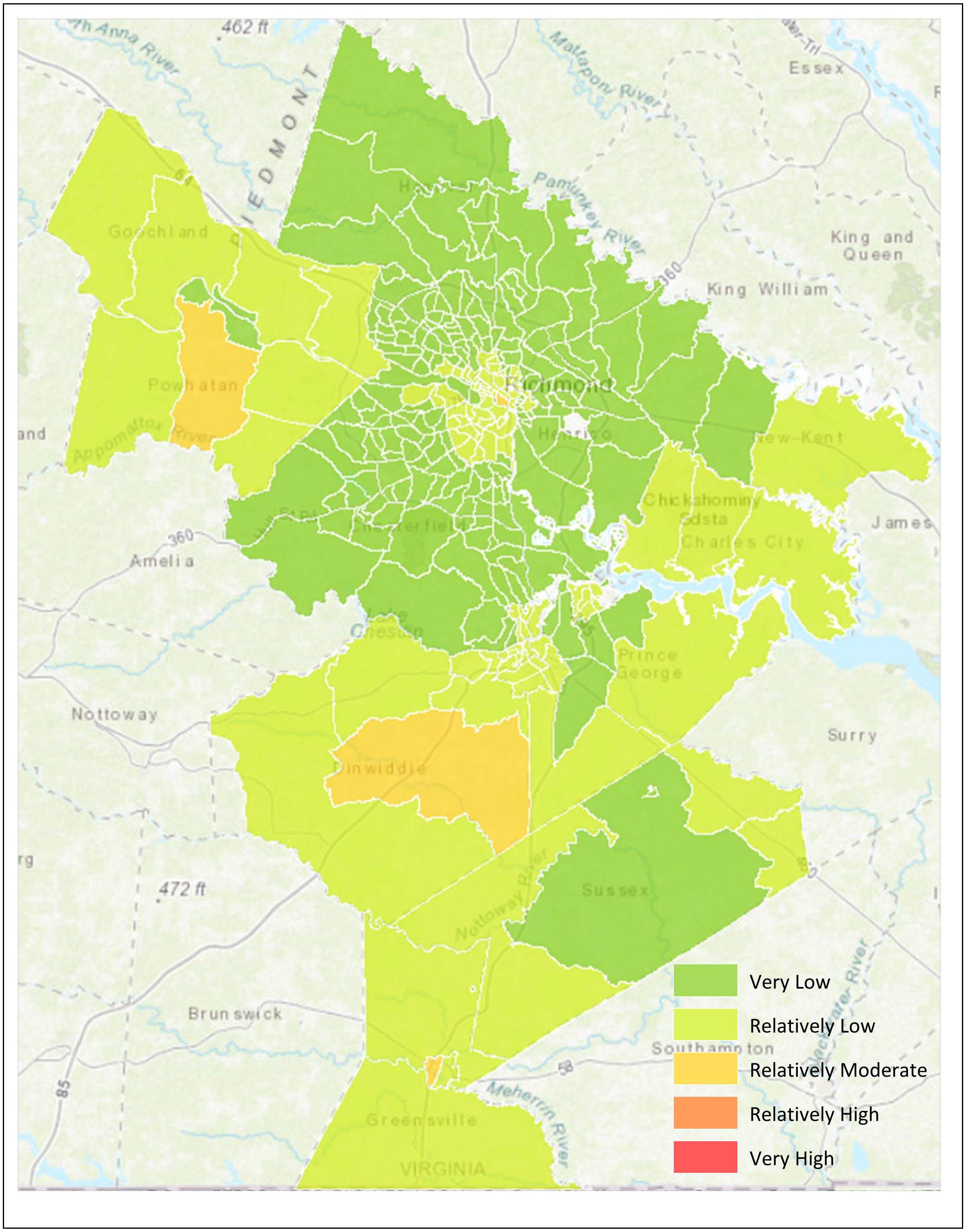
Figure 5.28: National Risk Index Rating, Lightning



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has relatively moderate social vulnerability for lightning.

Figure 5.29: National Risk Index Rating, Hail



Source: National Risk Index, FEMA 2021Note: The Town of Surry has very low social vulnerability for lightning.

Future Vulnerability, Land Use and Climate Change

Future vulnerability to hail and lightning damage may change if the nature of the hazard changes as a result of climate change. If the frequency and severity of thunderstorms increases as expected, with commensurate increases in lightning strikes and hail size and storm longevity, damage patterns could change, and human vulnerability may increase.

Mass evacuation is not expected in association with thunderstorms, lightning or hail.

5.11 Droughts and Extreme Heat

Hazard Profile

A drought can be characterized in several different ways depending on the nature of the impacts. The most common form of drought is agricultural. Agricultural droughts are characterized by unusually dry conditions during the growing season. Meteorological drought is an extended period of time (six or more months) with precipitation of less than 75% of normal precipitation. Severity of droughts often depends on the community's reliance on a specific water source. The probability of a drought is difficult to predict given the number of variables involved.

A heat wave is defined as a prolonged period of excessive heat, often combined with excessive humidity. Extreme heat is defined as temperatures that hover 10 degrees or more above the average high temperature for the region and last for several weeks. A heat wave combined with a drought is particularly dangerous.

Magnitude or Severity

Many problems can arise at the onset of a drought, some of which include diminished water supplies and quality, undernourishment of livestock and wildlife, crop damage, and possible wildfires. Secondary impacts from droughts pose problems to farmers with reductions in income, while food prices and lumber prices could drastically increase.

High summer temperatures can exacerbate the severity of a drought. When soils are wet, a significant portion of the sun's energy goes toward evaporation of the ground moisture. However, when drought conditions eliminate soil moisture, the sun's energy heats the ground surface and temperatures can soar, further drying the soil.

Table 5.30 provides a summary of drought categories and impacts produced by the U.S. Drought Monitor. The U.S. Drought Monitor classification uses both science and subjectivity to create a drought severity classification table for each dryness level. Notice that water restrictions are usually initiated as "voluntary" and can evolve to "mandatory."

Table 5.30: Drought Severity Classification and Possible Impacts		
Category	**Description**	**Possible Impacts**
D0	Abnormally dry	Going into a drought: short-term dryness slows planting, growth of crops or pastures; fire risk above average. Coming out of a drought: some lingering water deficits; pastures or crops not fully recovered.
D1	Moderate drought	Some damage to crops, pastures; fire risk high; streams, reservoirs, or wells low; some water shortages develop or are imminent; voluntary water use restrictions requested.
D2	Severe drought	Crop or pasture losses likely; fire risk very high; water shortages common; water restrictions imposed.
D3	Extreme drought	Major crop/pasture losses; extreme fire danger; widespread water shortages or restrictions.

Source: U.S. Drought Monitor

The impact of excessive heat is most prevalent in urban areas, where urban heat-island effects prevent inner-city buildings from releasing heat built up during the daylight hours. Secondary impacts of excessive heat are severe strain on the electrical power system and potential brownouts or blackouts.

Extreme heat also impacts the human body. When combined with high relative humidity that slows evaporation, extreme heat limits the body's ability to efficiently cool itself. Overexposure may result in first dehydration and heat cramps, and then heat exhaustion or heat stroke, which could lead to death. Heat stroke is caused by prolonged exposure to high temperatures or by physical activity. Sweating usually stops and body temperature becomes too high.

For excessive heat, the NWS uses heat index thresholds as criteria for the issuance of heat advisories and excessive heat warnings. NWS heat advisory bulletins inform citizens of forecasted extreme heat conditions. The bulletins are based on projected or observed heat index values and include:

- Excessive Heat Outlook when there is a potential for an excessive heat event within three to seven days.
- Excessive Heat Watch when conditions are favorable for an excessive heat event within 12 to 48 hours, but some uncertainty exists regarding occurrence and timing.
- Excessive Heat Warning/Advisory when an excessive heat event is expected within 36 hours.

These products are usually issued when confidence is high that the event will occur. A warning implies that conditions could pose a threat to life or property, while an advisory is issued for less serious conditions that may cause discomfort or inconvenience but could still lead to threat to life and property if caution is not taken.

Hazard History

There have been a number of significant droughts recorded in Virginia since 1900. An extended period of abnormally dry weather occurred during a period of four years, from 1998 to 2002. This period saw rainfall levels well below normal and caused many communities throughout the state to institute water restrictions.

Table 5.31 includes descriptions of major droughts that have occurred in the Richmond-Crater region. Drought conditions generally occur over a region or larger area rather than in a single jurisdiction. The NCEI database lists no significant drought or extreme heat events since 2016.

Table 5.31 History of Drought Events and Damages, 1976–2020

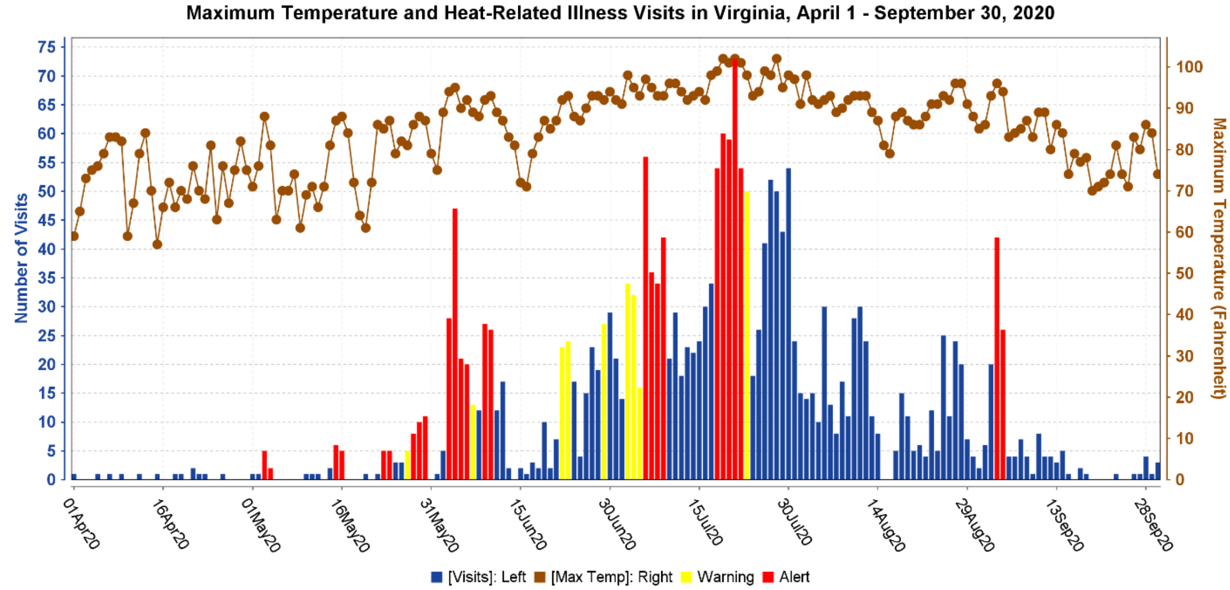
Date	Damages
November 1976 – September 1977	The region experienced ten months of below average precipitation. The drought began in November 1976 when rainfall totaled only 50% to 75% of normal. During the rest of the winter, storms tracked across the Gulf. During the spring and summer storms tracked across the Great Lakes. These weather patterns created significant droughts throughout most of Virginia.
1993	Hot, dry weather affected 23 counties and was responsible for an estimated $75 million in crop damages.
June – November 1998	A heat wave over the Southeast produced warm and dry conditions over much of Virginia. Unusually dry conditions persisted through much of the fall. The drought produced approximately $38.8 million in crop damages over portions of central and south-central Virginia.
December 2001 – November 2004	Beginning in the winter of 2001, the Mid-Atlantic began to show long-term drought conditions. The NWS issued reports of moisture-starved cold fronts that would continue throughout the winter. Stream levels were below normal with record lows observed at gauges for the York, James, and Roanoke River basins. By November 2002, the U.S. Secretary of Agriculture had approved 45 counties for primary disaster designation, while 36 requests remained pending.
2007	Unusually dry conditions persisted through a significant portion of the year through much of southern and central Virginia. Virginia as a whole experienced its tenth driest year on record.
2010	The summer of 2010 was hot and dry. Most of the state suffered from moderate to severe drought conditions, and some jurisdictions were placed under water restrictions.
July 21, 2011	This was one of the hottest July's in the last 75 years, breaking multiple records. According to the NCEI data, all counties were recorded as having excessive heat waves and drought throughout the entire month.
2012-2013	La Nina conditions produced extreme and exceptional drought conditions throughout much of the US, Canada, and Mexico. Peak drought conditions in July resulted in more than 80% of the country with at least abnormally dry conditions. For this event, much of Virginia was classified as either abnormally dry or as experiencing moderate to severe drought conditions.

The NCEI database contains only one extreme heat event for the study area. Between July 21 and July 23, 2011, high temperatures ranged from 96 to 103 degrees during the afternoons, with heat index values ranging from 110 to 119. Overnight lows only fell into the lower 70s to lower 80s. Zero fatalities or injuries and no damages were noted. In an online blog note from July 2021, the Virginia Department of Health (VDH) wrote that, "According to the Office of the Chief Medical Examiner, between 2018 and 2020 there were 28 heat-related deaths in Virginia."[16] Although the geographic location is not provided, these data do not match up with the NCEI data for the state, so NCDI-reported data should not be considered complete.

The VDH receives data on visits to emergency departments and urgent care centers in Virginia for purposes of public health surveillance. These data are analyzed through a syndromic surveillance system, known as ESSENCE, to monitor the health of the community and identify emerging trends of public health concern. In response to extreme heat, the Office of Epidemiology, Division of Surveillance and Investigation conducts surveillance for heat-related illness. While the data depicted in **Figure 5.30** are not readily available by jurisdiction, the statewide data provide insights about significant extreme heat dates, the maximum temperatures and the number of hospital visits for heat-related illness.

[16] https://www.vdh.virginia.gov/blog/2021/07/02/virginia-department-of-health-reminds-residents-to-be-aware-of-the-risks-of-heat-related-illness-enjoy-the-outdoors-this-holiday-weekend-but-make-sure-to-stay-hydrated-use-sunscreen-and-take/

Figure 5.30: Maximum Temperatures and Heat-Related Illness Visits in Virginia, 2016-2020



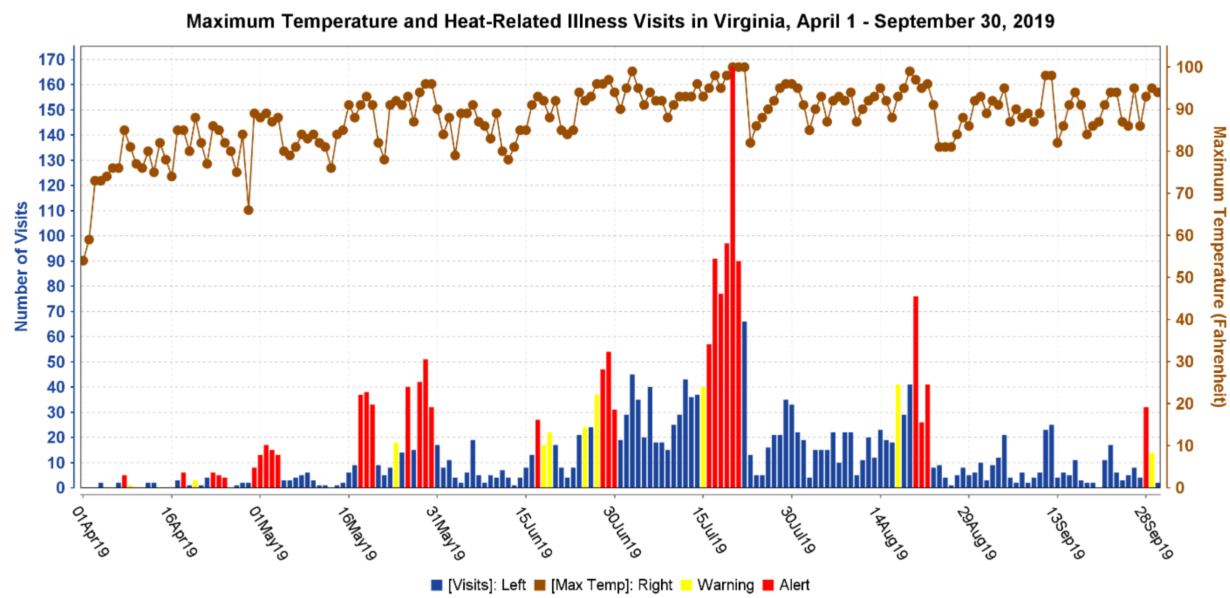
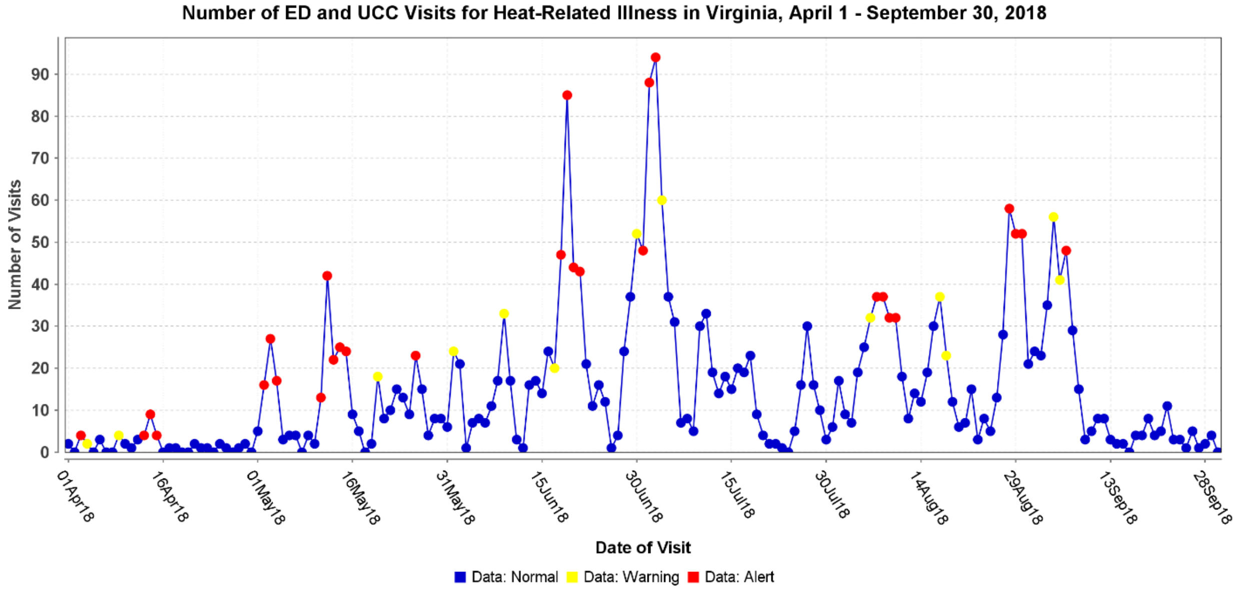


Figure 5.30: Maximum Temperatures and Heat-Related Illness Visits in Virginia, 2016-2020



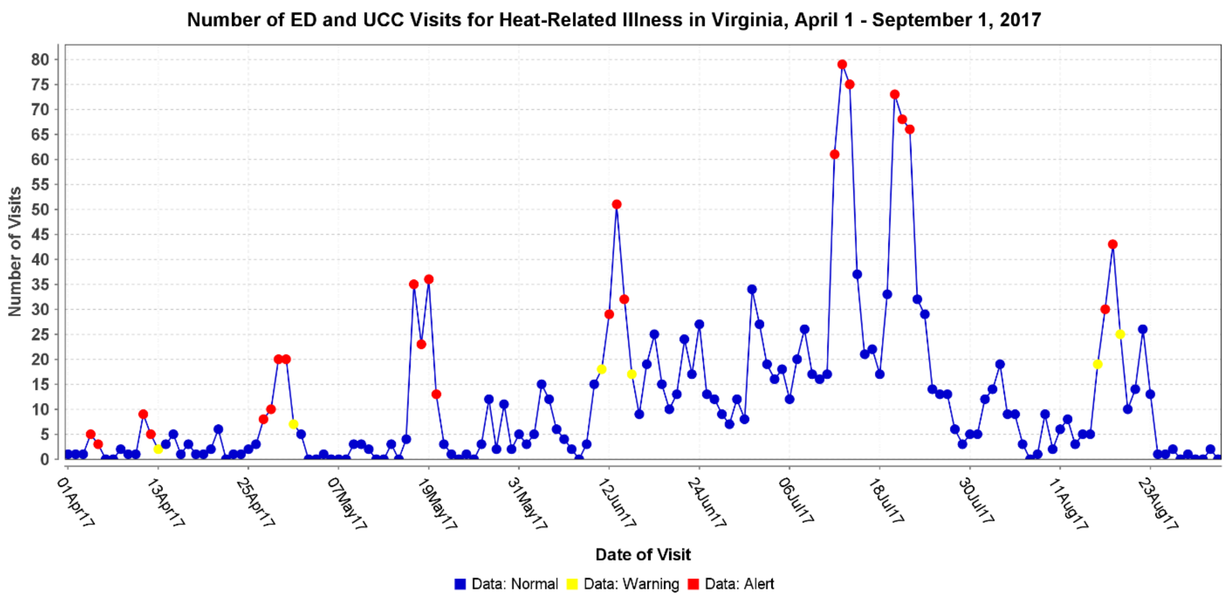
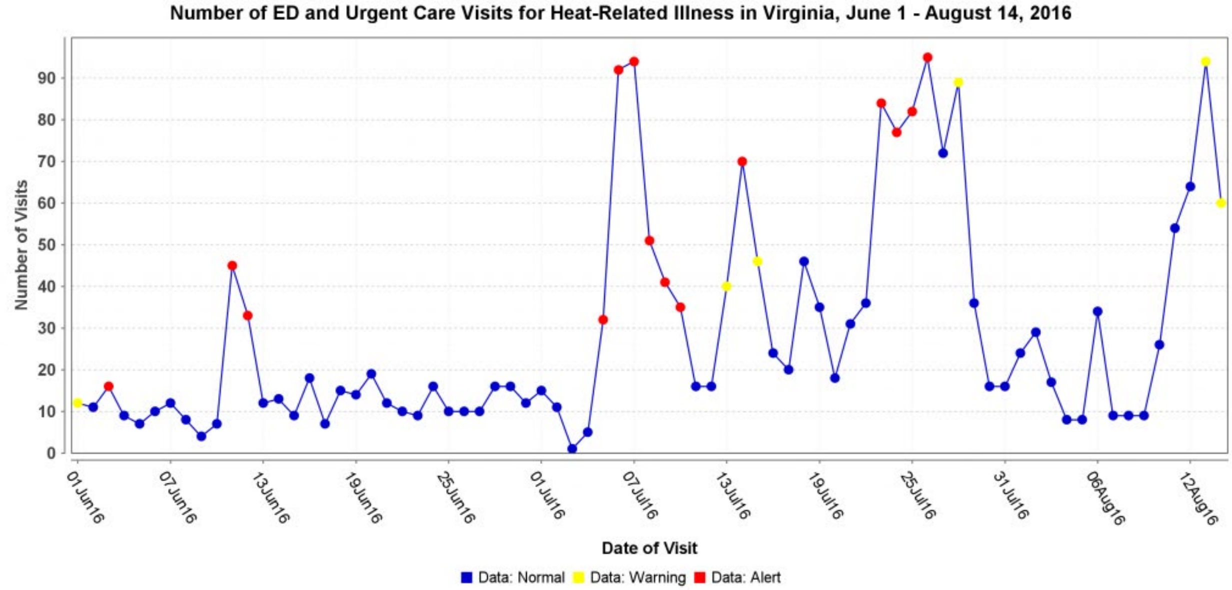


Figure 5.30: Maximum Temperatures and Heat-Related Illness Visits in Virginia, 2016-2020



Source: Virginia Department of Health, accessed online https://www.vdh.virginia.gov/surveillance-and-investigation/syndromic-surveillance/weather-surveillance/.

Vulnerability Analysis

Based on historical frequency of occurrence using NCEI, an annual determination of drought events can be made. **Table 5.32** indicates that drought events of some significance affect jurisdictions in the region. The annualized event occurrence and damages are shown for the study area.

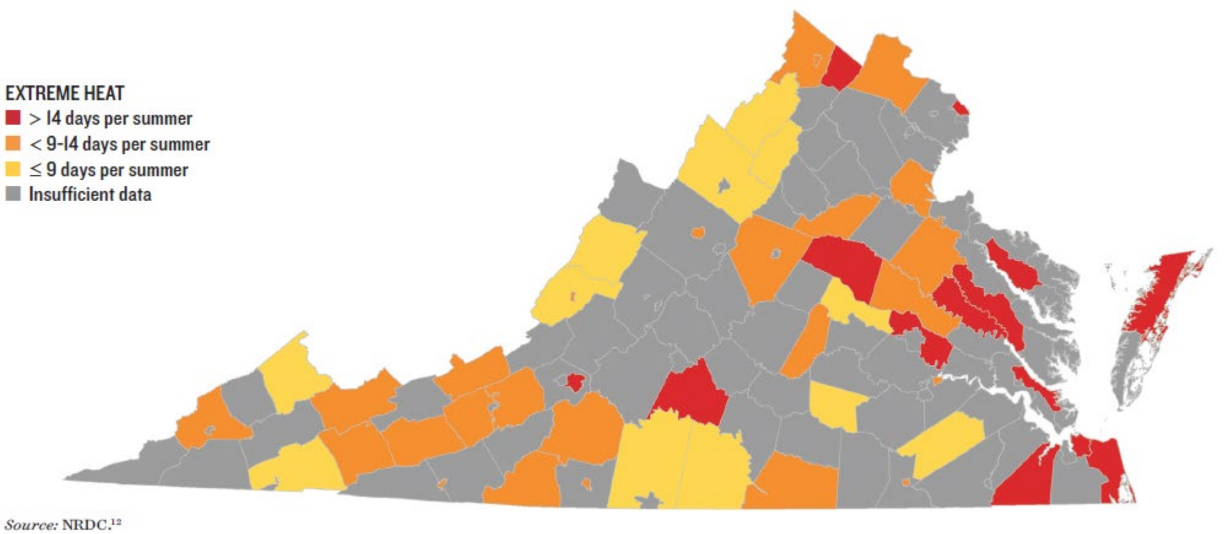
Table 5.32: Annualized Drought Events and Losses, 1993 – 2020

Jurisdiction	Annualized Number of Events	Annualized Property Losses	Annualized Crop Losses
Charles City County	0.14	-	$111,948
Chesterfield County	0.21	-	-
City of Colonial Heights	-	-	-
Dinwiddie County (inc. Town of McKenney)	-	-	$342,918
City of Emporia	-	-	-
Goochland County	-	-	$103,992
Greensville County (inc. Town of Jarratt)	-	-	-

Table 5.32: Annualized Drought Events and Losses, 1993 – 2020			
Jurisdiction	**Annualized Number of Events**	**Annualized Property Losses**	**Annualized Crop Losses**
Hanover County (inc. Town of Ashland)	0.21	-	$426,633
Henrico County	0.18	-	$207,982
City of Hopewell	0.21	-	-
New Kent County	0.21	-	$59,142
City of Petersburg	0.43	-	-
Powhatan County	0.11	-	$ 322,325
Prince George County	0.21	-	$190,100
City of Richmond	0.43	-	-
Surry County (inc. Town of Surry)	-	-	-
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	0.11	-	-
Totals	**0.40**	**$0**	**$1,765,040**

An examination of vulnerability to extreme heat by jurisdiction necessitates the use of data other than NCEI data, which are incomplete. **Figure 5.31** shows the average number of extreme summer heat days per year in Virginia, by county, between 2007 and 2016, from an NRDC report on Climate Change and Health in Virginia. While the data are insufficient in much of the study area, a definite urban heat island effect for metro Richmond is evident.

Figure 5.31: Average Number of Extreme Summer Heat Days per Year in Virginia



Source: NRDC, Climate Change and Health in Virginia, Issue Brief, April 2018. Accessed online: https://www.nrdc.org/sites/default/files/climate-change-health-impacts-virginia-ib.pdf

If a significant drought event were to occur, it could bring economic, social, and environmental impacts to the study area. Commonly, one of the most significant economic effects to a community is agricultural impact. Other economic effects could be felt by businesses that rely on adequate water levels for their day-to-day business, such as carwashes and Laundromats.

Droughts can also create conditions that lead to occurrence or worsening of other natural hazard events such as wildfires. The likelihood of flash flooding and sinkholes is increased if a period of severe drought is followed by a period of extreme precipitation. Low-flow conditions also decrease the quantity and pressure of water available to fight fires, while the dry conditions increase the likelihood that fires will occur.

Environmental drought impacts include those on both human and animal habitats and hydrologic units. During periods of drought, the amount of available water decreases in lakes, streams, aquifers, soil, wetlands, springs, and other surface and subsurface water sources. This decrease in water availability can affect water quality such as oxygen levels, bacteria, turbidity, temperature increase, and pH changes. Changes in any of these levels can have a significant effect on the aquatic habitat of numerous plants and animals found throughout the study area.

Low water flow can result in decreased sewage flows and subsequent increases in contaminants in the water supply. Decrease in the availability of water also decreases drinking water supply and the food supply as food sources become scarcer. This disruption can work its way up the food chain within a habitat. Loss of biodiversity and increases in mortality can lead to increases in disease in endangered species.

Precipitation at reliable, predictable times in the growing cycle of any crop is essential for the success of that crop, as every crop has a predictable growing season. During dry periods, including droughts, evapotranspiration from plant leaves can contribute to the loss of moisture in the soil, further impacting vegetation and crops. **Table 5.33** provides an overview of the agricultural products that could be affected by a drought. These numbers are based on the 2017 Census of Agriculture conducted by the U.S. Department of Agriculture. The numbers show all of the counties with significant agricultural sectors that could be impacted by droughts. Hanover County, in particular, has almost $50 million in products sold, most of which were crops.

Table 5.33: Value of Agricultural Products Potentially Affected by Drought

Jurisdiction	Number of Farms 2017 (% Change from 2012)	Total Value of Agricultural Products Sold	Total Acres Operated in Farms
Charles City County	77 (-2.0%)	$16,186,000	31,392
Chesterfield County	210 (13.0%)	$4,511,000	18,013
Dinwiddie County	358 (-25.0%)	$25,705,000	92,841
Goochland County	355 (40.0%)	$11,740,000	56,739
Greensville County	150 (-1.0%)	$19,448,000	54,544
Hanover County	567 (-33.0%)	$49,254,000	89,186
Henrico County	99 (-18.0%)	$7,286,000	9,820
New Kent County	138 (1.0%)	$5,128,000	18,335
Powhatan County	263 (13.0%)	$11,249,000	34,585
Prince George County	164 (-3.0%)	$9,284,000	39,630
Surry County	111 (-16.0%)	$23,899,000	42,062
Sussex County	124 (1.0%)	$42,178,000	66,257
Total	**2,616 (-30.0%)**	**$225,868,000**	**553,404**

Source: United States Department of Agriculture, Virginia Agricultural Statistics Service. 2017 Census of Agriculture

Except for potential water supply issues associated with a prolonged drought, droughts have little impact on critical facilities.

The data show recurrence of drought conditions, of varying magnitude, on a relatively regular basis. With records dating back to 1993, the NCEI database indicates that drought events of some significance occur regularly in the region. Based on historical data, it is reasonable to assume that drought events will continue to impact the region with some regularity. Annual regional crop losses associated with drought events just slightly exceeds $2 million.

Social Vulnerability

The main concern in periods of extreme heat is the potential public health impact, such as heat exhaustion or heat stroke. Individuals of concern include those living in residences without air conditioning, or in areas where electric service is unavailable due to system-wide blackouts. The elderly, small children, the chronically ill, livestock and pets are most vulnerable to extreme heat. **Figure 5.32** shows the relative social vulnerability to heat waves based on the National Risk Index data.

The NRI data for social vulnerability to drought are shown in **Figure 5.33**. Historical occurrence data were taken from the University of Nebraska-Lincoln National Drought Mitigation Center, U.S. Drought Monitor. The period of record was January 2000 to December 2017. Portions of Dinwiddie County and Hanover County appear to be the most socially vulnerable communities to the impacts of drought.

Future Vulnerability, Land Use and Climate Change

The VASEM 2021 report predicts that as this century comes to a close, agriculture will be impacted by more intense precipitation but also longer periods of drought. The cumulative effect will particularly be bad for crops near the warm end of their geographic range.

The risk of heat-related illnesses and deaths in Virginia will grow as climate change fuels more intense and frequent heat waves. NRDC analysis indicates that daily summer highs at Richmond International Airport averaged 88.6 degrees Fahrenheit in the past decade, compared with 85.6 degrees Fahrenheit in the 1960s.[17]

Neither droughts nor extreme heat are expected to cause mass evacuations.

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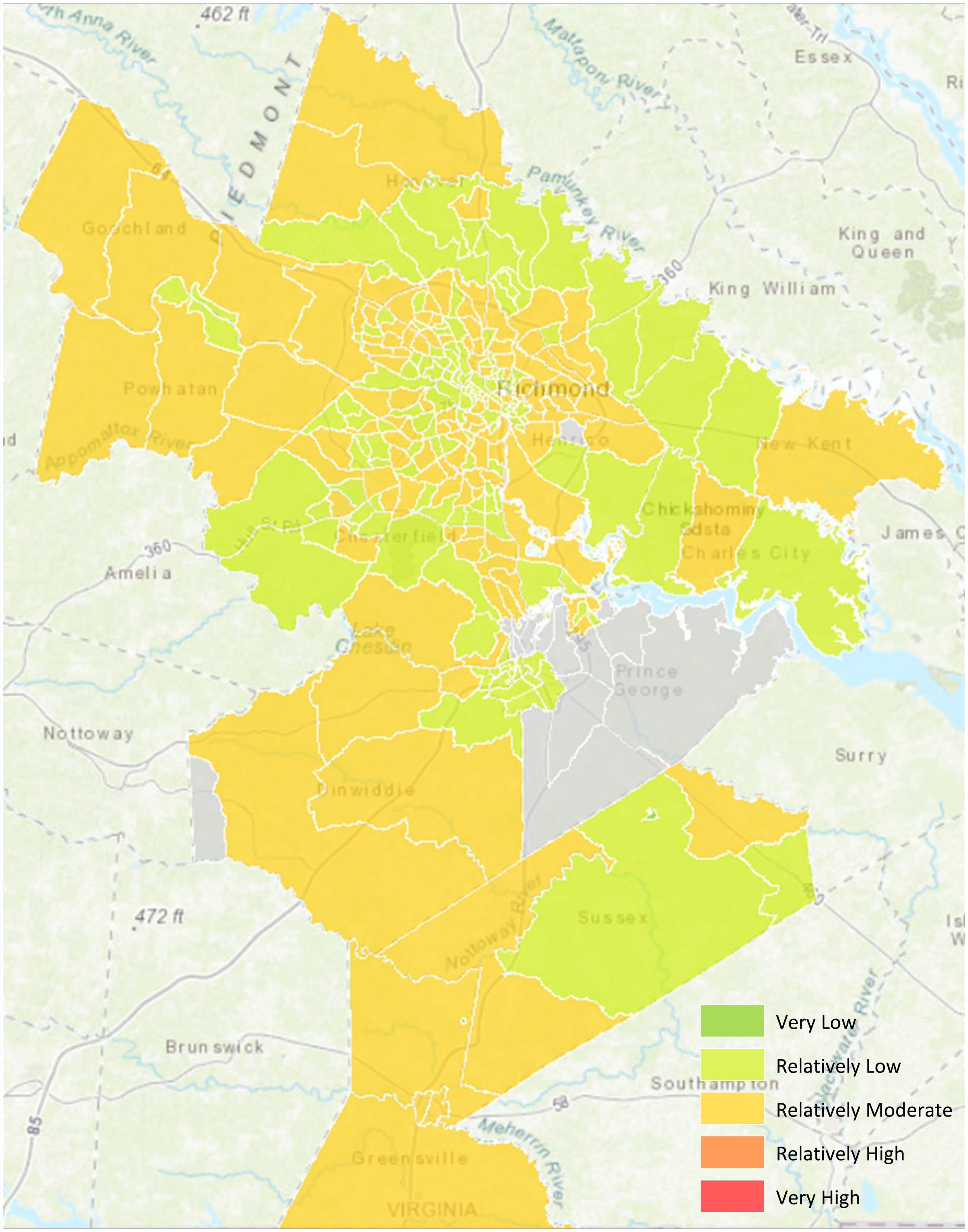
[17] NRDC: *Climate Change and Health in Virginia*, Issue Brief, April 2018. Accessed online: https://www.nrdc.org/sites/default/files/climate-change-health-impacts-virginia-ib.pdf

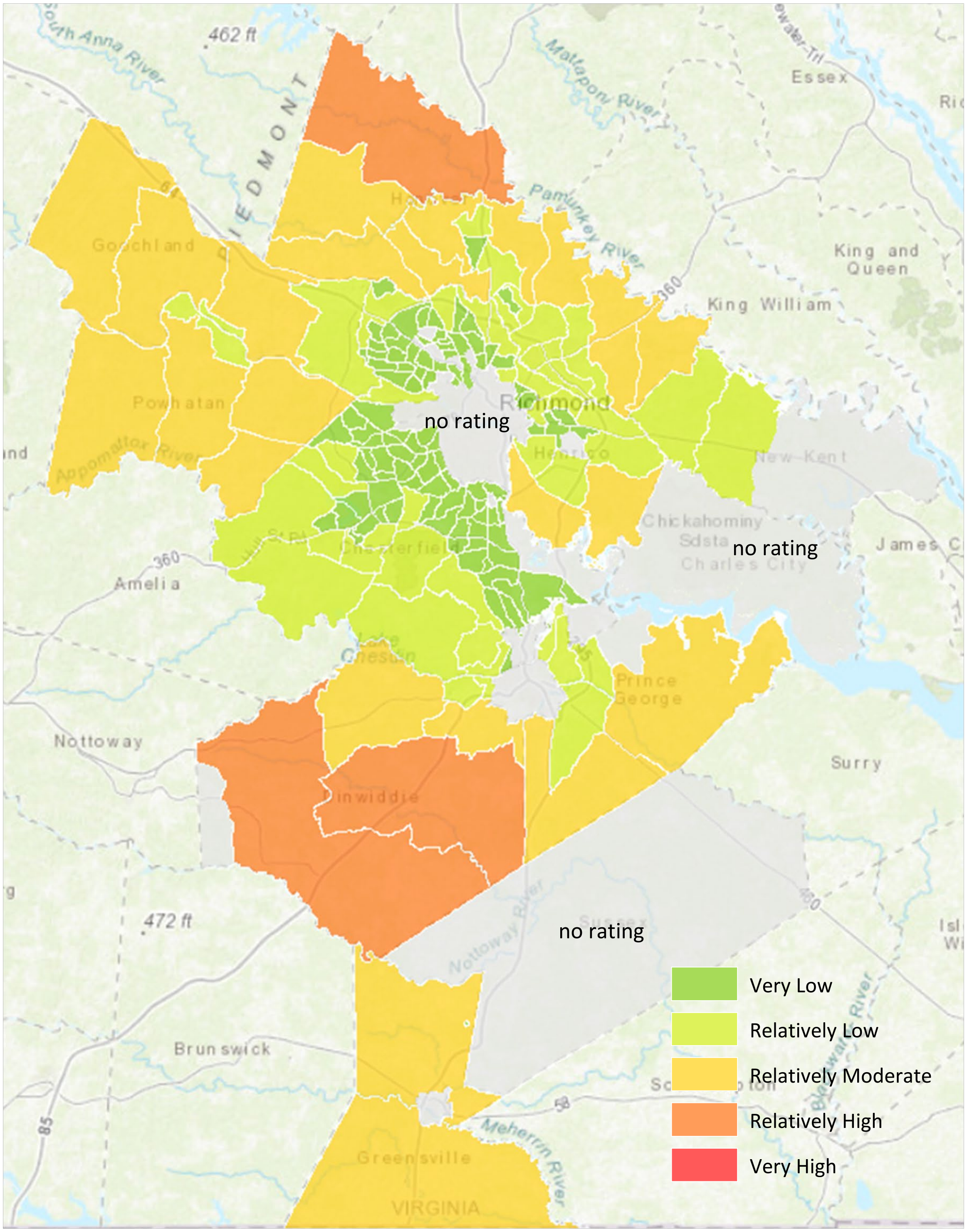
Figure 5.32: National Risk Index Rating, Heat Wave



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has relatively moderate social vulnerability for heat wave.

Figure 5.33: National Risk Index Rating, Drought



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has no NRI social vulnerability rating for drought.

5.12 Earthquakes

Hazard Profile

An earthquake is the motion or trembling of the ground produced by sudden displacement of rock in the Earth's crust. Naturally occurring earthquakes result from crustal strain, volcanism, landslides or the collapse of caverns but can also be triggered by mine blasts or collapse or nuclear testing. Earthquakes can affect hundreds of thousands of square miles; cause damage to property measured in the tens of billions of dollars; result in loss of life and injury to hundreds of thousands of persons; and disrupt the social and economic functioning of the affected area.

Most property damage and earthquake-related deaths are caused by the failure and collapse of structures due to ground shaking. The level of damage depends upon the amplitude and duration of the shaking, which are directly related to the earthquake size, distance from the fault, site and regional geology and soil.

Earthquakes are caused by the sudden release of accumulated energy, resulting in the rupture of rocks along fault planes in the Earth's lithosphere. The areas of greatest tectonic activity occur at the boundaries of the Earth's slowly moving tectonic plates, as these locations are subjected to the greatest strain from plates traveling in various directions and speeds. Deformation along plate boundaries causes strain in the rock and the consequent buildup of stored energy. When the built-up stress exceeds the rocks' strength, a rupture occurs. The rock on both sides of the fracture is snapped, releasing the stored energy and producing seismic waves, generating an earthquake.

Impacts from earthquakes can be severe and cause significant damage. Ground shaking can lead to the collapse of buildings and bridges, and disrupt utilities. Death, injuries, and extensive property damage are possible from earthquakes. Some secondary hazards caused by earthquakes may include fire, hazardous material release, landslides, flash flooding, avalanches, tsunamis, and dam failure.

Magnitude or Severity

Smaller earthquakes occur much more frequently than larger earthquakes. These smaller earthquakes are generally not felt by people and cause little or no damage. Very large earthquakes can cause tremendous damage and may be followed by a series of aftershocks occurring in the region for weeks after the event. Aftershocks generally have a smaller magnitude than the main shock, but may still be powerful enough to cause additional damage.

Earthquakes can be measured in terms of their magnitude or intensity. Magnitude is the amount of energy that is released by an earthquake. There are a number of ways that magnitude can be measured but probably the most familiar is the Richter Scale (**Table 5.34**). The Richter magnitude scale was developed in 1935 by Charles F. Richter of the California Institute of Technology, as a mathematical device to compare the size of earthquakes. The magnitude of an earthquake is determined from the logarithm of the amplitude of seismic waves recorded by seismographs. Adjustments are included for variation in the distance between the various seismographs and the epicenter of the earthquakes.[18] On the Richter Scale, magnitude is expressed as a dimensionless number from 0.0 to 10.0. For example, a magnitude 5.3 quake might be computed for a moderate earthquake, and a strong earthquake might be rated as magnitude 6.3. Because of the logarithmic basis of the scale, each whole number increase in magnitude represents a tenfold increase in measured amplitude; as an estimate of energy, each whole number step in the magnitude scale corresponds to the release of about 31 times more energy than the amount associated with the preceding whole number value.

Even though the original calculations developed by Richter to estimate earthquake magnitude have gone out of favor, newer formulae still retain the familiar Richter reporting methodology as shown in Table 5.34. Currently, the moment magnitude scale (MMS) is the primary reporting method used by the U.S. Geological Survey.[19]

Table 5.34: The Richter Scale

Richter Magnitudes	Earthquake Effects
Less than 3.5	Generally not felt but recorded.
3.5–5.4	Often felt, but rarely causes damage.
Under 6.0	At most, slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1–6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0–7.9	Major earthquake. Can cause serious damage over larger areas.
8 or greater	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

The effect of an earthquake on people and structures on the Earth's surface is called the intensity. The intensity scale consists of a series of certain key responses such as people awakening, movement of furniture, damage to chimneys, and finally, total destruction. Although numerous intensity scales have been developed in the last several hundred years to evaluate the effects of earthquakes, the one currently used in the United States is the Modified Mercalli Intensity Scale (**Table 5.35**). It was developed in 1931 by American seismologists Harry Wood and Frank Neumann. This scale, composed of 12 increasing levels of intensity that range from imperceptible shaking to catastrophic destruction, is designated by Roman numerals as shown in Table 5.35. The scale does not have a mathematical basis; instead, it is an arbitrary ranking based on observed effects.[20]

[18] USGS, accessed online at: https://earthquake.usgs.gov/learn/glossary/?term%3Drichter%2520scale&sa=D&source=docs&ust=1645377818946701&usg=AOvVaw08xBaSg2rM9bLm1i43j_D5

[19] Virginia Department of Energy, accessed online at: https://energy.virginia.gov/geology/Earthquakes.shtml

[20] USGS, accessed online at: https://www.usgs.gov/natural-hazards/earthquake-hazards/science/modified-mercalli-intensity-scale?qt-science_center_objects=0#qt-science_center_objects

The lower numbers of the intensity scale deal indicate the manner in which people perceive the earthquake. The higher numbers of the scale are based on observed structural damage. Structural engineers usually contribute information for assigning intensity values of VIII or above.

Table 5.35: Modified Mercalli Intensity Scale for Earthquakes

Scale	Intensity	Earthquake Effects	Corresponding Richter Scale Magnitude
I	Instrumental	Detected only on seismographs	
II	Feeble	Some people feel it	<4.2
III	Slight	Felt by people resting; like a truck rumbling by	
IV	Moderate	Felt by people walking	
V	Slightly Strong	Sleepers awake; church bells ring	<4.8
VI	Strong	Trees sway; suspended objects swing; objects fall off shelves	<5.4
VII	Very Strong	Mild alarm; walls crack; plaster falls	<6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures; poorly constructed buildings damaged	
IX	Ruinous	Some houses collapse; ground cracks; pipes break open	<6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread	<7.3
XI	Very Disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards	<8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves	>8.1

Earthquakes in the central and eastern U.S., although less frequent than in the western U.S., are typically felt over a much broader region. East of the Rockies, an earthquake can be felt over an area as much as ten times larger than a similar magnitude earthquake on the west coast. A magnitude 4.0 eastern U.S. earthquake typically can be felt at many places as far as 60 miles from where it occurred, and it infrequently causes damage near its source.[21] A magnitude 5.5 eastern U.S. earthquake usually can be felt as far as 300 miles from where it occurred, and sometimes causes damage out to 25 miles.

Hazard History

Earthquakes everywhere occur on faults within bedrock, usually several miles deep. Most bedrock beneath central Virginia was assembled as continents collided to form a supercontinent about 500-300 million years ago, raising the Appalachian Mountains. Most

[21] Virginia Tech Global Seismological Lab, accessed online at: http://www.magma.geos.vt.edu/vtso/cvsz.html

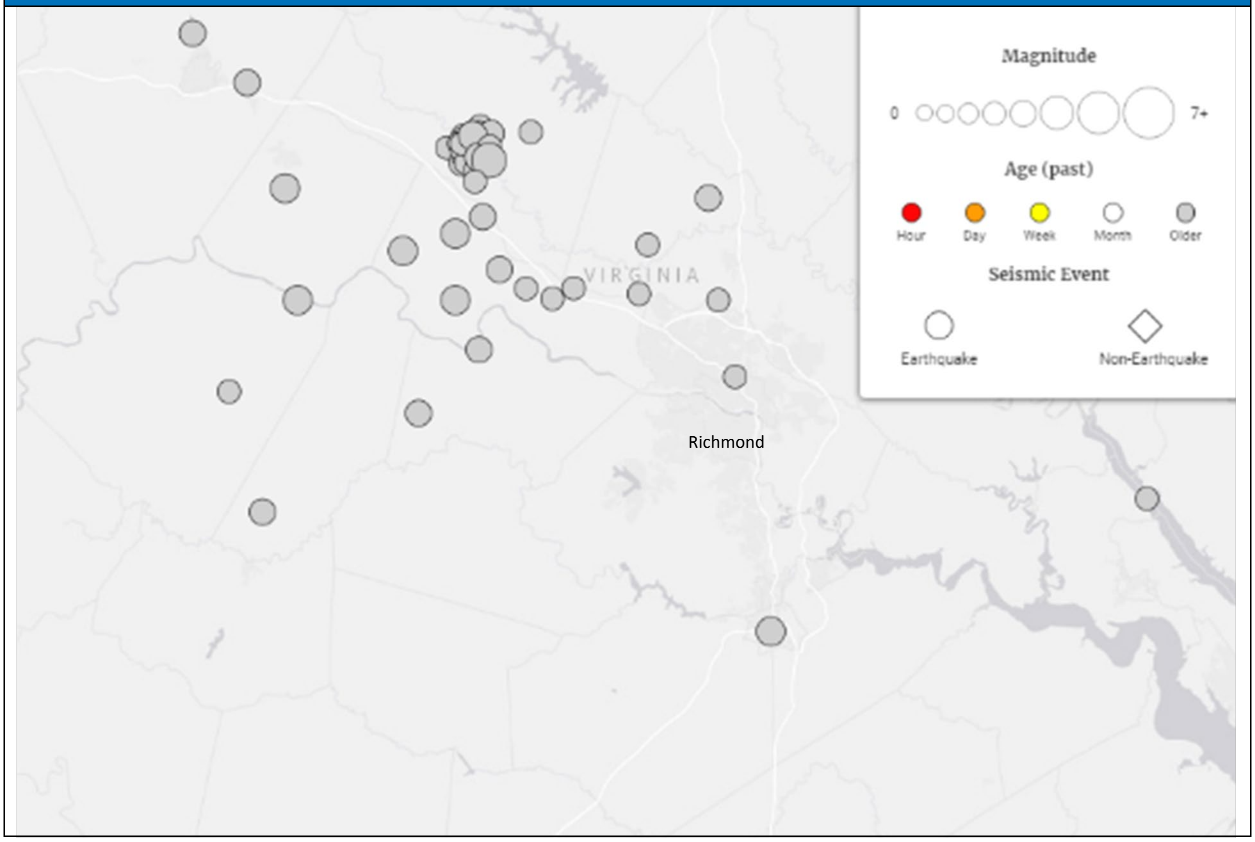
of the rest of the bedrock formed when the supercontinent rifted apart about 200 million years ago to form what are now the northeastern U.S., the Atlantic Ocean, and Europe.[22]

At well-studied plate boundaries like the San Andreas fault system in California, scientists can often determine the name of the specific fault that is responsible for an earthquake. In contrast, east of the Rocky Mountains this is rarely the case. The Central Virginia Seismic Zone is far from the nearest plate boundary, which are in the center of the Atlantic Ocean. The seismic zone is laced with known faults, but numerous smaller or deeply buried faults remain undetected. Even the known faults are poorly located at earthquake depths. Accordingly, few, if any, earthquakes in the seismic zone can be linked to named faults. It is difficult to determine if a known fault is still active and could slip and cause an earthquake. As in most other areas east of the Rockies, the best guide to earthquake hazards in the seismic zone is the earthquakes themselves.[23]

Earthquake activity in Virginia has generally been, with a few exceptions, low-magnitude but persistent. The first documented earthquake in Virginia took place in 1774 near Petersburg.[24] Virginia has had more than 160 earthquakes since 1977, of which 16% were felt. This averages to approximately one earthquake every month, with two felt each year.[25] **Figure 5.34** shows the significant earthquakes (magnitude greater than 2.5) that have impacted Virginia from 1774 to 2020. There have been eight noteworthy earthquakes centered in the region; however, surface faulting that generated these earthquakes remain unidentified.

[22] Virginia Tech Global Seismology Lab, accessed online at: http://www.magma.geos.vt.edu/vtso/cvsz.html
[23] Virginia Tech Global Seismology Lab, accessed online at: http://www.magma.geos.vt.edu/vtso/cvsz.html
[24] Virginia Department of Energy, accessed online at: https://energy.virginia.gov/geology/Earthquakes.shtml
[25] Virginia Tech Global Seismology Lab, accessed online at: http://www.geol.vt.edu/outreach/vtso/quake.html

Figure 5.34: Earthquake History in the Greater Richmond-Crater Region, 1774 - 2020



Source: USGS Earthquake Mapping Tool, accessed online 2021 at: https://earthquake.usgs177.gov/earthquakes/

Of the eight noteworthy earthquakes that have been recorded in the region, one was centered near the City of Petersburg, two near Goochland County, and one near Powhatan County. Historical earthquake occurrences, which have affected the region and are summarized in the following paragraphs, are based on available records from the Virginia Tech Seismological Observatory, Seismicity of the United States (USGS Paper 1527), the U.S. Geological Survey Earthquakes in Virginia and Vicinity 1774 – 2004 (USGS Open File Report 2006-1017), and the Virginia Department of Energy (DGMR Publication 185).[26]

The first major historical record for an earthquake (estimated Magnitude 4.5) occurred on February 21, 1774, near the City of Petersburg and Prince George County. The earthquake was felt in much of Virginia and southward into North Carolina. Many houses were moved considerably off their foundations in the cities of Petersburg and Blandford. The shock was described as "severe" in Richmond and terrified residents about 50 miles north in the City

[26] Virginia Department of Energy, accessed online at: https://energy.virginia.gov/geology/documents/FEMAHistoryReport.zip

of Fredericksburg but caused no damage in those areas. The total felt area covered about 57,900 square miles.

On August 27, 1833, an earthquake near Goochland County (estimated Magnitude 4.5) was felt from Norfolk to Lexington and from Baltimore, Maryland, to Raleigh, North Carolina – about 52,110 square miles. In Charlottesville, Fredericksburg, Lynchburg, and Norfolk, windows rattled violently, loose objects shook, and walls of buildings were visibly agitated.

Although it did not occur within the region, an earthquake (estimated Magnitude 4.3) was observed on November 2, 1852, with the epicenter in Buckingham County, Virginia. Chimney damage was reported in Buckingham and the earthquake was reported to be the strongest in Fredericksburg and Richmond, and the Town of Scottsville.

Centered near Goochland County, a series of shocks (estimated Magnitude 4.8) in quick succession were felt throughout the eastern two-thirds of Virginia and a portion of North Carolina on December 23, 1875. The highest intensities from this earthquake occurred mainly in towns near the James River shoreline in Goochland and Powhatan Counties, and in Louisa County. In Richmond and Henrico Counties, the most severe damage was sustained in the downtown business and residential areas adjacent to the James River. Damage included bricks knocked from chimneys, fallen plaster, an overturned stove, and several broken windows. Waves "suddenly rose several feet" at the James River dock in Richmond, causing boats to "part their cables" and drift below the wharf. At Manakin, about 20 kilometers west of Richmond, shingles were shaken from a roof and many lamps and chimneys were broken. The total felt area was about 50,180 square miles.

On February 11, 1907, an earthquake reaching magnitude 4.0 on the Richter Scale affected the community of Arvonia in Buckingham County. The earthquake was also felt strongly from Powhatan to Albemarle Counties.

The December 9, 2003, an earthquake occurred in Powhatan County (estimated Magnitude 4.5). The quake was a complex event consisting of two sub-events occurring 12 seconds apart and causing slight damage nearest the epicenter. The quakes were felt in much of Maryland and Virginia; in north-central North Carolina; and in a few areas of Delaware, New Jersey, New York, Pennsylvania, and West Virginia.

A 5.8 magnitude quake centered near Mineral, Virginia (Louisa County) occurred at 1:51 pm EDT on August 23, 2011. The earthquake was reportedly felt as far north as Canada, as far south as Georgia and as far west as Chicago. Effects of the earthquake were reported to the USGS through its online survey[27] from over 8,434 zip codes and ranged from weak intensity to very strong. In terms of damage, particularly hard-hit were brick and unreinforced structures and infrastructure near the quake's epicenter. In addition to cracks and buckling, some buildings were knocked off of their foundations. Minor injuries were reported as a result of the damage and debris. The earthquake forced the North Anna Power Station nuclear power plant offline pending an all-clear from a Nuclear Regulatory Commission review. Aftershocks of a lesser magnitude continued to plague the area for

[27] USGS, accessed online at: https://earthquake.usgs.gov/data/dyfi/

several weeks after the event. The strongest aftershock measured 4.5 and occurred on August 25 at 1:08 am EDT. Louisa County received over $6.6 million in individual assistance as well as $1.6 million in low-interest loans to individuals and businesses through the Small Business Administration (source: *2018 Commonwealth of Virginia Hazard Mitigation Plan*).

A magnitude 3.1 quake occurred May 22, 2014, 3.1 to 15 kilometers east-northeast of Cumberland, in Powhatan County. Reports of the quake were received by over 2,000 people in the central Virginia area. The earthquake depth was 9.0 kilometers.

Vulnerability Analysis

Earthquakes are high-impact, low-probability events. With the few historical incidents throughout the region and limited data, the probability is low. **Figure 5.36** show the relative seismic hazard throughout the study area, highlighting the Central Virginia Seismic Zone.

Since the 2011 earthquake in Louisa County, Virginia, scientists have worked to create an all-inclusive database of the state's fault lines based on all data available, particularly earthquake epicenters. The Central Virginia Seismic Zone coincides with much of the northern region of the Richmond-Crater study area. The 2011 earthquake is the largest historical earthquake within the Central Virginia Seismic Zone and the largest earthquake to have occurred in Virginia in historical time. [28]

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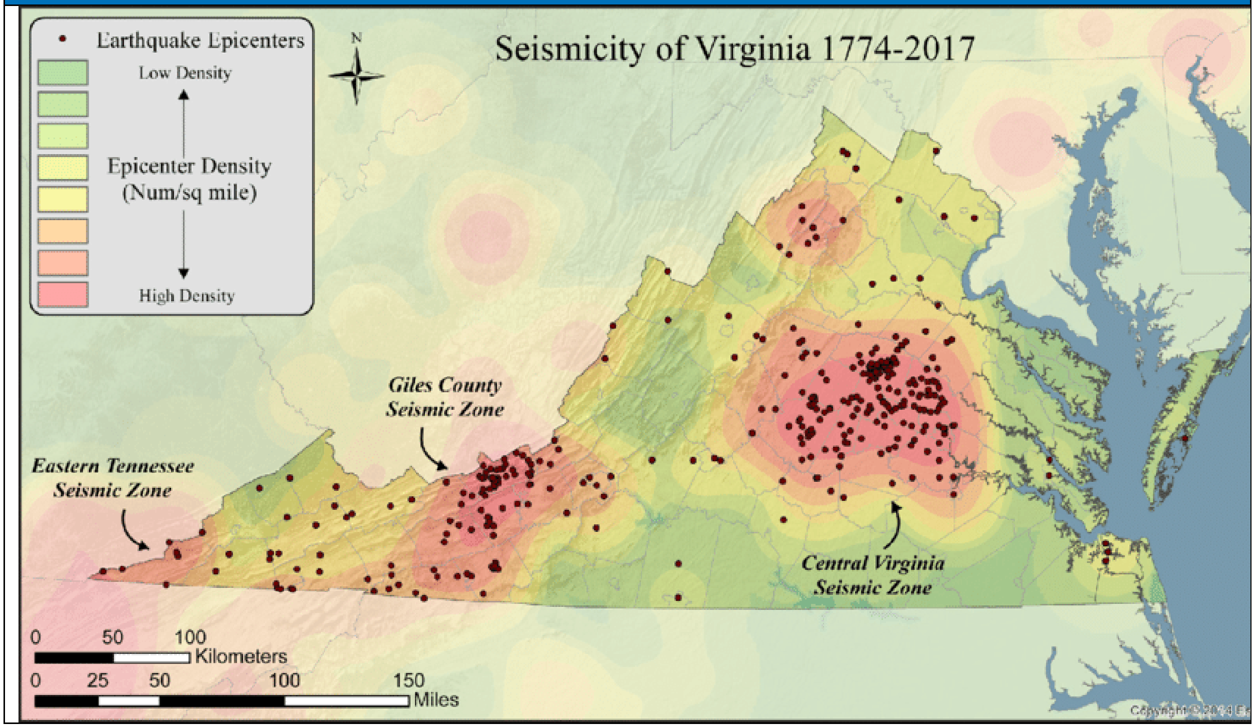
[28] Kelly, Wendy; A. Witt; M. Heller; and M. Chapman. August 2017. Virginia Division of Geology and Mineral Resources Publication 185 - Seismic History Of Virginia, August 2017.

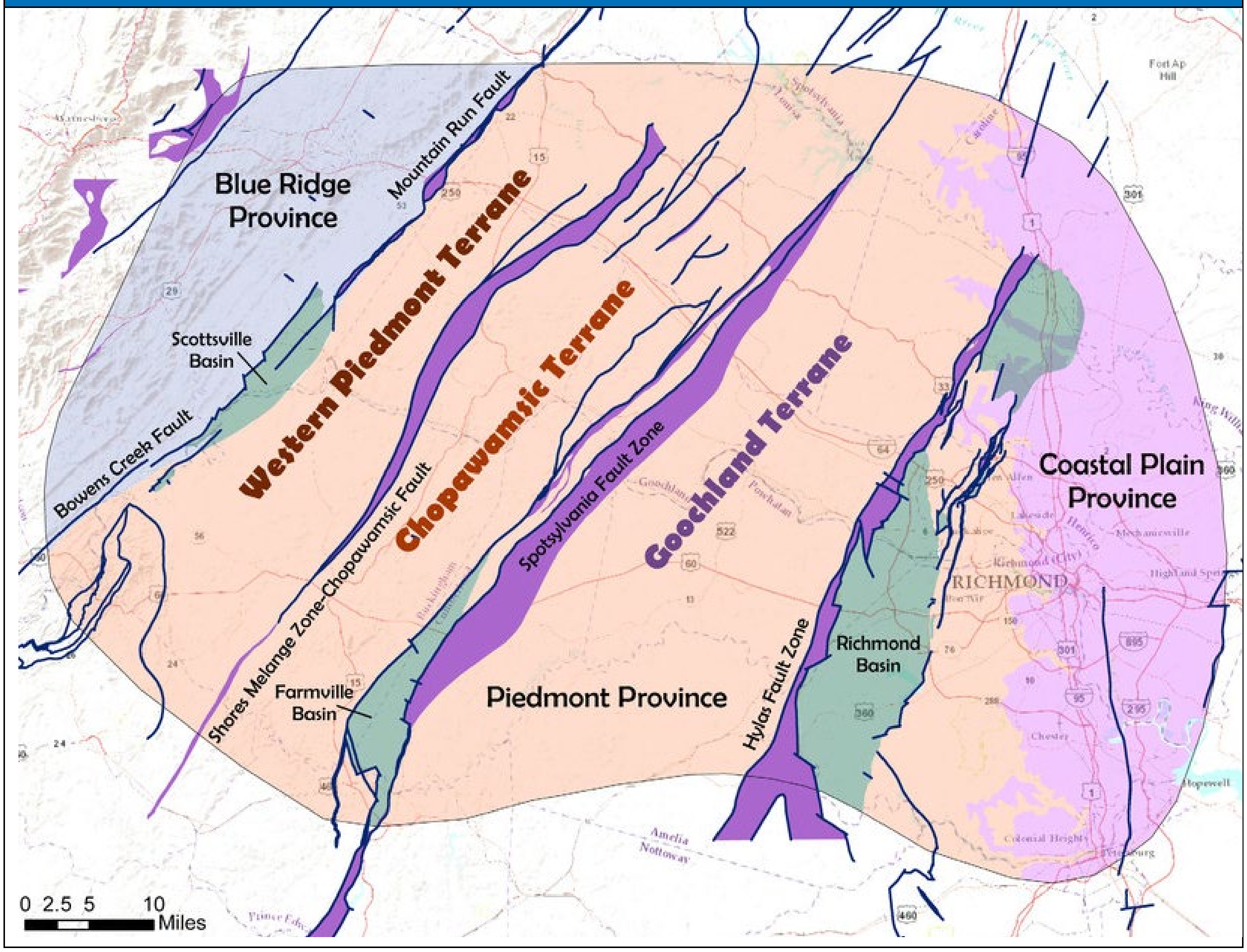
Figure 5.36: Seismicity of Virginia, 1774-2017



Source: Kelly, Wendy; A. Witt; M. Heller; and M. Chapman. August 2017. Virginia Division of Geology and Mineral Resources Publication 185 - Seismic History Of Virginia, August 2017.

Fault lines and zones in the study area are delineated in **Figure 5.37**, which shows the major faults (navy blue lines running southwest to northeast) and tectonic terranes within the Central Virginia Seismic Zone. Note the fault lines southwest and southeast of Richmond.

Figure 5.37: Major Faults and Tectonic Terranes within the Central Virginia Seismic Zone



Source: Kelly, Wendy; A. Witt; M. Heller; and M. Chapman. August 2017. Virginia Division of Geology and Mineral Resources Publication 185 - Seismic History Of Virginia, August 2017.

The Hazus earthquake model estimates damages and loss to buildings, lifelines, and essential facilities from customized-scenario and probabilistic earthquakes. Hazus was used to generate damage and loss estimates for the probabilistic ground motions associated with each of eight return periods (100-, 250-, 500-, 750-, 1,000-, 2,000-, and 2,500-year return periods), and then annualized to show the relative risk to each community in the study area.

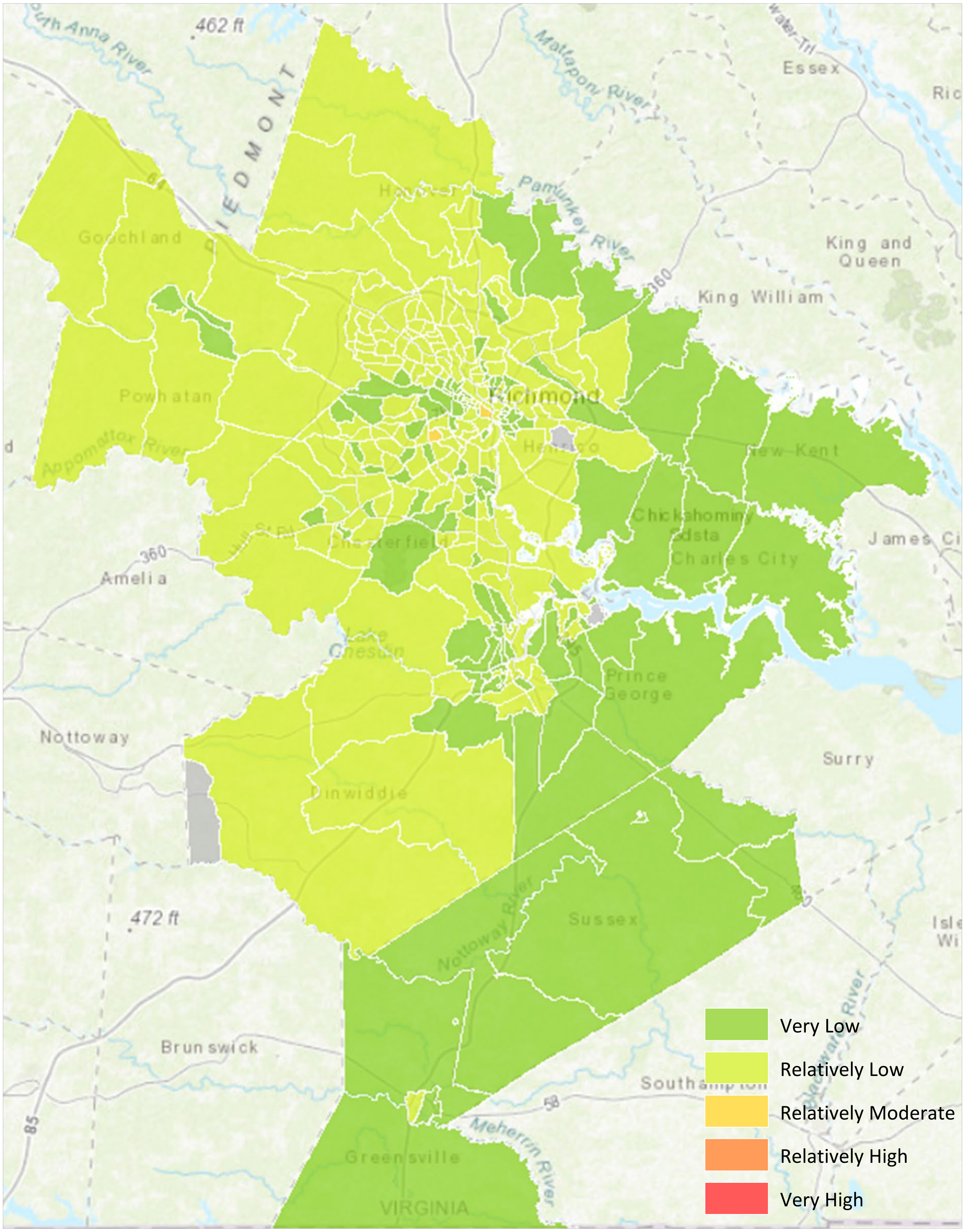
Table 5.36 shows results from the Hazus analysis for the jurisdictions in the region. These figures include direct economic losses for buildings, including non-structural damage, contents/inventory, and income losses from relocation, lost wages and lost rental income. Based on this analysis, Henrico County experiences the greatest losses on an annualized basis in the region, followed closely by Chesterfield County and the City of Richmond.

Table 5.36: Annualized Earthquake Losses	
Jurisdiction	**Annualized Total Damages**
Charles City County	$10,000
Chesterfield County	$1,032,000
City of Colonial Heights	$32,000
Dinwiddie County (inc. Town of McKenney)	$45,000
City of Emporia	$8,000
Goochland County	$132,000
Greensville County (inc. Town of Jarratt)	$9,000
Hanover County (inc. Town of Ashland)	$415,000
Henrico County	$1,384,000
City of Hopewell	$37,000
New Kent County	$27,000
City of Petersburg	$74,000
Powhatan County	$136,000
Prince George County	$46,000
City of Richmond	$763,000
Surry County (inc. Town of Surry)	$6,000
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	$11,000
Total	**$4,167,000**

Social Vulnerability

The NRI data for social vulnerability to earthquake are shown in **Figure 5.38**. The map reflects the history of earthquakes in Virginia, with few damages and slightly higher overall vulnerability near the Central Virginia Seismic Zone. There are two areas of relatively moderate social vulnerability in Richmond: the first is the downtown area where 195 and 95 converge; and the other is centered on Carnation Street, north of Midlothian Park and south of Jahnke Road.

Figure 5.38: National Risk Index Rating, Earthquake



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has very low social vulnerability for earthquake.

Future Vulnerability, Land Use and Climate Change

While scientists have observed some correlation between climate change on rising temperatures, melting glaciers and isostatic rebound, a causal connection to subsequent earthquakes is less documented, especially for the eastern United States. Earthquakes and weather have a few *possible* correlations that are still under investigation and should be considered more theoretical than scientific:

1. glacier melt and isostatic rebound causing earthquakes;
2. changing surface stress loads from increased surface water causing microseismicity or tiny earthquakes with magnitudes less than zero, and changes in water quantity stored in large dams inducing seismicity;
3. longer duration droughts and/or groundwater withdrawals that change stress loads on the Earth's crust causing earthquakes; and,
4. injection wells that lubricate faults and induce seismicity.[29]

While it is conceivable that a massive earthquake in the study area or in a large metropolitan area nearby, such as Hampton Roads or northern Virginia, could cause a mass evacuation if damage is severe, this likelihood is not supported by the history of earthquake damage in these regions of Virginia.

5.13 Landslides

Hazard Profile

A landslide is the downslope transport of a mass of soil and rock material and refers to a number of different varieties of ground movement landforms and processes. The primary driving force for a landslide is gravity, but other factors may contribute to the failure of a slope. Landslides are usually triggered by heavy rainfall, rapid snow melt, oversteepening of slopes by stream incision, or earthquakes, while certain man-made changes to the land, such as slope modification or drainage alteration, can greatly increase the likelihood of landslides. Sometimes a landslide may move slowly down a slope, but often the movement can occur without warning and be extremely fast. Soil creep and slumping cause property damage gradually, whereas rockslides and debris flows can sweep away people and property instantaneously. In the United States, landslides annually cause up to $2 billion in damages and take between twenty-five and fifty lives.[30]

Landslides occur in many manifestations and are usually classified according to the type of material involved and the mode of downslope movement. The material can range from loose

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[29] Buis, Alan. NASA: Global Climate Change: Vital Signs of the Planet. *Can Climate Affect Earthquakes, or are the Connections Shaky?* Feature dated October 29, 2019, accessed online at: https://climate.nasa.gov/news/2926/can-climate-affect-earthquakes-or-are-the-connections-shaky/

[30] Virginia Department of Energy, accessed online at: https://energy.virginia.gov/geology/Landslides.shtml&sa=D&source=docs&ust=1645377818936537&usg=AOvVaw2DI9rmYtgmQSFtoaok6Sgl

earth to blocks of solid rock. These materials may then move downslope by falling, sliding or flowing. The following are some of the more important types of mass movement:

Rockfalls entail large blocks of bedrock breaking off a cliff face and tumbling downslope;

Rockslides occur when a detached section of bedrock slides down an inclined surface, frequently along a bedding plane;

Earthslides involve masses of soil moving down a slip face, usually on top of the bedrock;

Creep is the slow, continuous, imperceptible downslope movement of soil and rock particles;

Rotational Slides or Slumps result from the rotation of a cohesive unit of soil or rock down a slip surface, leaving a curved scarp; and

Debris flows develop on steep slopes as a result of heavy rainfall that saturates the soil, which under the extra weight and lubrication breaks loose and becomes a slurry that takes everything with it, including large trees and houses. Channeled debris flows can reach speeds approaching a hundred miles an hour and strike without warning.

Landslides are most common in the mountainous terrain of Virginia because of the presence of steep slopes and highly fractured bedrock over shallow soils. The lower-relief areas of the Piedmont and Coastal Plain also have landslides, but they are often smaller and generated by human disturbance, such as making an oversteepened road cut. The most disastrous landslide events have been associated with heavy rainfall along the steep slopes of the Blue Ridge Mountains and the Appalachians. Areas that are prone to mass movement include areas where landslides have occurred in the past; steep slopes with an angle greater than 30 degrees; and oversteepened cuts and fills, particularly due to home and road building. Research in North Carolina has revealed that about fifty-six percent of recent landslides happened on slopes that had been altered in some way by development.

Landslides are capable of destroying buildings, rupturing gas, water, and sewer mains, and knocking out power and telephone lines while blocking transportation routes. Urban development can increase the damages caused by a landslide. Damages sustained by roads and highways during a landslide can result in long-term loss of use of certain transportation routes and contribute to increased traffic and emergency response times in the affected region. The soil movement that occurs during a landslide can destabilize structural supports for pipelines potentially resulting in pipeline ruptures and decreased or loss of service in a region.

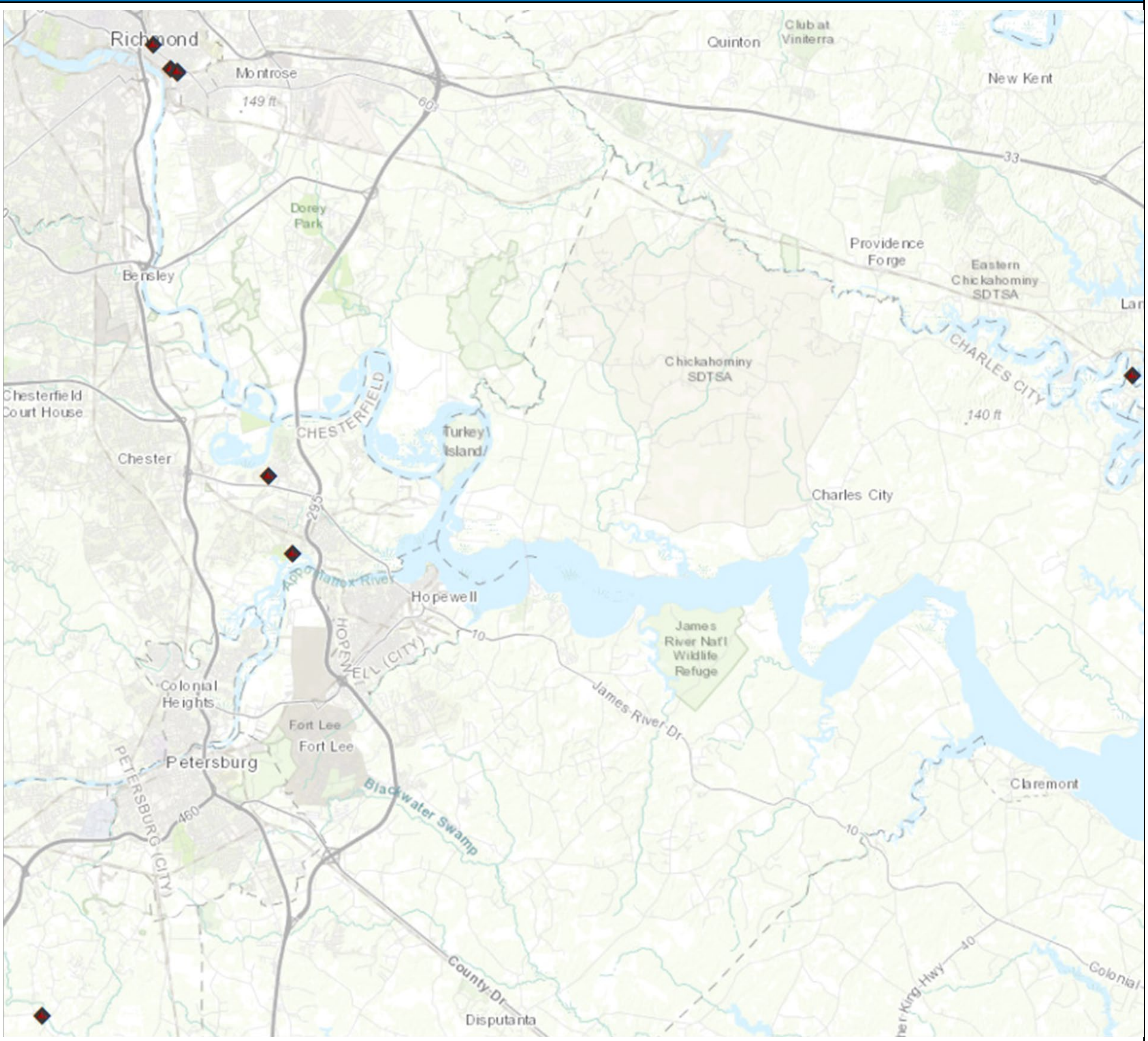
Magnitude or Severity

The severity of a landslide is dependent on many factors including the slope and width of the area involved, the speed of the earth movement, and any structures or infrastructure directly in the path of the slide. Impacts of a landslide can range from a minor inconvenience to a life-threatening situation when automobiles and buildings are involved.

Hazard History

Analysis of the hazards in the Richmond-Crater study area is limited by the availability of data and reporting of incidents; however, scientists at the Virginia Department of Energy maintain a statewide database of landslide locations. **Figure 5.39** shows the locations of landslides since 2004 on a map of the southeastern part of the region where the landslides occurred.

Figure 5.39: Locations of Recorded Landslides, 2004 – 2021



Source: Virginia Department of Energy, 2021

Table 5.37 provides additional detail on the landslides shown above. While details are preliminary, State geologists suggest that evidence shows in the Richmond-Crater and Virginia Peninsula regions, there is a higher incidence of landslide initiation near the contact between two geological formations, the Eastover and the Yorktown Formations, to pervasive geological units in the Virginia Coastal Plain. Slopes can be further destabilized due to excess runoff from development, including storm water drains and gutters.

Table 5.37: Landslides in Richmond-Crater Area, 2004 - 2021

Jurisdiction	Notes	Movement Date	Noted Impacts, If Any
City of Richmond	Chimborazo Hill Landslide – Translational debris slide was active and very rapid (>3 meters/minute) when observed. May have been active as early as the 1900's; more tension cracks evident in 2011 photography. Groundwater was present soil & bedrock seep.	8/30/2004	Home condemned, park and road severely damaged.
	 Chimborazo Hill Landslide photograph, *Virginia Minerals,* VA DMME, Vol. 48, November 2005.		
	This debris flow was rapid (>1.8 meters/hour).	8/30/2004	None reported.
	This debris slide was rapid (>1.8 meters/hour).	8/30/2004	None reported.
	Jefferson Park Landslide	8/30/2004	Covered Marshall Street
Chesterfield County	Homes were built on sand fill used to level a steep bluff that was once the edge of an open cut mine. Landslide is currently inactive. Debris slide was rotational on a cut slope.	1998 and 2016	Landslide is undermining foundations of houses.
	Large rotational slide in sandy sediment. Lower portions have scarping of up to 6 feet. Back rotated trees in slide. Slide likely undermined by stream. Sliding surface may be 1-3 foot thick clay lens within Cretaceous. Across from slide, clay lens is exposed in bank and groundwater noted at base of clay.	Not available	Damaged a walking trail.
Dinwiddie County	This debris slide was rotational.	Not available	Unverified

<table>
<tr><td rowspan="2">New Kent County</td><td>Claytor Landslide - homeowner says movement started during Hurricane Irene (2011). Headscarp is 5 feet from porch steps, two 10-foot sections of seawall at base of slope have been either toppled or covered by sediment from previous landslides. This is a series of concave erosional scarps along the riverbank.</td><td>2011 and March 5, 2019</td><td>Most recent scarp is threatening house.</td></tr>
<tr><td colspan="3">
Translational debris slide in New Kent County, VA DMME, 2021.</td></tr>
</table>

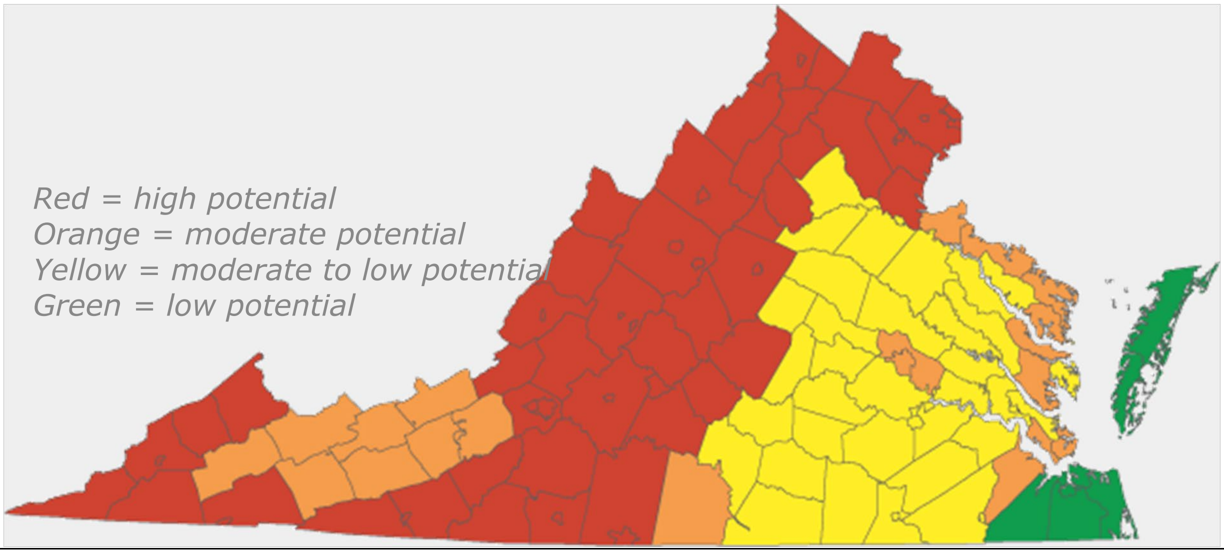
Source: Virginia Department of Energy, 2021

Local officials from the City of Richmond reported that a number of areas in the city were affected by landslides triggered by the rains of Tropical Storm Gaston in August 2004. The Church Hill and Riverside Drive sections of Richmond experienced 14 inches of rain in eight hours. Church Hill features unstable geologic formations which were destabilized by the heavy rainfall. One home in Church Hill was severely impacted by the Chimborazo Hill Landslide and was ultimately condemned and purchased by the City. Nearby tennis courts were also impacted. The Riverside Drive area features steep embankments along the south shore of the James River and abandoned granite quarries. During Gaston localized landslides also occurred near Forest Hill Park.

Vulnerability Analysis

Landslide events in the region are considered a low-probability event, with very localized impacts when and where they occur. The Virginia Department of Energy provided the map in **Figure 5.40** that shows counties in Virginia and related susceptibility to landslides. Because damages are rarely quantified or are extremely limited in nature, average annual damages from landslides are not very useful. Occurrence intervals are similarly flawed because of the short period of record. The Commonwealth's highest regional vulnerability is in the mountainous region west of this plan's study area. With the exception of the City of Richmond and Henrico County, the Richmond-Crater region is classified as having moderate to low potential for landslide. Richmond and Henrico County are classified as having moderate potential.

Figure 5.40: Susceptibility to Landslides by Virginia County/City

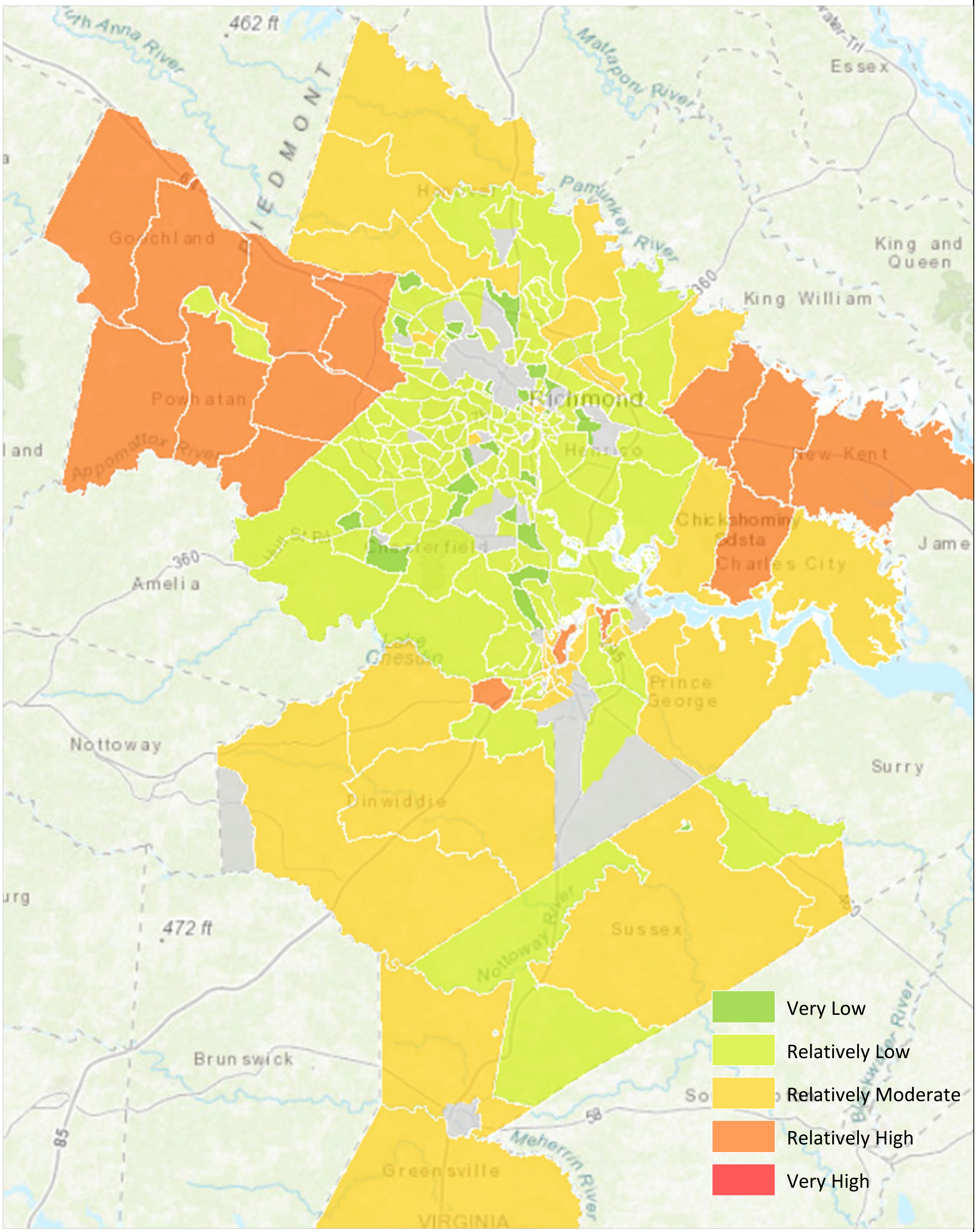


Source: Virginia Department of Energy, provided 2021

Social Vulnerability

The NRI data for social vulnerability to landslides are shown in **Figure 5.41**. The USGS Landslide Hazard Map was used as an input for hazard susceptibility, creating a raster that classified all of the conterminous United States as having either "some" or "negligible" landslide susceptibility based on slope and relief. This method may not adequately capture the unique geological conditions that are suspected as contributors to landslides in the study region. Nevertheless, the social vulnerability shown in Figure 5.41 is a starting point for discussions regarding factors that could affect a household's vulnerability to landslide.

Figure 5.41: National Risk Index for Landslide



Source: National Risk Index, FEMA 2021

Note: The Town of Surry has relatively moderate social vulnerability for landslide south of Route 10, and relatively high social vulnerability for landslide north of Route 10.

Future Vulnerability, Land Use and Climate Change

As noted in the previous section, landslides have occurred in the City of Richmond following periods of heavy precipitation but have generally been limited in geographic scope and/or damage extent. The primary area of concern noted by city officials is Government Road.

Current building code requirements restrict fill materials used to fill a building site prior to new construction; however, homes built on debris fill, or on oversteepened slopes (such as along a river bluff) may be more vulnerable to landslides in the future, especially on or near slopes near the contact between the Yorktown and Eastover convergence. The Virginia Department of Energy is interested in identifying and mapping at-risk areas in the region.

Climate change has the potential to worsen the risk associated with landslides in the study area. Precipitation patterns are expected to become more intense, prolonged and frequent as a result of a warming climate. There is a risk that these precipitation events could destabilize fragile slopes in the region, leading to more frequent and damaging landslides.

Based on the hazard's history in the region, mass evacuations caused by landslides are not expected.

5.14 Shoreline Erosion

Hazard Profile

Shoreline or coastal erosion is a process whereby large storms, flooding, strong wave action, sea level rise, and human activities, such as inappropriate land use, alterations, and shore protection structures, wear away beaches, banks and bluffs. Erosion undermines banks and can destroys homes, businesses, and public infrastructure.

Magnitude or Severity

The extent or severity of erosion may vary from year to year and is related to a number of factors: composition of the shoreline (rock, sand, clay, marsh, or human-made structures), fetch, orientation to prevailing wind direction, and relative sea level rise. The degree of recession at a particular site may also be dependent upon intensity of the wave action and exposure to tidal currents, character of the sediments and degree of vegetative cover, supply of sand moving along the shoreline, gradient or slope from fastland to shoreline to nearshore bottom.

While coastal erosion can destroy infrastructure like roads, septic tanks, and even structures such as homes and businesses, the most common damage in the Richmond-Crater region is loss of trees, denuded shores, wetland loss and sediment introduced into the Chesapeake Bay system.

While tidal surge events can cause nominal increases in the rate of erosion, large-scale storm events generating an extensive surge will cause a rapid acceleration in coastal erosion rates. Accelerated erosion in areas with no natural or man-made protective features is more likely to increase severe impacts to infrastructure. Through loss of land and undercutting, infrastructure such as pipelines, piers, roadways, and other structures can be significantly damaged or destroyed.

Hazard History

The shoreline areas of the region are consistently undergoing coastal erosion. However, severe storms that increase wave activity (hurricanes, tropical storms, and nor'easters), sea level rise, and shoreline development can increase both short-term and long-term erosion along the region's shorelines. The banks of the James River have historically experienced varying rates of shoreline erosion from storm events and that change has been studied over time, particularly for Prince George, Charles City and Surry Counties.

The *Prince George County Shoreline Management Plan*[31], prepared by the Virginia Institute of Marine Science (VIMS) at the College of William & Mary in November 2016, breaks the county's portion of the James River into four reaches. Researchers calculated End Point Rate (EPR) by determining the distance between the oldest and most recent shoreline in the data and dividing it by the number of years between them. This method provides an accurate net rate of change over the long term and is relatively easy to apply to most shorelines since it only requires two dates. This method does not, however, use the intervening shorelines so it may not account for changes in accretion or erosion rates that may occur through time. The study documented very low erosion to very low accretion for the four reaches in Prince George County as shown in **Table 5.38**. The shoreline management plan concluded that "nearly 75% of the shoreline in Prince George County can be managed simply by enhancing the riparian buffer or the marsh if present."

The *Charles City County Shoreline Management Plan*[32], similarly prepared by VIMS in February 2015, concluded that "nearly 85% of the county's shoreline could be managed by enhancing the riparian buffer or marsh if present."

VIMS prepared *Shoreline Evolution: Surry County, Virginia James River Shorelines Data Summary Report*[33] in September 2011, which provides rates of shoreline change for the reaches shown in Table 5.38. Hog Island shoreline has the highest rates of documented change in the study area.

While VIMS has collected data regarding shoreline condition for other counties in the study area, they have not calculated rates of shoreline change or prepared shoreline management plans. **Figure 5.42** graphically shows shoreline change data compiled by VIMS for the 1937/38 shoreline, the 2009 shoreline and the 2017 shoreline. Areas showing a significant difference between the shorelines of the past and the present indicate areas of historic erosion. The map viewer online can be used to zoom in on areas of interest at:

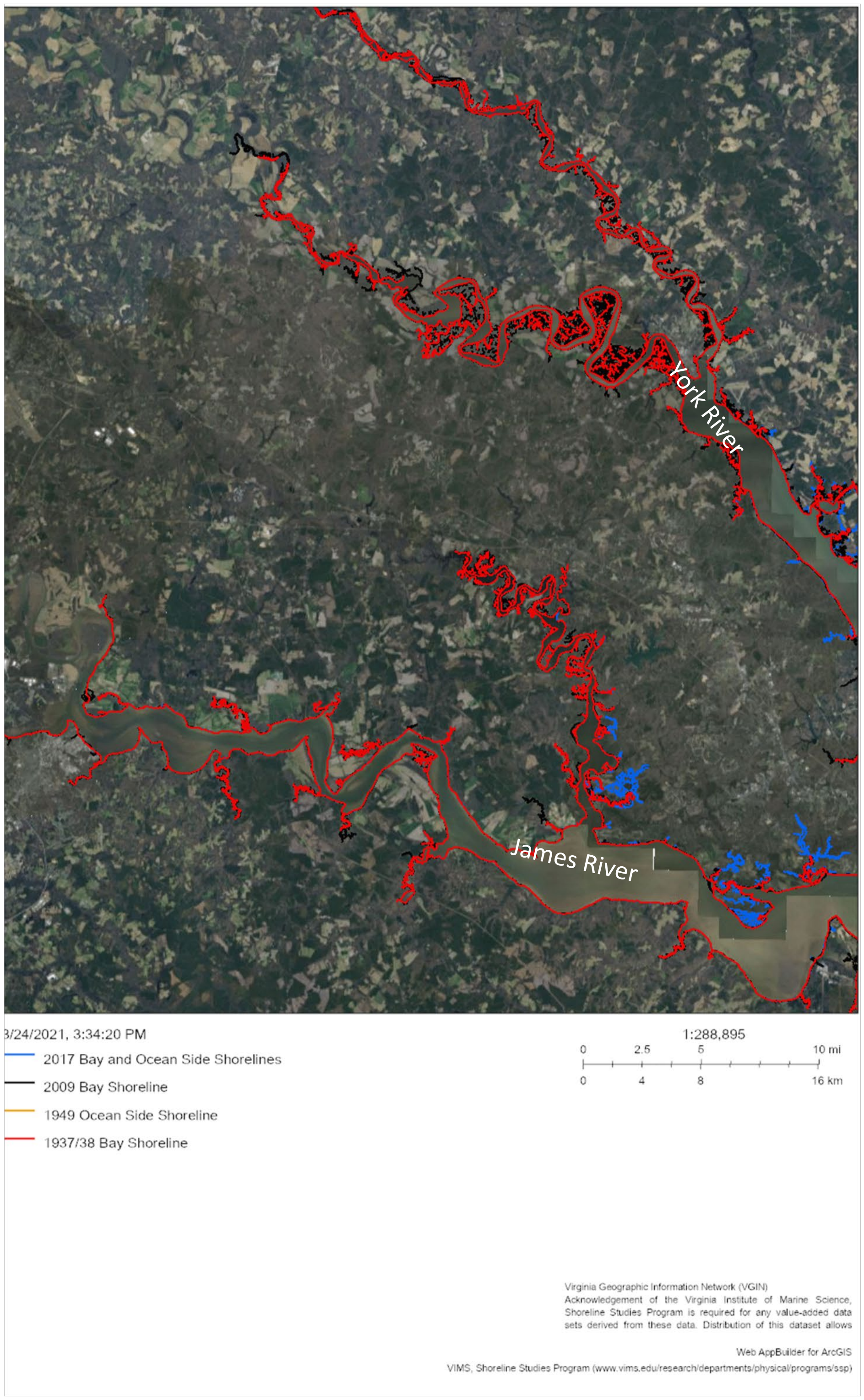
[31] Accessible online at: https://www.vims.edu/research/departments/physical/programs/ssp/_docs/PrinceGeorge_Shore%20Man_2016-lr.pdf
[32] Accessible online at: https://scholarworks.wm.edu/cgi/viewcontent.cgi?article=1255&context=reports
[33] https://scholarworks.wm.edu/cgi/viewcontent.cgi?article=1575&context=reports

https://www.vims.edu/research/departments/physical/programs/ssp/shoreline_evolution/gis_maps/index.php.

Table 5.38: Rates of Shoreline Change in the Richmond-Crater Region (1937 – 2009)			
Jurisdiction	**Reach Name**	**Average End Point Rate of Change (Ft/Yr)**	**Category**
Prince George County	Reach 1: Appomattox River – Harrison Creek to James River	-0.4	Very Low Erosion
	Reach 2: James River – City Point to Coggins Point	0.0	Very Low Accretion
	Reach 3: James River – Coggins Point to Windmill Point	-0.1	Very Low Erosion
	Reach 4: James River – Windmill Point to Kennon Marsh	-0.4	Very Low Erosion
	Reach 5: James River – Kennon Marsh to Upper Chippokes Creek	-0.4	Very Low Erosion
	Reach 6: Upper Chippokes Creek	-0.8	Very Low Erosion
Charles City County	James River Turkey Island Creek to Epps Island	-0.1	Very Low Erosion
	James River Epps Island to Herring Creek	-0.3	Very Low Erosion
	Herring Creek	-0.4	Very Low Erosion
	James River Herring Creek to Queens Creek	-0.5	Very Low Erosion
	Queens Creek	-0.3	Very Low Erosion
	James River Queens Creek to Kennon Creek	-0.4	Very Low Erosion
	James River Kennon Creek to Tomahund Creek	-0.1	Very Low Erosion
	Chickahominy River	-0.6	Very Low Erosion
Surry County	A - Upper Chippokes Creek	-1.4	Not classified
	B - James River	0.0	
	C – James River	-0.1	
	D – James River	-0.6	
	E – Swanns Point	-0.6	
	F – Grays Creek	-0.7	
	G - James River	-0.1	
	H – James River	0.2	

Table 5.38: Rates of Shoreline Change in the Richmond-Crater Region (1937 – 2009)			
Jurisdiction	**Reach Name**	**Average End Point Rate of Change (Ft/Yr)**	**Category**
	I – James River, Cobham Bay	0.0	
	J – James River	-0.4	
	K – James River, Hog Island	-1.8	
	L – James River, Hog Island	-1.2	
	M – James River	-1.1	
	N – Lawnes Creek	-0.7	
Source: VIMS, Center for Coastal Resources Management, Virginia's Coastal Zone Locality Portals and individual Shoreline Management Plans, accessed online at: https://www.vims.edu/ccrm/ccrmp/portals/index.php			

Figure 5.42: Regional Shoreline Change, 1937/38 - 2017



Source: VIMS, 2021

Vulnerability Analysis

Shoreline erosion is likely to continue along some of the region's shorelines, especially in areas that have experienced historic erosion as shown in the figure above. In addition, the condition of the shoreline, wave climate, tide range, storm surge occurrence and rates of sea level rise are all factors in determining vulnerability of shoreline reaches to future erosion. Shorelines without best management practices (BMPs) for protection such as groin fields, healthy marshes, living shorelines or revetments may be more vulnerable, and shorelines with nearby buildings are of highest importance for mitigation. VIMS provides a Shoreline Assessment Mapper that displays site-specific coastal resource data across the coastal plain portion of the study area: http://cmap2.vims.edu/SAM/ShorelineAssessmentMapper.html

VIMS provides a site-specific set of BMPs throughout the study region, specifically for property owners interested in improving their shoreline's resistance to the damaging effects of erosion. The self-guided decision tools are interactive and lead users through questions about shoreline conditions to help choose the most effective erosion control strategies based on surrounding shoreline conditions. Access the main tool online at: https://cmap2.vims.edu/LivingShoreline/DecisionSupportTool/ShorelineDST.html

Social Vulnerability

Any measurement of social vulnerability to shoreline or coastal erosion requires considerably more knowledge about the location of vulnerable structures in each locality. Mitigation Action MH-4 in the 2018 Commonwealth of Virginia Hazard Mitigation Plan proposes VDEM involvement in assisting localities, state agencies, and PDCs with identification of vulnerable structures and application for funding to implement soil stabilization projects to reduce risk to structures or infrastructure from erosion. Future revisions to the plan may be able to more precisely define socially vulnerable areas of the study region for shoreline or coastal erosion using information developed under this or a similar effort.

Future Vulnerability, Land Use and Climate Change

The Commonwealth's Stormwater Management program and enabling statutes help to manage future land use, and reduce stream channel erosion, water pollution, depletion of groundwater resources and more frequent localized flooding to protect property value and natural resources throughout the region.

While waves are the primary force in determining the prevailing shoreline processes in the short-term of months or individual storms, sea level rise is the primary driver of shoreline change over the long-term. Documented sea level rise in the study area is expected to accelerate and will continue to impact shoreline morphology in the future. Shoreline management plans cited above contain recommended projects and conceptual designs for erosion mitigation.

Shoreline or coastal erosion are not expected to contribute to a mass evacuation for the study area or surrounding areas.

5.15 Sinkholes

Hazard Profile

Sinkholes are basin-like, funnel-shaped, or vertical-sided depressions in the land surface. In Virginia, the formation and modification of sinkholes is a natural process in areas underlain by limestone and other soluble rock. In general, sinkholes form by the subsidence of unconsolidated materials or soils into voids created by the dissolution of the underlying soluble bedrock. The rock exposed in a collapsed sinkhole is usually weathered and rounded, but some sinkholes contain freshly broken rock along their steep sides. Freshly broken rock may indicate that the sinkhole has formed by the collapse of a cave (naturally occurring) or a mine (man-made). Where sinkholes and caves have formed by the dissolution of soluble rock, such as limestone, dolomite, and gypsum, surface water is uncommon, and streams may sink into the ground. This type of topography is referred to as karst terrain. In karst terrain, sinkholes are input points where surface water enters the groundwater system. Signs of karst-related sinkhole formation may include:

- Slumping or falling fence posts;
- Wilting vegetation;
- Discolored well water;
- Structural cracks in walls, floors or foundations; and
- Cracks in soil/subsidence.

There are three types of potential problems associated with the existence or formation of sinkholes: subsidence (including catastrophic collapse and damage to infrastructure), flooding, and pollution. Sinkholes are the result of differential subsidence of the land surface. The term subsidence is commonly used to imply a gradual sinking, but it also can refer to an instantaneous or catastrophic collapse.

The location and rate at which sinkholes form can be affected by human activities. Sinkholes result from various mechanisms, including consolidation from loading, consolidation from dewatering, hydraulic compaction, settling as materials are removed by groundwater flow, raveling of materials into a void, and instantaneous collapse into a void. Although the formation of sinkholes is a natural process in karst terrains, man-made modifications to the hydrology of these areas commonly results in the acceleration of this process. The lowering of the water table in unconsolidated materials or soils, especially near the soil-bedrock interface, can result in the draining of voids caused by the dissolution of bedrock or the removal of soil by groundwater flow.

Patterns of pumping from high-yield wells over extended periods of time can result in large, rapid drawdowns of the water table. Where such drawdowns occur in unconsolidated materials, sinkhole collapse can be catastrophic, and subsidence can be extensive over the area subject to the drawdown. Disposal of stormwater in sinkholes or shallow dry wells can induce subsidence. The collapse of soil or rock above a void created by underground mining activities is another mode of sinkhole formation.

Sinkhole flooding can develop from a number of natural conditions, but two man-made conditions are the most common causes in Virginia: the plugging of natural sinkhole drains by sediment, and the overwhelming of natural sinkhole drains by increases in runoff from impermeable surfaces. Inadequate erosion control during construction can result in the plugging of natural sinkhole drains by sediment-laden runoff. The accompanying restriction of subsurface drainage causes an increase in ponding or flooding. Increased runoff from roads, parking lots, and structures is the most significant cause of sinkhole flooding. Much of the precipitation that would have percolated through a vegetated soil cover is introduced rapidly into surface and subsurface (input through sinkholes) drainage networks.

The potential impacts of land subsidence depend on the type of subsidence that occurs (regional or localized, gradual or sudden) and the location in which the subsidence occurs. The impacts of subsidence occurring in non-urban areas are likely to be less damaging than subsidence that occurs in heavily populated locations. The amount of structural damage depends on the type of construction, the structure location and orientation with respect to the subsidence location, and the characteristics of the subsidence event (sag or pit).

Potential impacts from land subsidence could include damage to residential, commercial, and industrial structures; damage to underground and above-ground utilities; damage to transportation infrastructure, including roads, bridges, and railroad tracks; as well as damage to or loss of crops.

Magnitude or Severity

Depending on size, sinkholes can cause damage to bridges, roads, railroads, storm drains, sanitary sewers, canals, levees, and private and public buildings. Karst topography can impact aquifers, introducing the potential for groundwater contamination. The greatest impact occurs when polluted surface waters enter karst aquifers. This problem is universal among all populated areas located in karst terrain. The groundwater problems associated with karst can be accelerated by: (1) expanding urbanization, (2) misuse and improper disposal of environmentally hazardous chemicals, (3) shortage of suitable repositories for toxic waste (both household and industrial), and (4) ineffective public education on waste disposal and the sensitivity of the karstic groundwater system.

Mine collapses have resulted in losses of homes, roadways, utilities, and other infrastructure. Subsidence is often exacerbated by the extensive pumping of groundwater associated with underground mining. Abandoned coal mines occur in Henrico, Chesterfield, and Goochland Counties in the Richmond coal basin.[34]

In addition to areas of karst and underground or abandoned mine sites, aging or crumbling infrastructure is another potential source of sudden sinkholes. This can occur anywhere, and magnitude and severity are difficult to predict because each case is unique and based on the site-specific conditions of the soil, groundwater, infrastructure and other factors.

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[34] For additional information, see: https://energy.virginia.gov/coal/mined-land-repurposing/Abandoned-Mine-Land.shtml&sa=D&source=docs&ust=1645377818936136&usg=AOvVaw1d-de58AG4LD6i_gLTSbss

Hazard History

Dramatic collapses of land that swallow homes or persons have happened in Virginia but are generally rare. According to the *2018 Virginia State Hazard Mitigation Plan*, there have been no Federally-declared disasters or NCEI recorded events for karst-related events in the Commonwealth. Land subsidence is very site-specific. A comprehensive long-term record of past events in Virginia is not available; however, several documented occurrences are included in **Table 5.39**.

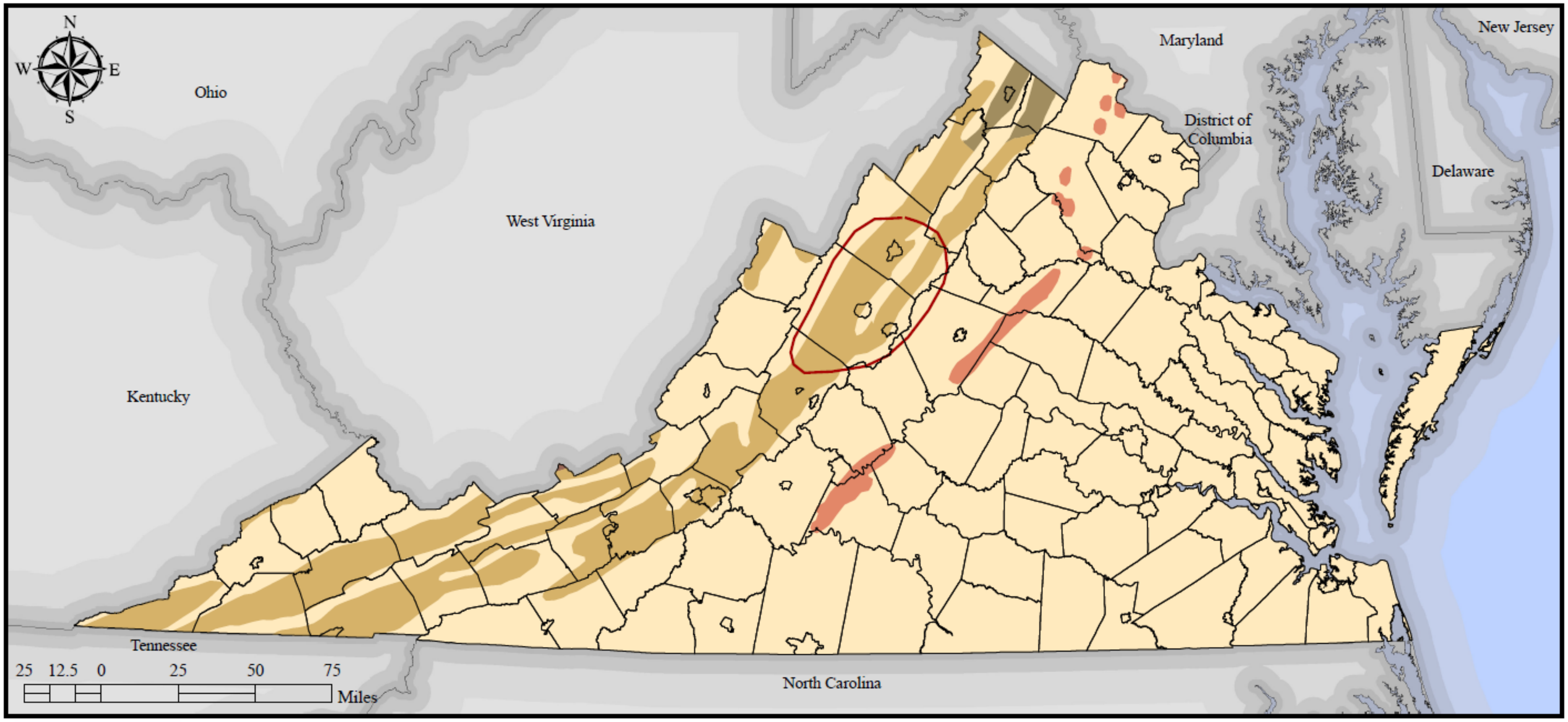
Table 5.39: Notable Sinkholes, 2010 – 2020

Date	Damages
December 2008	**Chesterfield County:** Sinkholes discovered at a home off Coalboro Road were declared an emergency by DMME and suspected to be part of the Richmond Coalfield Mine. Source: NBC12 On Your Side online.
January 4, 2010	**City of Richmond:** The ramp from I-95 North to Broad Street in downtown Richmond was closed because of a sinkhole. Reports say that what started as a pothole quickly became a gaping hole in which the ground collapsed, with about 5 feet of earth underneath it washed away. Source: WWBT-TV NBC 12
August 2010	**Chesterfield County:** Sinkholes in the Scottingham neighborhood were reported around storm drain infrastructure. Source: WWBT-TV NBC 12
March 2011	**City of Richmond:** A sinkhole closed the intersection of Grove and Stafford Avenues in Richmond. Source: *Richmond Times-Dispatch*
September 5, 2012	**Chesterfield County:** VDOT closed part of State Route 10 near Rivers Bend for an extended period because of a sinkhole. Source: *Richmond Times-Dispatch* online
April 17, 2017	**Henrico County:** A sinkhole on a baseball field near Holman Middle School in Glen Allen caused the field to be closed for repairs for a short time. Source: WRIC 8News online
~ January 2018	**Henrico County:** Sinkhole opened up and slowly increased in size, behind a new residential structure. Sinkhole had standing water after precipitation. Source: WTVR Ch 6 online.
June 2018	**Richmond:** Sinkholes reported at Hull & 19th St, 35th & East Marshall St, and North 22nd St (utility issue). Source: WRIC news online.
May 7, 2019	**Henrico County:** A deep sinkhole opened in a residential backyard, threatening the oil tank and structure. Water could be heard at the bottom of the hole. County speculated it could be an abandoned septic system. Source: WTVR CBS 6 online.
September 2019	**Henrico County:** A family was forced to move out of their condo when a sinkhole opened up and threatened to collapse the building's foundation. Source: https://independentamericancommunities.com/2019/09/17/no-word-on-what-caused-hole-beneath-henrico-county-condo/
October 21, 2019	**Henrico County:** A water main break caused a sinkhole to form that covered an entire lane of unspecified roadway. Source: WBAL TV11 online.

Vulnerability Analysis

In Virginia, the principal area affected by sinkholes is the Valley and Ridge province, an extensive karst terrain underlain by limestone and dolomite, but the narrow marble belts in the Piedmont and some shelly beds in the Coastal Plain are also pocked with sinkholes. A majority of the karst regions in Virginia follow Interstate-81, as seen in **Figure 5.43**.

Figure 5.43: Karst Areas in the Commonwealth of Virginia



Center for Geospatial Information Technology

VIRGINIA DEPARTMENT OF EMERGENCY MANAGEMENT

PROJECTION: *VA Lambert Conformal Conic North American Datum 1983*

DATA SOURCES:
USGS Engineering Aspects of Karst
VGIN Jurisdictional Boundaries
ESRI State Boundaries

LEGEND:
Historical Subsidence
Karst Type (Long)
In moderately to steeply dipping beds of carbonate rock
In gently dipping to flat- lying beds of carbonate rock
Karst Type (Short)
In metamorphosed limestone, dolostone, and marble
In moderately to steeply dipping beds of carbonate rock

HAZARD IDENTIFICATION:
Long Karst Type: Fissures, tubes, and caves over 1,000 ft long; 50 ft to over 250 ft vertical extent
Short Karst Type: Fissures, tubes and caves generally less than 1,000 ft long; 50 ft or less vertical extent

Historical subsidence represents areas of extensive sinkhole development.

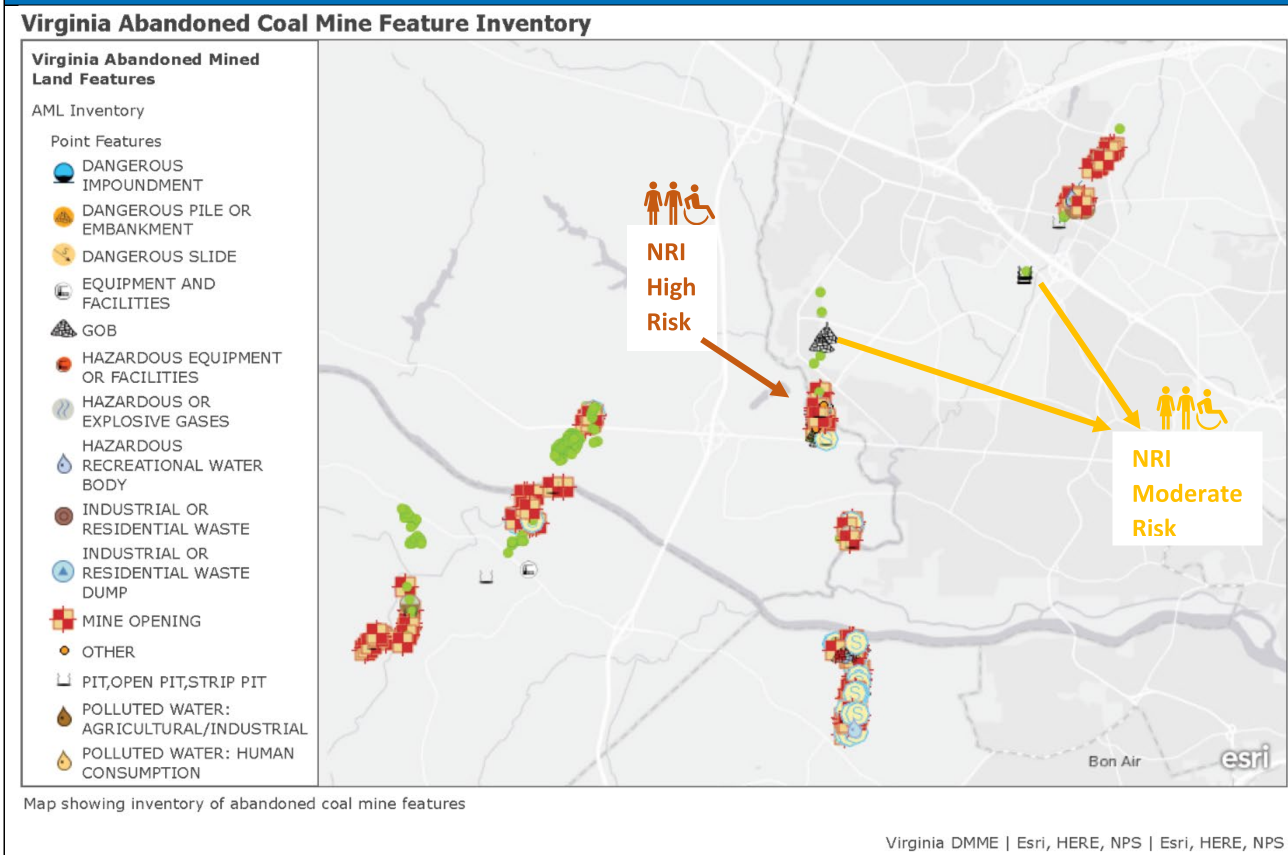
DISCLAIMER: Majority of available hazard data is intended to be used at national or regional scales. The purpose of the data sets are to give general indication of areas that may be susceptible to hazards. In order to identify potential risk in the Commonwealth available data has been used beyond the original intent.

Commonwealth of Virginia Hazard Mitigation Plan 2013

Source: 2013 Virginia State Hazard Mitigation Plan

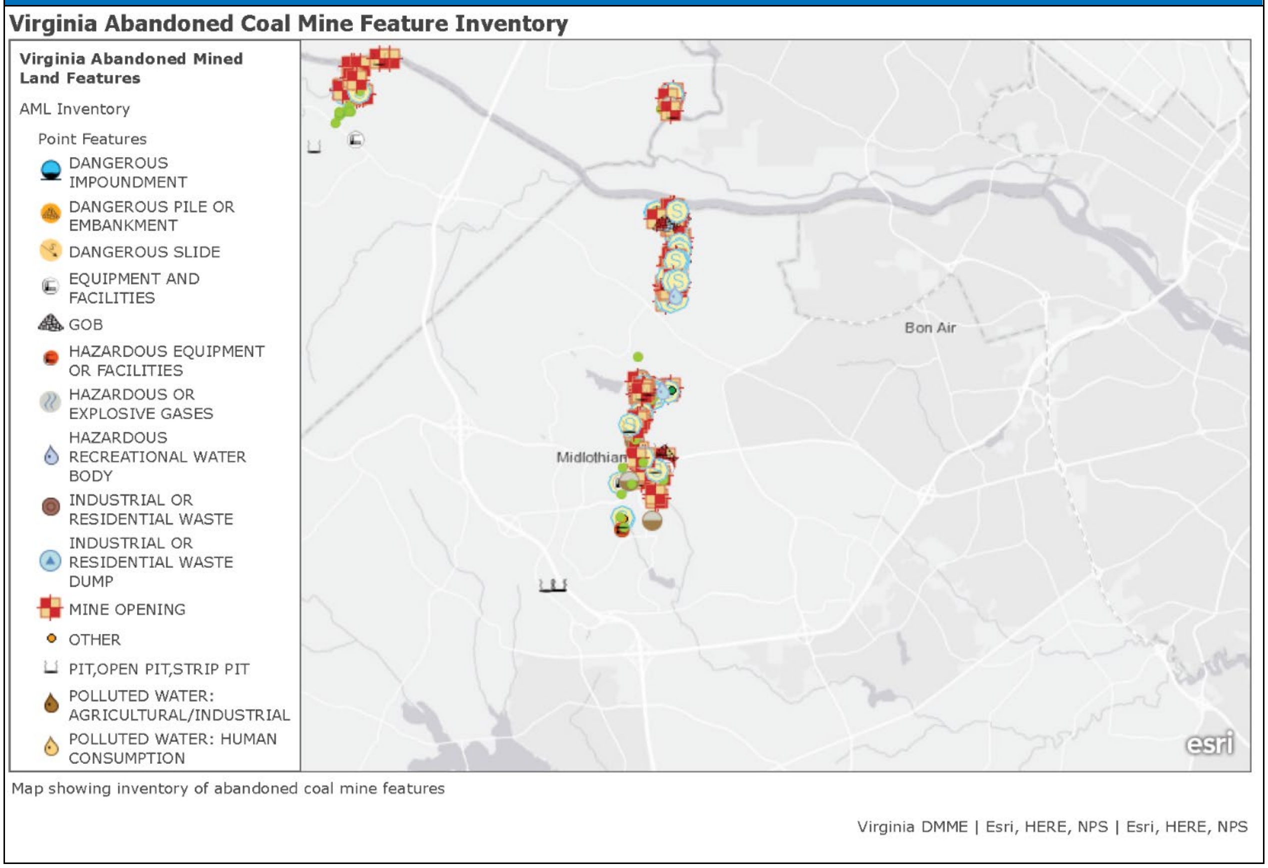
Abandoned coal mines are present in the Richmond-Crater region and, as stated previously, areas over underground mine workings are susceptible to sinkhole formation. Maps of abandoned coal mine features in the region are shown in **Figures 5.44a through 5.44c,** courtesy of the Virginia Department of Energy. For site specific information, go to: https://vadmme.maps.arcgis.com/home/index.html.

Figure 5.44a: Abandoned Coal Mine Features, James River Northwest of Richmond



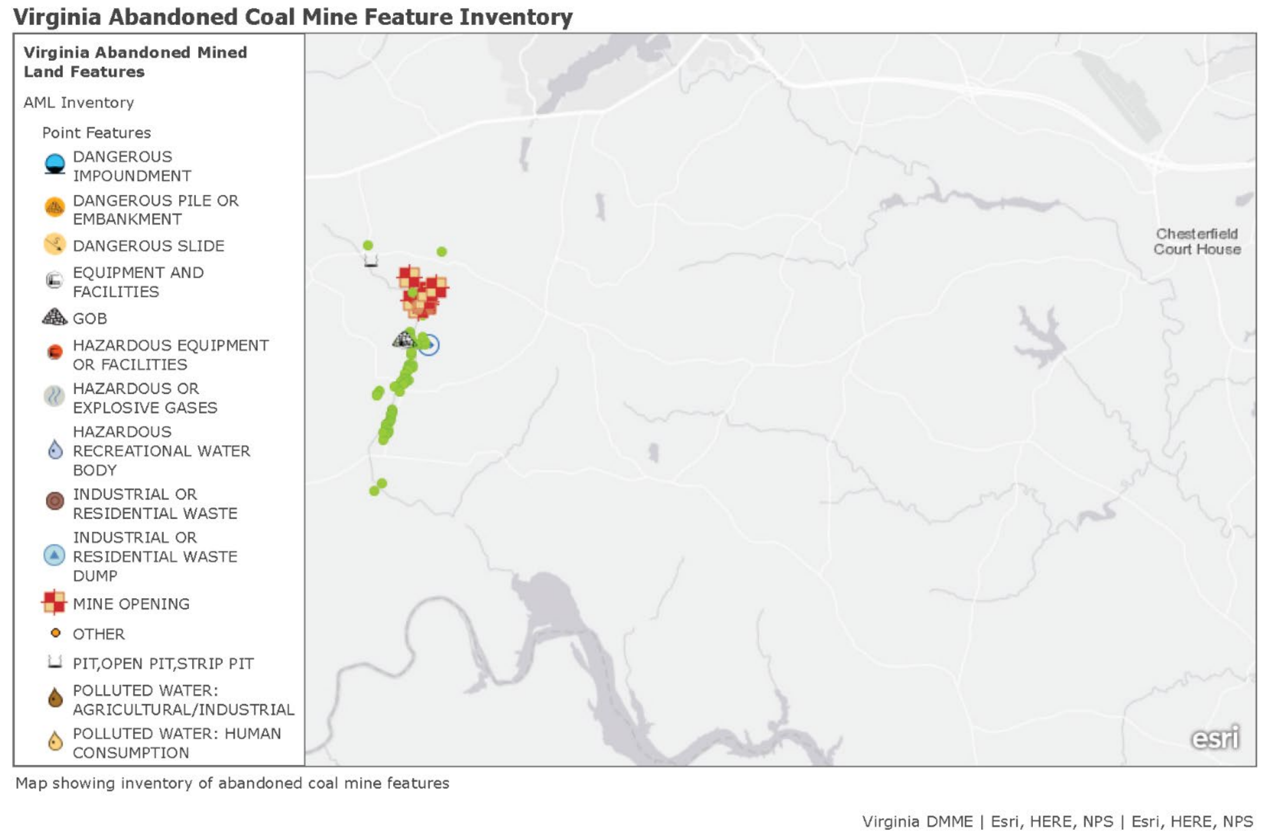
Source: Virginia Department of Energy, 2021

Figure 5.44b: Abandoned Coal Mine Features, James River, West of Richmond



Source: Virginia Department of Energy, 2021

Figure 5.44c: Abandoned Coal Mine Features, Chesterfield County



Source: Virginia Department of Energy, 2021

Existing soil types in the region are not generally conducive to creating natural sinkholes. There are no known sources of data for determining relative sinkhole probability within the region, except for the maps in Figures 5.44a through 5.44c above. Based on previous instances, likely the result of aging infrastructure, and the fact that abandoned mines exist, there is at least a low probability of future sinkhole occurrences in the region.

Limited data prevent a detailed vulnerability analysis at the jurisdictional level. Those jurisdictions with underground infrastructure in need of replacement or repair and those sitting on top of abandoned mine locations are at an elevated risk from sinkholes as compared to those without such risk factors. Potential damage and loss due to sinkholes or land subsidence is nearly impossible to assess because the nature of the damage is site- and event-specific.

Social Vulnerability

Locations of abandoned coal mine features in the study area were compared to the NRI baseline social vulnerability map to determine if any areas of moderate or high social vulnerability coincided with areas at risk of sinkholes. Figure 5.44a above shows the only areas identified as having elevated vulnerability. The areas with moderate and high social vulnerability that correlate with mine features are all in or near retirement, independent or assisted living facilities in Henrico County: Hermitage at Cedarfield, Gayton Terrace Assisted Living, Lynmoore, and Lakewood Manor Independent Living.

Future Vulnerability, Land Use and Climate Change

As noted in the previous section, sinkholes have occurred in the Richmond-Crater region, often following periods of heavy precipitation. The phenomena are generally limited in geographic scope and/or damage extent.

Climate change has the potential to worsen the risk associated with sinkholes in the study area. Precipitation patterns are expected to become more intense, prolonged and frequent as a result of a warming climate. More severe precipitation events may accelerate the relevant factors in sinkhole formation for the region (*e.g.,* dissolution of overlying sediments or rock, differential subsidence, vulnerability of aging infrastructure), possibly leading to more frequent and damaging sinkholes.

Based on the hazard's history in the region, mass evacuations caused by sinkholes are not expected.

5.16 Radon Exposure

Hazard Profile

Radon is a colorless, odorless naturally occurring gas that forms by the radioactive decay of uranium, thorium, or radium, found in certain types of rocks, soil, and groundwater. Radon is found naturally in the atmosphere in trace amounts, where it disperses rapidly and is generally not a health issue. Radon exposure becomes dangerous in confined areas, where the gas can accumulate, and the inert gas can be inhaled into the lungs where it adheres to lung tissue.

Under the earth's surface, radon may be transported as a soil gas or dissolved in ground water. It can enter a building via cracks in solid floors, construction joints, cracks in walls, gaps in suspended floors, gaps around service pipes and drains, cavities inside walls or through the water supply. Well water used for bathing or washing can potentially carry radon, especially if faucets are aerated. Due to less ventilation, radon concentrations in buildings are typically higher in the winter. Any home, school or workplace may have a radon problem, whether it is new or old, well-sealed or drafty, or with or without a basement. The EPA estimates that nearly one out of every 15 homes in the U.S. has elevated annual average levels of indoor radon,[35] and that nearly one in five schoolrooms has a short-term radon level above the actionable level.[36]

The concentration of radon in buildings is highly variable and is based on the underlying rocks or sediments, weather and construction methods. The amount of radon emitted by a particular soil is controlled by the underlying rock type, the concentration of uranium,

[35] *US EPA's Map of Radon Zones, Virginia.* Radon Division, Office of Radiation and Indoor Air, September 1993.
[36] US EPA Radon in Schools, accessed 4/23/21 online at: https://www.epa.gov/radon/radon-schools

thorium, or radium in the rock or sediment, and the permeability of the rock, sediment and soil. [37]

Magnitude or Severity

The EPA recommends taking action to reduce radon in homes, schools or other buildings that have a radon level at or above 4 picocuries per liter (pCi/L) of air (a "picocurie" is a common unit for measuring the amount of radioactivity). That level of risk is more than 10 times the average outdoor level, more than receiving the equivalent radiation of 200 chest x-rays per year, and almost five times the average non-smoker's risk. A radon level of 40 pCi/L is more than the risk of a 2 pack-a-day smoker.

The EPA indicates that radon is estimated to cause about 21,000 lung cancer deaths per year in the United States.[38] When a person breathes in radon, radioactive particles from radon gas can get trapped in the lungs, emitting radiation. Over time, these radioactive particles increase the risk of lung cancer. People who smoke and are exposed to radon are at a greater risk of developing lung cancer. Damage may be undetected for years before health problems appear.

The chances of getting lung cancer from radon depend primarily on:

- How much radon is in one's home–the location where you spend most of your time (e.g., the main living and sleeping areas);
- The amount of time spent in the home;
- Whether one is a smoker or has ever smoked;
- Whether one burns wood, coal, or other substances that add particles to the indoor air; and
- Combinations of these factors that multiply the impacts.

Lung cancer may start with a nagging cough, shortness of breath or wheezing. Other symptoms such as coughing up blood, chest pain or weight loss may also present. There are no medical tests to test the body for radon exposure, but doctors can check for signs of lung cancer and homes can be easily tested for radon levels.

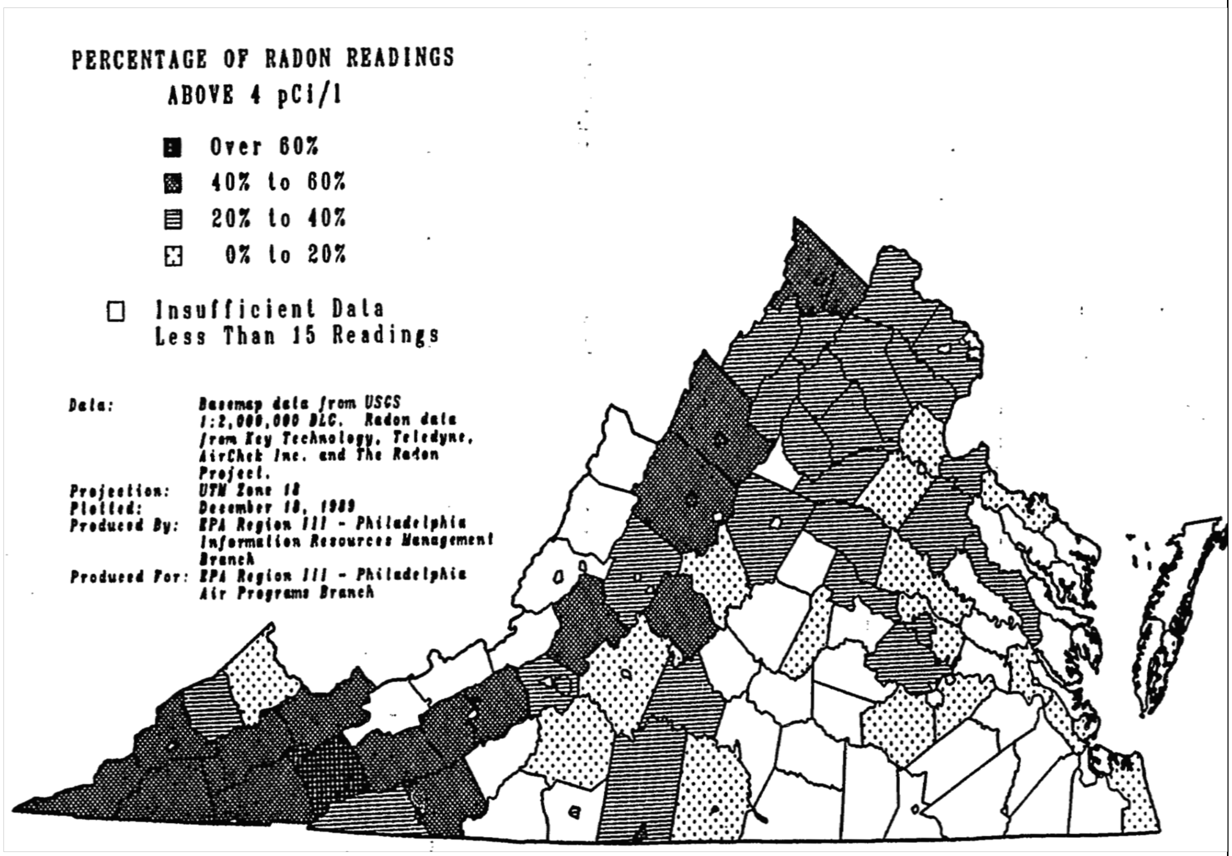
Hazard History

Radon exposure from ground sources happens over a long period of time, often remaining undetected, thus historical "events" are rarely quantifiable. Section 307 and 209 of the 1988 Indoor Radon Abatement Act directed the EPA to identify areas of the United States that have the potential to produce elevated levels of radon. As part of this study, two data sources were analyzed in Virginia: 1) indoor radon data from 1,156 random homes were sampled in the winter of 1991-1992 (results shown in **Table 5.40**); and 2) non-random commercial data compiled by EPA Region 3 were examined as shown in **Figure 5.45**. Additional data from 1990-2017 from a private vendor, Air Chek, are also included in Table

[37] Born, Rebecca Skye. *Radon in Yorktown Formation Sediments and Petersburg Granite, Eastern Virginia.* Undergraduate Thesis, College of William & Mary, April 1994.
[38] US EPA, *A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family from Radon,* EPA 402/K-12/002, 2016.

5.40 for jurisdictions with more than 50 test results. Alpha-Energy Laboratories non-random data from the region since 2001 are also included in Table 5.40.

Figure 5.45: Vendor Screening, Indoor Radon Data for Virginia



Source: US EPA's Map of Radon Zones, Virginia. Radon Division, Office of Radiation and Indoor Air, September 1993.

Table 5.40: Screening Indoor Radon Data											
Jurisdiction	**1991-1992, Residential**				**1990-2017, Air Chek**			**Alpha Energy Laboratories January 2001 to June 2020**			
	Number of Tests	**Mean (pCi/L)**	**% >4 pCi/L**	**%>20 pCi/L**	**Number of Tests**	**Mean (pCi/L)**	**% ≥4 pCi/L**	**Number of Tests**	**Mean (pCi/L)**	**% >4 pCi/L**	**%>10 pCi/L**
Charles City County	1	1.1	0	0				6	1.08	0	0
Chesterfield County	59	3.1	17	3	1,319	3.5	26	2089	4.13	18.0	8.8
City of Colonial Heights	5	2.4	20	0				33	3.29	21.2	6.1
Dinwiddie County	6	13.9	17	17				38	4.07	21.1	15.8
City of Emporia	2	0.5	0	0				None reported	n/a	n/a	n/a
Goochland County	3	3.1	33	0				285	3.51	23.2	6.0
Greensville County	2	0.5	0	0				16	1.60	6.3	0
Hanover County	13	0.9	0	0	195	4.9	19	327	2.37	17.1	1.2
Henrico County	30	1.7	7	0				1544	3.23	15.2	5.7
City of Hopewell	5	0.6	0	0				29	3.01	13.8	6.9

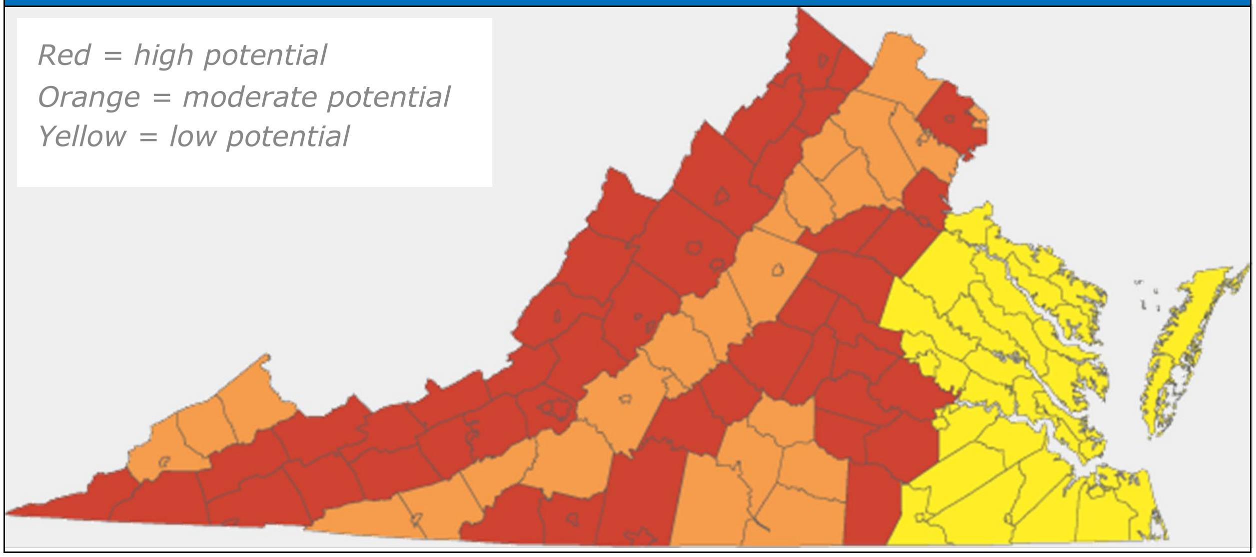
New Kent County	6	2.1	17	0				44	3.62	13.6	9.1
City of Petersburg	5	1.1	0	0				61	1.99	6.1	1.6
Powhatan County	3	0.4	0	0				162	2.98	17.2	4.3
Prince George County	3	0.3	0	0				29	2.61	17.2	3.5
City of Richmond	73	1.4	7	0	611	2.5	18	800	3.28	20.4	5.4
Surry County	1	0.6	0	0				5	1.00	0	0
Sussex County	2	0.7	0	0				3	1.00	0	0
Source: US EPA's Map of Radon Zones, Virginia. Radon Division, Office of Radiation and Indoor Air, September 1993.					*Source: Radon in Virginia Real Estate Transactions, Virginia Department of Health, ~2017*			*Source: Non-random test results by private business.* https://getresults.doctorhomeair.com/fmi/webd/Alpha_ResultsInArea			

Vulnerability Analysis

The types and distribution of lithologic units and other geologic features in an assessment area are of primary importance in determining radon potential. Rock types that are most likely to cause indoor radon problems include carbonaceous black shales, glauconite bearing sandstones, certain kinds of fluvial sandstones and fluvial sediments, phosphorites, chalk, karst-producing carbonate rocks, certain kinds of glacial deposits, bauxite, uranium-rich granitic rocks, metamorphic rocks of granitic composition, silica-rich volcanic rocks, many sheared or faulted rocks, some coals, and certain kinds of contact metamorphosed rocks. Rock types least likely to cause radon problems include marine quartz sands, non carbonaceous shales and siltstones, certain kinds of clays, silica-poor metamorphic and igneous rocks, and basalts. Uranium and radium are commonly found in heavy minerals, iron-oxide coatings on rock and soil grains, and organic materials in soils and sediments. Less common are uranium associated with phosphate and carbonate complexes in rocks and soils, and uranium minerals.

Figure 5.46 provides the EPA's map of Radon Zones for Virginia, released in 1993. The map is based on an assessment of five factors that are known to be important indicators of radon potential: indoor radon measurements, geology, aerial radioactivity, soil parameters and foundation types.

Figure 5.46: EPA Map of Radon Zones, Virginia



Source: U.S. EPA 1993 Map of Radon Zones in Virginia, modified by Virginia Department of Energy

The Coastal Plain of Virginia, including Hanover, Henrico, Charles City, New Kent, Prince George, Surry, Sussex, Greensville Counties and the Cities of Emporia, Richmond, Colonial Heights and Petersburg, are ranked low in geologic radon potential. In general, the upper Tertiary to Quaternary-aged sediments of the Coastal Plain have low radon potential. However, recent studies of radon potential in the sediments and marine fossils of the Yorktown Formation, a 4- to 5-million-year-old widespread geological unit in the Coastal Plain, could be a source for elevated levels of indoor radon. The Yorktown Formation is a marine unit, meaning the sediments that it is made of were once deposited underwater when sea-level was much higher than it is today. As a marine unit, it holds whale bones that are mixed into the sand/clays. The bones that accumulate in the Yorktown Formation are perhaps able to enrich themselves under certain geochemical conditions with heavy metals that might be in the water. Since the Yorktown Formation is so widespread and close to the earth's surface throughout the Virginia Coastal Plain, it is the only geologic unit that has been investigated thus far for radon potential in the Coastal Plain. These hypotheses are part of ongoing research at the College of William and Mary.[39] Future updates to this plan should include results of such research, particularly if the findings point to changes in the relative vulnerability presented above. The westernmost edge of the Yorktown Formation intersects the study area as shown in **Figure 5.47** below.

The rest of the study area lies within the Piedmont, including Goochland, Powhatan, Chesterfield, and Dinwiddie Counties and the City of Hopewell. Here the Goochland

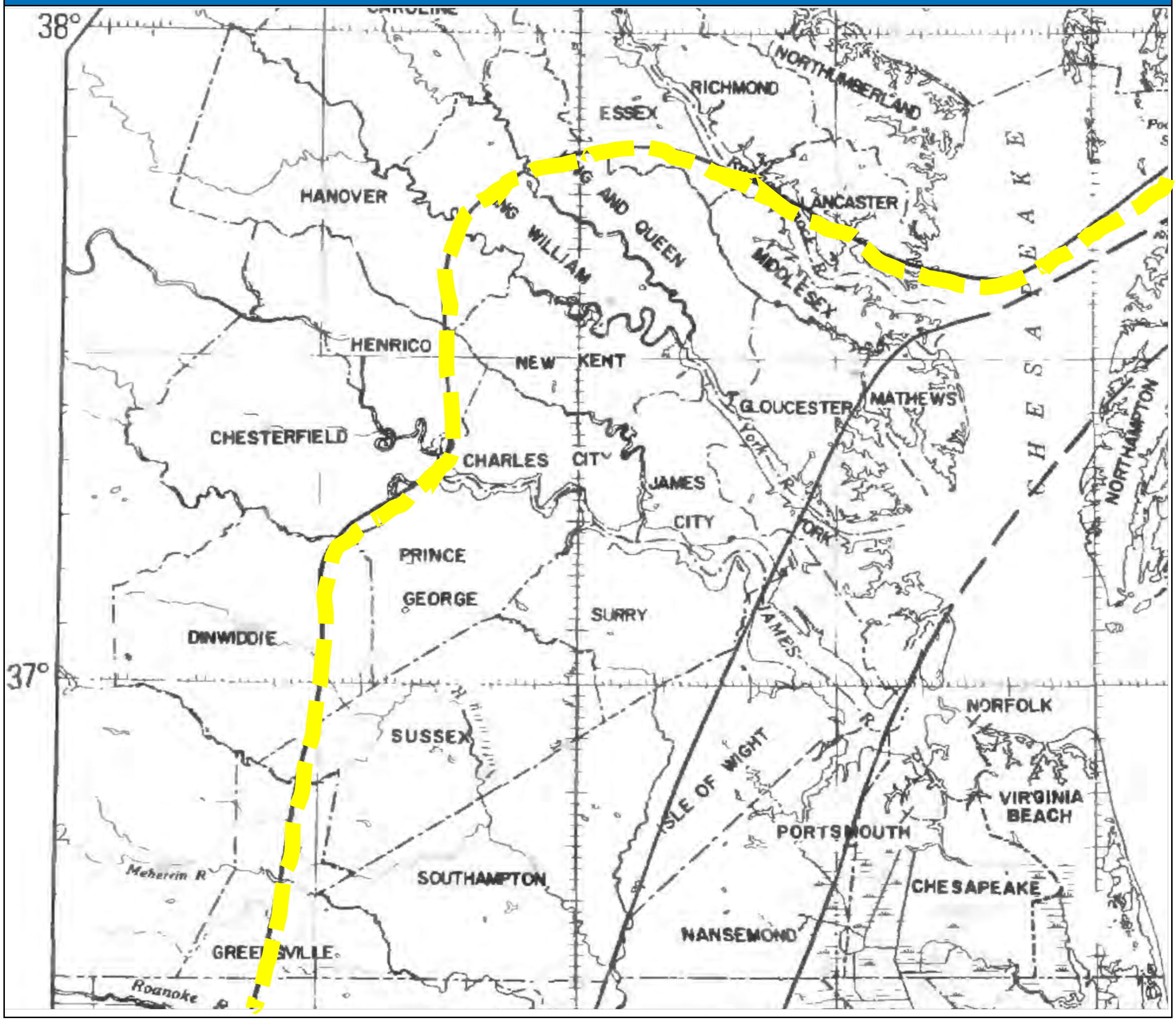
[39] Email exchanges with Anne Witt, Geohazards Specialist, Virginia Department of Mines, Minerals and Energy, spring 2021.

terrane and Inner Piedmont have been ranked high in radon potential, with numerous well-documented uranium and radon occurrences.

In 1994, an undergraduate student at the College of William & Mary studied radon emittance from the Petersburg Granite, a large body of intrusive igneous rock, extending from Hanover County to the southern border of Dinwiddie County[40]. The Petersburg Granite was selected for her study as a possible source of radon because the mineral zircon was found in the granite, which can have uranium and thorium incorporated into its crystal structure. Outcrops of the granite in Pocahontas State Park were studied using alpha-track radon detectors to determine concentrations of the gas being emitted as a decay product. Radon concentrations in a series of eight wells, tested over four time periods each, indicated radon concentrations in the ground ranging from 140 pCi/L to 3,536 pCi/L. The student concluded that these concentrations are high, and that homes built on the Petersburg Granite should be tested for radon. The general location of the Petersburg Granite, or Petersburg batholith, is shown in stippled red in **Figure 5.48**.

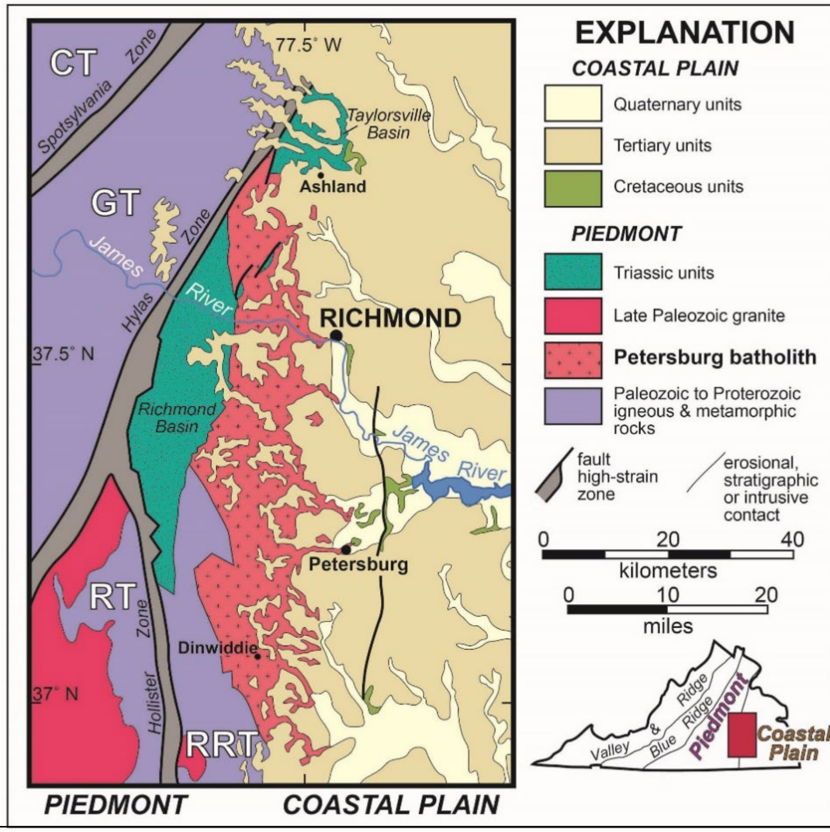
[40] Born, Rebecca Skye. *Radon in Yorktown Formation Sediments and Petersburg Granite, Eastern Virginia.* Undergraduate Thesis, College of William & Mary, April 1994.

Figure 5.47: Westernmost Extent of the Yorktown Formation (yellow line)



Source: Ward, Lauck W. and Blake W. Blackwelder. Stratigraphic Revision of Upper Miocene and Lower Pliocene Beds of the Chesapeake Group, Middle Atlantic Coastal Plain. Geological Survey Bulletin 1482-D, U.S. Department of the Interior, 1980.

Figure 5.48: Generalized Geologic Map of the Petersburg Batholith



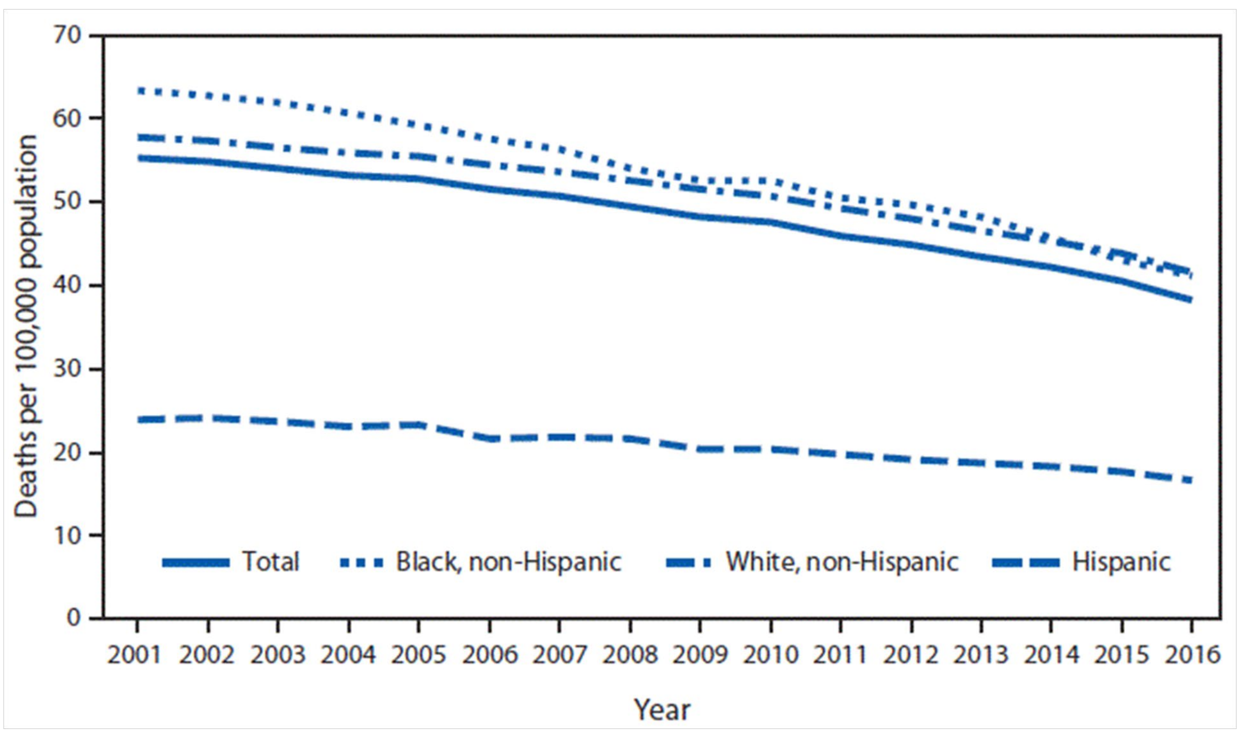
Source: Online blog https://wmblogs.wm.edu/cmbail/power-washing-paleozoic-petersburg-pluton/ and as modified from Owens, B.E., Carter, M., and Bailey, C.M., 2017, Geology of the Petersburg batholith, eastern Piedmont, Virginia, in Bailey, C.M., and Jaye, S., eds., From the Blue Ridge to the Beach: Geological Field Excursions across Virginia: Geological Society of America Field Guide 47, p. 123–133.

Radon testing in Virginia has been sporadic and not necessarily reported to any single data repository. Thus, the only way to know if any structure or group of structures has a radon problem is to test. Testing of residential structures is easy and inexpensive. Low-cost test kits are available through the mail and at home improvement stores. Qualified testers can also do long-term residential testing and set up systems for testing larger non-residential buildings. Mitigation or treatment of structures with high radon concentrations is also possible, relatively inexpensive and can be very effective if done properly. Testing is most important for structures in the red or orange zones indicated in Figure 5.46 above, and especially important for structures in which inhabitants spend their time in parts of the structure below ground or in contact with the ground. Future updates to this plan may include identification of specific structure types, for example structures with basements, in the highest radon potential counties to further define vulnerability, especially if the EPA's 1993 map of radon zones is updated based on more testing or other new scientific information.

Social Vulnerability

Unlike many other hazards in this plan, structures are not physically damaged by radon exposure; instead, human lives are directly at risk. CDC QuickStats show that death rates from lung cancer declined between 2001 and 2016, but also indicate a disparity based on race/ethnicity (see **Figure 5.49**). During this period, the lung cancer death rates for the total population (deaths per 100,000 population) declined from 55.3 to 38.3, as well as for each racial/ethnic group shown. The death rate for the non-Hispanic Black population decreased from 63.3 to 41.2, for the non-Hispanic white population from 57.7 to 41.5, and for the Hispanic population from 23.9 to 16.6. Throughout this period, the Hispanic population had the lowest death rate.

Figure 5.49: Age-Adjusted Death Rates from Lung Cancer, by Race/Ethnicity, United States, 2001-2016

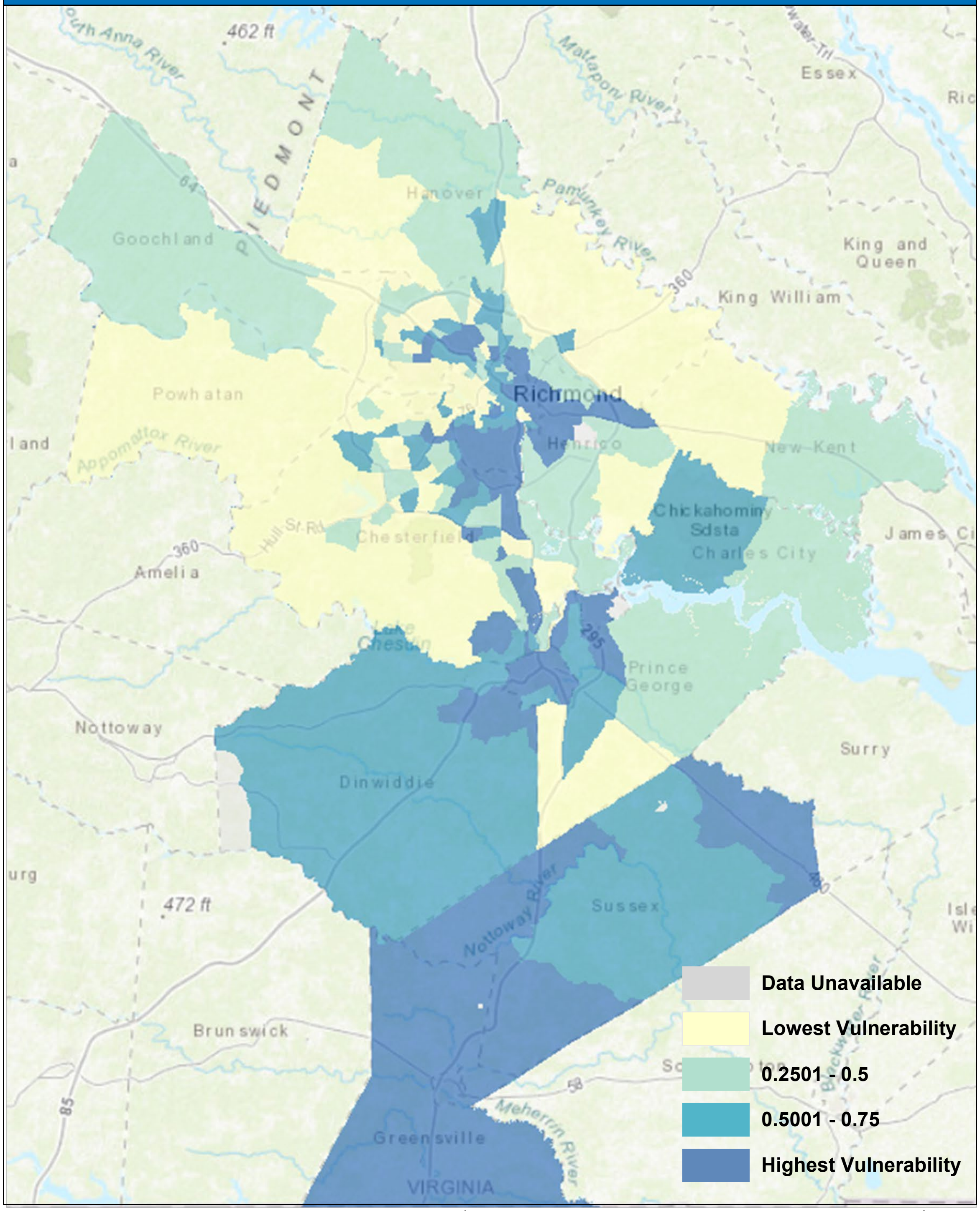


** Deaths per 100,000 population age-adjusted to the 2000 U.S. standard population.*
Source: Centers for Disease Control and Prevention, accessed online 4/22/22 at:
https://www.cdc.gov/mmwr/volumes/67/wr/mm6730a8.htm

The Centers for Disease Control and Prevention Agency for Toxic Substances and Disease Registry (ATSDR) created a Social Vulnerability Index geared toward preparing for and responding to exposure to dangerous chemicals (and other natural hazards, as well). This index is better suited to examining the social vulnerability related to radon, although many of the inputs are the same. Overall vulnerability for this index is based on: socioeconomic status (below poverty, unemployed, income, no high school diploma); household composition and disability (aged 65 or older, aged 17 or younger, civilian with disability, single-parent households); minority status and language; and housing type and transportation (multi-unit structures, mobile homes, crowding, no vehicle, group quarters). **Figure 5.50** provides the CDC ATSDR 2018 data for the study region. Perhaps once more information is collected regarding the underlying geology of the region and the relationship to radon, this map can be further refined in the future to more accurately isolate the social vulnerability to radon. Structures with basements could also be identified to further enhance the analysis.

The CDC ATSDR map below shows the highest social vulnerability is in the southernmost region of the study area, north into Petersburg and Colonial Heights, and in the central and eastern parts of Richmond.

Figure 5.50: CDC ATSDR Social Vulnerability Index



Source: Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. CDC/ATSDR Social Vulnerability Index 2018 Database State.

Note: The Town of Surry has medium/high social vulnerability through the CDC index.

Future Vulnerability, Land Use and Climate Change

According to Memorial Sloan Kettering Cancer Center, major scientific organizations believe that radon contributes to approximately 12% of lung cancers annually in the United States. It is the second leading cause of lung cancer.[41] With 5,820 new cases of lung and bronchus cancer expected in Virginia in 2021[42], this translates to approximately 700 of those new cases being caused by radon exposure.

Radon levels are localized down to the household level and additional testing is needed to verify EPA zones for the study area. There are no federal or state laws that require radon testing prior to a real estate transaction, but some contracts do include radon testing or mitigation contingency clauses at the buyer's request.

Virginia Code at Section 15.2-2280 currently gives all red zone (Zone 1) counties and cities the option of requiring passive radon resistant construction features, but as of 2021 none of the study area Zone 1 communities had adopted the ordinance into their building codes.

In 1993, the Virginia General Assembly passed legislation that requires all schools in the Commonwealth to be tested for radon after July 1, 1994 and includes any new school buildings and additions built after that date. Each school is required to maintain files of their radon test results.

In the early 1990s the Virginia Department of Education purchased long-term radon test kits that were used to test all Virginia public school K-12 classrooms that were in contact with the ground at that time. Long term tests are generally more accurate than short term tests because they sample anywhere from 90 to 365 days. Short term tests usually sample for only 2 to 7 days. Since radon levels can fluctuate over time, the longer the test duration, the more accurate the results will be. The EPA school testing protocol recommends testing during the heating season which runs roughly from late October through the end of March. A VDH review of the original testing data from the long-term tests done at that time indicated that some of these test results were not valid or usable due to:

- School classrooms not being identified on the test report;
- Testing periods that were outside of the preferred heating season; and
- Improper testing of unoccupied areas such as boiler and storage rooms.

In general, radon test results for the vast majority of school classrooms in Virginia are below the EPA action level of 4.0 pCi/L for indoor air. For the few classrooms that have shown elevated radon levels, the problem was usually solved by making adjustments to the school's HVAC system. However, in some cases the HVAC adjustments did not work, and a radon mitigation system was installed to reduce the radon to acceptable

[41] Memorial Sloan Kettering Cancer Center https://www.mskcc.org/news/5-myths-about-radon-and-lung, accessed online 4/22/21

[42] American Cancer Society, Cancer Statistics Center accessed online 4/22/21 at: https://cancerstatisticscenter.cancer.org/#!/state/Virginia

levels. Future updates to this plan may include evaluation of data for study area schools, as available.

With regard to future climate change, changes in the environment and human behavior may alter the risks associated with radon for individual buildings. According to the EPA, the primary factors that influence radon entry into buildings include: 1) radon content of the soil; 2) pressure differential between the interior of a structure and the soil; 3) air exchange rate for the building; 4) moisture content surrounding the structure; and 5) presence and size of entry pathways. Climate change can affect these same factors and, therefore, may cause direct or indirect changes in indoor air quality within a structure. In addition, certain changing human behavioral factors driven by climate change may further impact air quality. Examples of how climate change may impact indoor air quality include:

1. Increased Air Conditioning and Decreased Fan Usage: air conditioning used as a result of rising temperatures contributes to "closed house conditions" and reduced stratification of radon between floors;

2. Activity Patterns and Spatial Radon Variation: rising outdoor temperatures may result in increased use of basements where radon concentrations are generally higher;

3. Weatherization and Energy Efficiency: although undetermined, tightening structures for energy efficiency may increase radon concentrations for structures with indoor radon sources;

4. Weather-Related Influences: increased wind can change pressure differentials between structure levels and the outside, and increased precipitation rates or totals may change hydrologic conditions causing a rise in the water table and force vapors from the vadose zone, or unsaturated zone, into a less dense media, such as a basement.

5. High Density Housing: concrete construction used in high density housing (constructed to reduce greenhouse emissions) may be an increasing source of elevated radon exposure for some occupants. 43

Radon exposure is not expected to be associated with any types of mass evacuation.

5.17 Infectious Diseases

Hazard Profile

Both influenza pandemics and communicable diseases can affect large numbers of people in a short period of time. An influenza pandemic is an epidemic of an influenza virus that spreads on a worldwide scale and infects a large proportion of the human

[43] Field, William R., Contractor Report prepared for U.S. EPA. *Climate Change and Indoor Air Quality*, June 10, 2010.

population. In contrast to the regular seasonal epidemics of influenza, these pandemics occur irregularly. Pandemics can cause high levels of mortality.

Influenza pandemics occur when a new strain of influenza virus is transmitted to humans from another animal species. These novel strains are unaffected by any immunity people may have to older strains of human influenza and can therefore spread extremely rapidly and infect very large numbers of people.

The CDC uses a Pandemic Intervals Framework (PIF) to describe the progression of an influenza pandemic (**Table 5.41**). This framework is used to guide influenza pandemic planning and provides recommendations for risk assessment, decision-making, and action in the United States. These intervals provide a common method to describe pandemic activity which can inform public health actions. The duration of each pandemic interval might vary depending on the characteristics of the virus and the public health response.

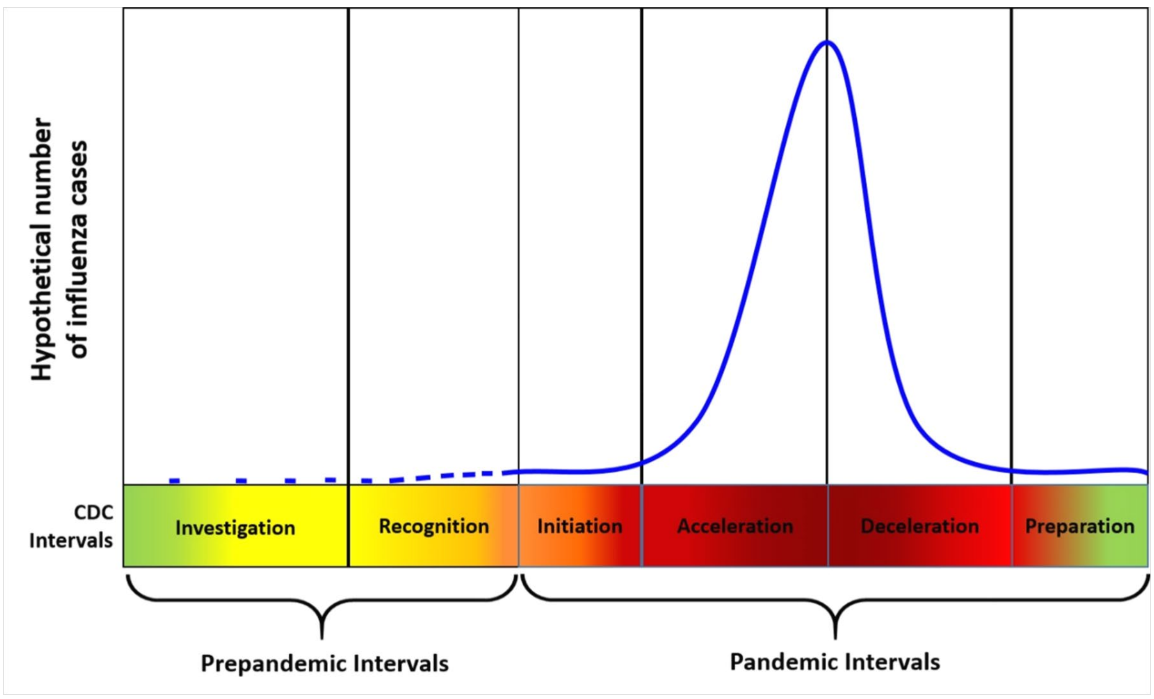
Table 5.41: CDC Pandemic Intervals Framework

Interval	Description
1) Investigation of cases of novel influenza A virus infection in humans	When novel influenza A viruses are identified in people, public health actions focus on targeted monitoring and investigation. This can trigger a risk assessment of that virus
2) Recognition of increased potential for ongoing transmission of a novel influenza A virus	When increasing numbers of human cases of novel influenza A illness are identified and the virus has the potential to spread from person-to-person, public health actions focus on control of the outbreak, including treatment of sick persons.
3) Initiation of a pandemic wave	A pandemic occurs when people are easily infected with a novel influenza A virus that has the ability to spread in a sustained manner from person-to-person.
4) Acceleration of a pandemic wave	The acceleration (or "speeding up") is the upward epidemiological curve as the new virus infects susceptible people. Public health actions at this time may focus on the use of appropriate non-pharmaceutical interventions in the community (e.g., school and child-care facility closures, social distancing), as well the use of medications (e.g., antivirals) and vaccines, if available. These actions combined can reduce the spread of the disease and prevent illness or death.
5) Deceleration of a pandemic wave	The deceleration (or "slowing down") happens when pandemic influenza cases consistently decrease in the United States. Public health actions include continued vaccination, monitoring of pandemic influenza A virus circulation and illness, and reducing the use of non-pharmaceutical interventions in the community (e.g., school closures).
6) Preparation for future pandemic waves	When pandemic influenza has subsided, public health actions include continued monitoring of pandemic influenza A virus activity and preparing for potential additional waves of infection. It is possible that a 2nd pandemic wave could have higher severity than the initial wave. An influenza pandemic is declared ended when enough data shows that the influenza virus, worldwide, is similar to a seasonal influenza virus in how it spreads and the severity of the illness it can cause.

Source: https://www.cdc.gov/flu/pandemic-resources/national-strategy/intervals-framework.html

Figure 5.51 provides a graphical illustration of the intervals for a hypothetical virus pandemic.

Figure 5.51: Preparedness and response framework for novel influenza A virus pandemics: CDC intervals



Source: CDC, online at https://www.cdc.gov/flu/pandemic-resources/national-strategy/intervals-framework.html

A pandemic is characterized by human-to-human spread of the virus over a very wide area, crossing international boundaries and affecting a large number of people. While many countries may not be affected early on in a pandemic, the CDC collaborates with the World Health Organization (WHO) and other international agencies to monitor and assess influenza viruses and illness. These organizations send strong signals to the public when research indicates a pandemic is imminent in their country, region, state or locality, and that the time to finalize the communication and implementation of planned mitigation measures is short.

Previous pandemics have been characterized by waves of activity spread over months and separated by oceans. Once the level of disease activity drops, a critical communications task is balancing this information with the possibility of another wave. Pandemic waves can be separated by months and an immediate "at-ease" signal may be premature. Pandemic waves can also be specific to a country or a subregion or state within a country, making local messaging a critical component in controlling the spread of the virus.

A modern global economy that is focused on international trade and shipping, business and leisure travel to other countries can help spread an early-phase pandemic across the globe far more quickly than in past centuries. While quarantines and travel restrictions may help restrict the spread in later intervals, the damage wrought by virus carriers early on is irreversible.

Communicable diseases are illnesses spread by bacteria or viruses that are spread from one person to another through contact with bodily fluids, blood products, contaminated surfaces, insect bites or through the air. Examples include HIV, hepatitis A, B, and C, Salmonella, measles, and blood-borne illnesses. Mitigation of spread may include testing, vaccination, and educating the public on methods of transmission.

Hazard History

Flu pandemics have occurred throughout history. There have been about three influenza pandemics in each century for the last 300 years. Since 1918, five significant events stand out, each with different characteristics.

1918 – 1919: Spanish Flu

Illness from the 1918 flu pandemic, also known as the Spanish flu, came on quickly. Some people felt fine in the morning but died by nightfall. People who caught the Spanish Flu but did not die from it often died from complications caused by bacteria, such as pneumonia. Approximately 20% to 40% of the worldwide population became ill, and an estimated 50 million people died, including early 675,000 people in the United States. Unlike earlier pandemics and seasonal flu outbreaks, the 1918 pandemic flu saw high mortality rates among healthy adults. In fact, the illness and mortality rates were highest among adults 20 to 50 years old. The reasons for this remain unknown.

1957 – 1958

In February 1957, a new flu virus was identified in the Far East. Immunity to this strain was rare in people younger than 65. A pandemic was predicted. To prepare, health officials closely monitored flu outbreaks. Vaccine production began in late May 1957 and was available in limited supply by August 1957.

In the summer of 1957, the virus came to the United States quietly with a series of small outbreaks. When children returned to school in the fall, they spread the disease in classrooms and brought it home to their families. Infection rates peaked among school children, young adults, and pregnant women in October 1957. By December 1957, the worst seemed to be over. However, a dangerous "second wave" of illness came in January and February of 1958.

Most influenza–and pneumonia–related deaths occurred between September 1957 and March 1958. Although the 1957 pandemic was not as devastating as the 1918 pandemic, about 69,800 people in the United States died. The elderly had the highest rates of death.

1968 – 1969: Hong Kong Flu Virus

In early 1968, a new flu virus was detected in Hong Kong. The first cases in the United States were detected as early as September 1968. Illness was not widespread in the United States until December 1968. Deaths from this virus peaked in December 1968 and January 1969. Those over the age of 65 were most likely to die. The number of deaths between September 1968 and March 1969 was 33,800, making it the mildest flu pandemic in the 20th century. The same virus returned in 1970 and 1972.

Several reasons may explain why fewer people in the United States died as a result of this virus:

The Hong Kong flu virus was similar in some ways to the 1957 pandemic flu virus. This might have provided some immunity against the Hong Kong flu virus.

The Hong Kong flu virus hit in December of 1968, when school children were on vacation. This caused a decline in flu cases because children were not at school to infect one another. This also prevented it from spreading into their homes.

Improved medical care and antibiotics that are more effective for secondary bacterial infections were available for those who became ill.

2009 – 2010: H1N1 (Swine Flu)

In the spring of 2009, a new flu virus spread quickly across the United States and the world. The first U.S. case of H1N1 (swine flu) was diagnosed on April 15, 2009. By April 21, the Centers for Disease Control and Prevention (CDC) was working to develop a vaccine for this new virus. On April 26, the U.S. government declared H1N1 a public health emergency.

By June, 18,000 cases of H1N1 had been reported in the United States. A total of 74 countries were affected by the pandemic. H1N1 vaccine supply was limited in the beginning. People at the highest risk of complications got the vaccine first.

By November 2009, 48 states had reported cases of H1N1, mostly in young people. That same month, over 61 million vaccine doses were ready. Reports of flu activity began to decline in parts of the country, which gave the medical community a chance to vaccinate more people. An estimated 80 million people were vaccinated against H1N1, which minimized the impact of the illness.

The CDC estimates that 43 million to 89 million people had H1N1 between April 2009 and April 2010. They estimate between 8,870 and 18,300 H1N1 related deaths.

On August 10, 2010, the WHO declared an end to the global H1N1 flu pandemic

March 2020 - 2022: COVID-19 or SARS-CoV-2

In early 2020, a novel, infectious respiratory disease began to spread worldwide and eventually impacted all aspects of life throughout the world for over a year. Scientists determined that COVID-19 spread by droplets or aerosols from the nose and mouth when an infected person coughed, sneezed or exhaled. Airborne transmission also happened in indoor spaces without good ventilation, especially with infected people breathing heavily, like when singing or exercising. Infected people were able to spread the disease before having symptoms or feeling sick, and asymptomatic people could also spread the disease without ever exhibiting a single symptom. Several variants circulated globally as the virus mutated over time. In the case of COVID-19, the variants were determined to be more contagious.

Symptoms of COVID-19 could appear 2 to 14 days after exposure and include fever, cough, shortness of breath, chills, headache, muscle pain, sore throat, fatigue, congestion, or loss of taste or smell. Other less common symptoms included gastrointestinal symptoms like nausea, vomiting, or diarrhea. Even after recovering from the virus, many people experienced lingering symptoms such as fatigue, cough or joint pain. The elderly, those living in group settings (*e.g.,* nursing homes, jails) and people of any age with serious underlying medical conditions such as lung disease or diabetes, were at highest risk for developing complications from COVID-19. Fully effective and dependable treatments for the virus were limited.

Mitigation of COVID-19 depended on wearing protective masks, distancing from others who were able to transmit disease, washing hands to prevent disease spread, contact tracing to warn those who may have had exposure, and rapid development of testing measures to determine COVID-positive populations. Despite public health campaigns to prevent spread, the disease sickened millions and killed over 965,000 in the United States alone (https://covid.cdc.gov/covid-data-tracker/#datatracker-home, 3/15/22). As of March 15, 2022, the VDH reported 1,656,000 total cases, 48,188 hospitalizations and 19,356 deaths in Virginia. The virus also impacted the Richmond-Crater region as shown in **Table 5.42**.

Table 5.42: COVID-19 Regional Impacts

Jurisdiction	Cases	Hospitalizations	Deaths
Charles City County	1,146	51	27
Chesterfield County	71,667	1,345	738
City of Colonial Heights	4,796	111	94
Dinwiddie County (inc. Town of McKenney)	5,262	165	84

Table 5.42: COVID-19 Regional Impacts			
Jurisdiction	**Cases**	**Hospitalizations**	**Deaths**
City of Emporia	1,147	59	53
Goochland County	3,884	90	46
Greensville County (inc. Town of Jarratt)	3,313	78	37
Hanover County (inc. Town of Ashland)	21,520	463	269
Henrico County	63,707	1,387	890
City of Hopewell	6,096	164	119
New Kent County	4,576	99	32
City of Petersburg	8,279	251	139
Powhatan County	4,951	97	55
Prince George County	8,222	145	67
City of Richmond	43,954	1,051	478
Surry County	1,082	58	19
Sussex County (inc. Towns of Stony Creek, Wakefield, Waverly)	2,409	73	39
Totals	**256,011**	**5,687**	**3186**

Source: https://www.vdh.virginia.gov/coronavirus/covid-19-in-virginia/, accessed online March 15, 2022

In addition to the pandemic history described above, several pandemic flu threats have occurred that did not prove as dangerous as the events described above. When the 1976 swine flu was identified at Fort Dix, New Jersey it was called the "killer flu." Experts were concerned because they thought the virus was similar to the 1918 Spanish flu. To prevent a major pandemic, the United States launched a vaccination campaign. In fact, the virus—later named "swine flu"—never moved outside the Fort Dix area. Later, research on the virus showed that it would not have been as deadly as the 1918 flu if it had spread.

In 1997, at least a few hundred people caught H5N1 (avian flu) in Hong Kong. Like the 1918 pandemic, most severe illness affected young adults. Eighteen people were hospitalized. Six of those people died. This avian flu was unlike other viruses because it passed directly from chickens to people. Avian flu viruses usually spread from chickens to pigs before passing to humans. To prevent the virus from spreading, all chickens in Hong Kong—approximately 1.5 million— were slaughtered. Because this flu did not spread easily from person to person, no human infections were found after the chickens were killed.

In 1999, a new avian flu virus appeared. The new virus caused illness in two children in Hong Kong.

In the Central Virginia Health District, the VDH indicates that Hepatitis B and C, Salmonella and Campylobacteriosis are the most commonly reported communicable diseases during the period 2013 to 2018, the most recent data available. **Table 5.43** summarizes the VDH data for the region during this period. Hepatitis B and C are viruses that cause an infection that attacks the liver and leads to inflammation. The infection is spread by blood products such as unclean needles, and most people have no symptoms. Campylobacteriosis is an infection by the Campylobacter bacterium, a common bacterial infection of humans, often a foodborne illness. The bacteria produce an inflammatory diarrhea or dysentery syndrome, mostly including cramps, fever and pain. The salmonella bacteria have a similar food-related source and causes upset stomach, diarrhea, fever, and pain and cramping in the belly.

Table 5.43 Communicable Disease in the Virginia's Central Health District		
Year	**Top Four Diseases**	**Number Of Cases**
2013	Hepatitis C, chronic	1308
	Hepatitis B, chronic	263
	Salmonellosis	166
	Campylobacteriosis	116
2014	Hepatitis C, chronic	1269
	Hepatitis B, chronic	237
	Salmonellosis	212
	Campylobacteriosis	146
2015	Hepatitis C, chronic	1715
	Hepatitis B, chronic	250
	Salmonellosis	221
	Campylobacteriosis	183
2016	Hepatitis C, chronic	2560
	Hepatitis B, chronic	256
	Salmonellosis	219
	Campylobacteriosis	196
2017	Hepatitis C, chronic	2545
	Hepatitis B, chronic	230
	Campylobacteriosis	225
	Salmonellosis	220
2018	Hepatitis C, chronic	2374
	Salmonellosis	255
	Hepatitis B, chronic	249
	Campylobacteriosis	221

Source: VDH, https://www.vdh.virginia.gov/data/communicable-diseases/ accessed 4/15/21 and confirmed to be most recent 3/15/2022

Vulnerability Analysis

Based on historical experience and the fact that at the time of this planning process an ongoing pandemic threatens public health, the region is expected to experience waves of pandemic flu and communicable disease outbreak in the future.

An outbreak of widespread disease may burden local medical facilities in terms of capacity for treatment, may burden the region's health departments, emergency responders and other essential workers with additional staff responsibilities, and may burden local funeral homes with higher demand for services, but would not be expected to damage the built environment or community infrastructure in any significant way. Experience with COVID-19 has shown that economic impacts and job losses may affect housing starts, and the number of people remaining at home for work and schooling can increase demand for home renovation services. These impacts are somewhat temporary and may be further ameliorated by Federal stimulus dollars distributed as a result of a public health disaster, and eviction prohibitions issued at various government levels.

Social Vulnerability

Analysis of the impacts of COVID-19 on populations of varying economic, social and ethnic backgrounds is ongoing at the time of this study. Understanding how the virus spread requires examination of the specific geographic circumstances of where people are required to travel. Social isolation was quickly recognized as a critical element in managing the spread, but isolation is not an option for many essential workers who are critical to the healthcare system, food supply chain and transportation systems. There are clear divides in the region's communities regarding who can work from home and who is required to go out in public. COVID-19 clearly did not affect everyone equally. The Virginia Center for Inclusive Communities (https://inclusiveva.org/covid19/) noted the following disparities:

- older adults were more susceptible to the virus itself, leading to large numbers of socially isolated seniors;
- school closures led to food insecurity, disparities in technology and internet access, and a need for special services for students with disabilities and students learning English;
- persons with pre-existing conditions but less access to high quality, preventive healthcare were more susceptible to the virus;
- small businesses with existing banking relationships had better access to State and Federal financial assistance, especially during the early part of 2020;
- inequities related to transportation access impacted how the virus affected people;
- and violence against intimate partners, Asians, Islamics and others increased during the pandemic.

Fortunately, by February 2021, at least seven different vaccines had already been developed and were being administered to the most vulnerable populations throughout the world. Three primary vaccines were being used in Virginia, and by mid-March

2022, over 6.2 million Virginians, or 72.3% of the population, were fully vaccinated against the virus.[44]

As COVID-19 demonstrated, the nature and characteristics of a virus, such as how it is transmitted and who is most likely to suffer from severe symptoms, affects the populations most likely to be impacted. Social vulnerability can be influenced by financial health, physical health, mental health and other aspects of where and how a person lives. Similarly, access to virus testing, healthcare for those who contract the virus, and access to medications and vaccinations are all components in an assessment of social vulnerability to each virus and such assessment is difficult to manage while resources are committed to managing an ongoing virus. Communication and outreach to socially vulnerable groups is a key mitigation measure for lessening the impact of viruses that unequally impact demographic groups.

Future Vulnerability, Land Use and Climate Change

Future land use is expected to have less impact on future vulnerability than the protection of public health through dissemination of proper individual protection measures and emergency notification with regard to flu or disease outbreak.

Many causes of climate change also increase risk of pandemic, including deforestation, loss of habitat and loss of species. Warming temperatures and increasingly severe rainfall patterns make conditions better for Lyme disease, waterborne diseases and mosquito-borne diseases.

Mass evacuation is not expected to be a factor related to infectious disease, although COVID-19 did change transportation habits and work habits in the study area.

5.18 Conclusions on Hazard Risk

The risk and vulnerability assessment performed for the Richmond-Crater region provides significant findings that allow committee members to prioritize hazard risks and proposed hazard mitigation strategies and actions. Prior to assigning conclusive risk levels for each hazard, the committee reviewed the results of the assessments shown in the following tables.

Damages and frequency information from the risk and vulnerability assessments are summarized in **Table 5.44**. This table provides a quantitative assessment of existing data for the hazards, recognizing that some hazards are not readily assessed, nor are the assessments truly comparable.

[44] Virginia Department of Health, accessed online at: www.vdh.virginia.gov/coronavirus/see-the-numbers/covid-19-in-virginia/covid-19-vaccine-summary/

Table 5.44: Frequency and Damage Assessment from the Hazard Identification and Risk Assessment			
Hazard	**NCEI Annual Frequency**	**NCEI Annualized Damages**	**Other Damages and Notes**
Flooding	9.59	$95,000	$3,877,630,847 100-year flood damages (Hazus)
Severe Wind Events	0.852	$1,436,741	$9.7 million annual damage (Hazus)
Droughts	0.40	$1,765,040	
Tornadoes	1.97	$1,488,825	
Thunderstorms	3.22	$17,601	Annualized events include hail, lightning and thunderstorm events
Severe Winter Weather	0.06-0.75	$40,411	
Extreme Heat	0.01	$0	
Wildfires	n/a	n/a	$1,488,825 annual damage (VDOF) 1.97 events per year
Sinkholes	n/a	n/a	1.1 events per year
Infectious Diseases	n/a	n/a	.05 events per year (Pandemic Flu)
Earthquakes	n/a	n/a	$4,167,000 annual (Hazus)
Shoreline Erosion	n/a	n/a	
Radon Exposure	n/a	n/a	
Flooding Due to Impoundment Failure	n/a	n/a	

Table 5.45 summarizes the relative degree of mitigation priority assigned for all identified hazards in the region based on the application of the workshop qualitative assessment voting tool discussed in Methodologies Used (Section 5.2.1) at the beginning of Section 5.

Table 5.45: Summary of Qualitative Assessment	
Hazard	**Mitigation Priority Ranking**
Flooding and Flooding due to Impoundment Failure	$ 19,850,000
Severe Wind Events	$ 4,125,000
Shoreline Erosion	$ 3,125,000
Infectious Diseases	$ 2,575,000
Severe Winter Weather	$ 2,500,000
Droughts and Extreme Heat	$ 1,950,000
Tornadoes	$ 1,225,000
Thunderstorms	$ 325,000
Sinkholes	$ 325,000
Earthquakes	$ 300,000
Wildfires	$ 275,000
Radon Exposure	$ 50,000
Landslides	$ -

Risk level ranking was based on historical and anecdotal data, as well as input from committee members. This ranking was done collaboratively in Workshop #1 for each hazard, using the matrix shown in **Figure 5.52**. Each hazard was discussed and analyzed based on the participants' knowledge about consequences and likelihood. This risk scoring tool is a simplified approach to estimating risk that is easy to understand, based on a method developed for the Australian Institute for Disaster Resilience (AIDR)[45]. Scores from likelihood and consequence are then multiplied to provide a risk score, as shown in **Table 5.46**. Some hazards, such as landslides, sinkholes and shoreline erosion were grouped for simplicity's sake.

[45] AIDR. (2015). *Handbook 10: National Emergency Risk Assessment Guidelines*. 2nd Edition. Australian Institute for Disaster Resilience, Australian Government Attorney-General's Department.

Figure 5.52: Results of Committee Workshop Hazard Ranking Exercise

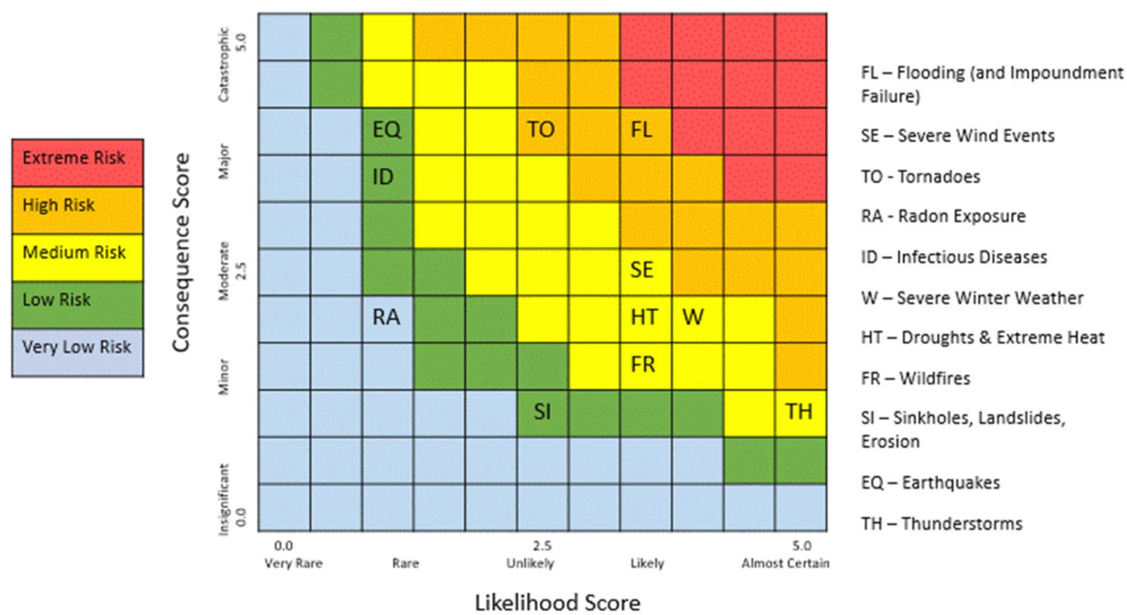


Table 5.46: Risk Scores for Each Hazard

Hazard	Risk Score	Risk Description
Flooding and Flooding due to Impoundment Failure	14	High
Tornadoes	10	High
Severe Wind Events	8.75	Medium
Severe Winter Weather	8	Medium
Droughts and Extreme Heat	7	Medium
Wildfires	5.25	Medium
Thunderstorms	5	Medium
Earthquakes	4	Low
Infectious Diseases	3.5	Low
Sinkholes, Landslides, Erosion	2.5	Low
Radon Exposure	2	Very Low

The conclusions drawn from the assessments, combined with an examination of the rankings in the 2017 plan, as well as final determinations and discussion from the committee, were considered for a final summary of hazard risk for the region based on High, Moderate, Low, or Negligible designations (**Table 5.47**). Although some hazards are classified as posing Low or Negligible risk, their occurrence is still possible.

Table 5.47: Conclusions on Hazard Risk for Richmond-Crater Region	
CRITICAL HAZARD - HIGH RISK	FLOODING SEVERE WIND EVENTS TORNADOES
CRITICAL HAZARD - MODERATE RISK	SEVERE WINTER WEATHER DROUGHTS AND EXTREME HEAT THUNDERSTORMS
NONCRITICAL HAZARD - LOW RISK	WILDFIRES INFECTIOUS DISEASES EARTHQUAKES SHORELINE EROSION FLOODING DUE TO IMPOUNDMENT FAILURE RADON EXPOSURE
NEGLIGIBLE CONSEQUENCES	SINKHOLES LANDSLIDES

6.0 Capability Assessment

6.1 Updates for 2022

The Capability Assessment was updated in 2021/2022 using a new questionnaire distributed to communities, interviews and discussions with committee members, and research on new capabilities added at the state and Federal levels. Local government highlights were expanded to capture many of the mitigation actions and programs completed since the previous plan was enacted.

6.2 Introduction

A "capability assessment" qualitatively summarizes the current and anticipated future capacity of the communities within the Richmond-Crater study area to mitigate the effects of the natural hazards identified in Section 5.0 of this plan. The capability assessment includes a comprehensive examination of the following local government capabilities:

- *Administrative Capability* – describes the forms of government in the region, including the departments that may be involved in hazard mitigation.
- *Technical Capability* – addresses the technical expertise of local government staff.
- *Fiscal Capability* – examines budgets and current funding mechanisms.
- *Policy and Program Capability* – describes past, present, and future mitigation projects in the region and examines existing plans (e.g., emergency operations plan, comprehensive plan).
- *Legal Authority* – describes how jurisdictions in the region use the four broad government powers (i.e., regulation, acquisition, taxation, and spending) to influence hazard mitigation activities.

The purpose of a capability assessment is to identify resources that will support implementation of potential hazard mitigation opportunities available to the region's local governments. For the most part, the towns in the region, with the exception of Ashland, are extremely small with several functions such as building inspections and public safety supported or performed by the corresponding county. To the extent information regarding towns was available, it is included in the capability assessment.

Analysis of capabilities helps planners detect existing gaps, shortfalls, or weaknesses within existing government activities that could exacerbate a community's vulnerability. The assessment will highlight positive measures already in place or being taken at the local level, which should continue to be supported and enhanced, if possible, through future mitigation efforts.

The capability assessment serves as a foundation for designing an effective hazard mitigation strategy. It not only helps establish the goals and mitigation actions for the Richmond-Crater region communities to pursue, but assures that those goals and actions are realistically achievable by communities.

6.3 Staff and Organizational Capability

The counties within the PlanRVA region operate under a Board of Supervisors – County Administrator/Manager system. In this form of government, the elected board of supervisors hires a county administrator/manager who oversees daily operations of the county. Charles City County has the smallest board with three members. Goochland, Henrico, New Kent, and Powhatan Counties each have five board members. Hanover County's board is the largest in the region with seven members.

The City of Richmond operates under the Mayor-Council system of government. The nine members of the council and the mayor are elected. The mayor appoints, with council approval, a chief administrative officer who oversees daily business operations of the city.

Charles City and Chesterfield Counties are dual members of both regional planning district commissions. Within the Crater region, the size of the Board of Supervisors also varies from jurisdiction to jurisdiction. Greensville has the smallest board with four members, Dinwiddie has a five-member board, and the remaining counties have six-member boards. The cities in the Crater region operate under the City Council -City Manager system. The city council is an elected body. Emporia has an eight-member council and the other cities have seven-member councils. The council, in turn, appoints a city manager who acts as the city's chief executive officer.

Incorporated towns in the Commonwealth of Virginia also have an elected governing body. Towns have zoning and planning authority though most choose to use the county planning commission as their town planning commission. Towns have the ability to issue general obligation and revenue bonds. In addition, towns of more than 5,000 residents may appoint an emergency services director and exercise emergency powers separate from the county.

Under the county administrator/manager, city mayor/manager, or town manager/mayor, each jurisdiction has numerous departments and boards that are responsible for the various functions of local government. Committee members for this mitigation planning process are members of various departments as shown in Table 3.2; their primary contributions or skills with regard to hazard mitigation are also provided in that table. While exact responsibilities differ from jurisdiction to jurisdiction, the general duties of the primary departments involved in this process are described below.

Building Inspections offices enforce the VUSBC, which contains the building regulations that govern new buildings, structures, and additions or repairs to existing buildings. The regulations must also be referenced when maintaining or repairing an existing building or renovating or changing the use of a building or structure. The VUSBC is comprised of three parts: Virginia Construction Code, Virginia Existing Building Code and Virginia Maintenance Code. Design requirements set out a minimum level of protection from wind, flood and snow loads, as well as requiring foundation protection from a variety of hazards. Building inspectors play a critical role in inspecting buildings damaged by hazards and determining if they are safe to inhabit or if repairs must be made prior to reoccupation.

Departments of Emergency Management/Fire/Emergency Medical Services (EMS)/Public Safety are responsible for the mitigation, preparedness, response, and recovery operations that deal with both natural and human-caused disaster events. These departments are typically categorized as "first responders" and encompass emergency response, emergency management, and fire safety. In addition, Fire/EMS departments provide medical aid and fire suppression at the scene of accidents and emergencies. These departments are often responsible for responding to hazardous materials incidents, water rescues, and entrapments. Many departments are also active in public engagement activities, informing community members through reverse 911, social media, and other outreach. Members of the Richmond Regional-Crater Hazard Mitigation Steering Committee were primarily emergency managers who also engaged local participation from other departments within their jurisdictions. They also work with other departments to ensure that their vulnerability analysis and mitigation actions are integrated into appropriate jurisdictional comprehensive plan updates, zoning and floodplain management regulatory or policy changes, emergency operations plan updates, disaster recovery plans and resiliency planning as these plans and policies are updated and renewed.

The Police or Sheriff's department is responsible for public safety and evacuation activities that might occur prior to events and assists in the response and recovery operations that deal with both natural and human-made disaster events. They also work to ensure the safety and security of residents and businesses as well as personal property during the immediate recovery period.

Parks and Recreation departments may be responsible for open-space programs. If acquisition projects are undertaken, coordination with this department becomes critical.

The Planning Department (or Department of Community Development) addresses land use planning and zoning. Planning and Community Development departments are typically responsible for managing grant programs funded by the U.S. Department of Housing and Urban Development (HUD), but some larger jurisdictions may have separate housing departments or authorities who manage HUD programs. These grant programs provide assistance to low- and moderate-income persons for needed housing improvements. These departments also may develop residential and commercial revitalization plans for older areas, serve as a resource for housing and community development issues, and manage special redevelopment projects. Zoning ordinances, which may include the floodplain management and Chesapeake Bay Act overlay districts, are typically enforced by the Planning or Planning and Zoning Department, as well.

Economic Development departments concentrate on ensuring the growth and prosperity of existing businesses. These departments often administer small business loan programs, state economic development programs, and workforce training programs. In smaller jurisdictions, such as Charles City County, this function is managed through the County Administrator's office. Government entities such as Economic Development departments are also increasingly involved in recruiting new businesses to a jurisdiction.

Public utilities departments or cooperatives, in some jurisdictions, oversee community potable water treatment and natural gas services. Rural areas may be served by rural electric cooperatives which are not for profit, while a large extent of the region is served by Dominion Energy.

In many jurisdictions, Public Works or Engineering departments oversee maintenance of infrastructure including roadways, stormwater management, sewer, and wastewater treatment facilities. These departments may also review new development plans, ensure compliance with stormwater management and erosion and sediment control regulations, and work with VDOT on road issues.

GIS staff, vital in their support of mitigation with tools such as multiple data sets and mapping capability, provide data to various local government departments and residents. GIS staff may be located within one of several departments, or in multiple departments, depending on the local government organizational structure. Some communities in the region contract with a private firm for GIS services.

Depending on the jurisdiction, departments of Planning, Public Works, Engineering or Zoning may enforce the NFIP requirements. Two communities, the City of Richmond and the Town of Ashland, participate in the FEMA Community Rating System, which provides NFIP policyholders within the regulated floodplain a discount on their flood insurance policy premium at rate commensurate with the participating community's CRS classification.

6.4 Technical Capability

A mitigation program typically depends on a broad range of staff with diverse technical capabilities. Planners, engineers, building inspectors, emergency managers, floodplain managers, GIS staff, and grant writers are all important in supporting mitigation actions implemented at the local level. **Table 6.1** provides information on each jurisdiction's technical capabilities.

All localities have GIS capabilities or receive technical support from their county (in the case of most towns) or their planning district commission. Most local governments have incorporated basic GIS systems into their existing planning and management operations. Several of the larger localities are expanding their GIS capabilities to provide more enhanced assistance to first responders and to improve data needed for hazard identification and risk analysis. For instance, Chesterfield County used information on power outages to examine communities dependent on well water. The fire department was then able to prioritize delivery of drinking water to these homes. The county also uses their GIS system to link data to damage assessment photos, a process that speeds up communication with VDEM after a disaster.

Staff members in all the jurisdictions have internet access. Most local governments use social media; fire, police, and emergency managers leverage Facebook pages and Twitter feeds for messaging. Some localities keep these sites active year-round while others activate them only during emergencies to relay vital information to the public.

Table 6.1: Technical Capabilities of Richmond-Crater Jurisdictions

Jurisdiction	Mitigation Assigned to Specific Department	GIS	Adequate Zoning Staff	Dedicated Floodplain Management Staff	Building Inspectors	Overall Technical Capabilities
Charles City County	Planning	Yes	Yes	No	Yes	Moderate
Chesterfield County	Environmental Engineering Planning Building Inspections	Yes	Yes	Yes	35	Moderate
City of Colonial Heights	Engineering Public Works Fire Department Building Official	Yes	Yes	1	3	Moderate
Dinwiddie County	Public Safety/	Yes	Yes	Yes	3	Moderate

Table 6.1: Technical Capabilities of Richmond-Crater Jurisdictions						
Jurisdiction	**Mitigation Assigned to Specific Department**	**GIS**	**Adequate Zoning Staff**	**Dedicated Floodplain Management Staff**	**Building Inspectors**	**Overall Technical Capabilities**
	Emergency Services					
Town of McKenney	County handles mitigation	Yes	Yes	No	N/A	Limited
City of Emporia	City Manager/Emergency Management	Yes	Yes	Yes	2	Moderate
Goochland County	Fire and Rescue	Yes	Yes	No	3	Moderate
Greensville County	No	Yes	Yes	Yes	2	Moderate
Town of Jarratt	County handles mitigation	Yes	Yes	No	N/A	Limited
Hanover County	Planning Fire/EMS	Yes	Yes	No	4	Moderate
Town of Ashland	Planning Police	Yes	Yes	No	Yes	High
Henrico County	Emergency Management	Yes	Yes	Yes	35	High
City of Hopewell	Emergency Management	Yes	Yes	Yes	2	Moderate
New Kent County	Fire , Sheriff and Social Services	Yes	Yes	No	Yes	Moderate
City of Petersburg	Fire/Rescue; Public Works	Moderate	No	No	2	Moderate
Powhatan County	Emergency Management	Yes	Yes	No	Yes	Moderate
Prince George County	All Departments	Yes	No	No	6	Limited
City of Richmond	Emergency Management/ Police/Fire	Yes	Yes	Yes	Yes	High
Town of Surry	County handles mitigation	Surry County	Surry County	Surry County	Surry County	Limited
Sussex County	Public Safety	Yes	Yes	No	2	Limited

Table 6.1: Technical Capabilities of Richmond-Crater Jurisdictions						
Jurisdiction	**Mitigation Assigned to Specific Department**	**GIS**	**Adequate Zoning Staff**	**Dedicated Floodplain Management Staff**	**Building Inspectors**	**Overall Technical Capabilities**
	Planning and Zoning					
Town of Stony Creek	County handles mitigation	Sussex County	Sussex County	No	Sussex County	Limited
Town of Wakefield	County handles mitigation	Sussex County	Sussex County	No	Sussex County	Limited
Town of Waverly	County handles mitigation	Sussex County	Sussex County	No	Sussex County	Limited

High: No increase in capability needed.
Moderate: Increased capability desired but not needed.
Limited: Increased capability needed.

6.5 Fiscal Capability

The counties and cities in the study area receive most of their revenue through local real estate tax, state and local sales tax, local services, and restricted intergovernmental contributions (federal and state pass-through dollars). With regard to mitigation, since 1998 Virginia has provided a 20% match on all eligible HMGP projects. These in-kind matches help to reduce the local contribution to less than 5% cash match, making mitigation projects much more feasible for local jurisdictions and for interested property owners. **Table 6.2** provides an indication of the operating budgets for the cities and counties in the study area.

Table 6.2: Fiscal Capability		
Jurisdiction	**Total FY22 Budget**	**Public Safety FY22 Budget**
Charles City County	$9,126,683	$1,400,107
Chesterfield County	$807,045,000	$207,070,800
Colonial Heights	$96,978,695	$ 12,694,931
Dinwiddie County	$51,552,250	$3,342,951
City of Emporia	$25,283,809	$4,913,139

Table 6.2: Fiscal Capability		
Jurisdiction	**Total FY22 Budget**	**Public Safety FY22 Budget**
Goochland County	$141,274,251	$16,076,318
Greensville County	$21,246,995 (FY 21)	$243,784 (FY 21)
Hanover County	$513,200,000	$88,000,000
Henrico County	$1,431,936,068	$932,525 (EM only)
City of Hopewell	$54,356,282	$5,261,335
New Kent County	$114,283,910	$12,500,685
City of Petersburg	$103,613,656	$17,322,301
Powhatan County	$135,866,359	$592,384
Prince George County	$112,000,000	$112,000,000
City of Richmond	$772,831,959	$200,528,261
Sussex County	$22,050,598	$1,612,820

Sources: Jurisdictional budget offices; websites.

Most communities in the Richmond-Crater region use capital improvement plans and general obligation bonds to plan and fund large-scale public expenditures. Most jurisdictions in the study area also use intergovernmental agreements to leverage resources.

6.6 Policy and Program Capability

6.6.1 Previous Mitigation Efforts

The region does not currently have strong participation amongst jurisdictions in FEMA HMA programs. However, some highlights of past grant-funded projects and other mitigation projects are presented below. Most localities in the region do not apply for HMA grants but instead incorporate mitigation strategies and actions into other regulatory and non-regulatory programs and support activities. Such programs include, but are not limited to, emergency preparedness outreach, floodplain management and building inspections.

6.6.2 Hazard Mitigation Activity Highlights

The region's Central Virginia Emergency Management Alliance is supported by an emergency management planner from PlanRVA. Since local adoption of the *2011 Richmond-Crater Hazard Mitigation Plan*, which merged the previous Crater PDC and Richmond Regional PDC plans, local mitigation has been intertwined with emergency management activities, especially for outreach and messaging. Regional mitigation program highlights are outlined below.

Education and Outreach: Prior to the COVID-19 pandemic, local emergency managers kept a busy calendar of outreach festivals and events which centered on hazard-based safety outreach. The pandemic has limited gatherings in recent years, which has impacted some community outreach efforts. Many previous projects were nationally-branded efforts, which each jurisdiction customized to their locality. Examples include tornado awareness month in March with preparedness drills, annual preparedness days for hazards such as floods, wind, and tornado, Turn Around Don't Drown, the June 1 beginning of hurricane season, and promotion of Virginia preparedness supplies sales tax free weekends. On August 27, 2016, a regional PreparAthon community festival was sponsored by local media and corporations and conducted at the Virginia Science Museum in Richmond Virginia. Preparedness was celebrated by teaching participants how to prepare for and react to disasters and emergencies. Participants who signed up for a Disaster Preparedness Workshop received a free kit worth $45.

Early Warning and Notification: Most communities have refined their early warning and notification systems to allow cell phone and sometimes text notifications and other technological advances, often with targeted abilities for populations with disabilities. Localities with river flood stage monitoring use river and stream gage data to inform warning messaging, but rarely to target detailed evacuation planning. Virginia Commonwealth University uses a loudspeaker system as well as digital notification.

Plan Integration: The 2011 plan was used by some locality planners to inform sections of local comprehensive plans. GIS technicians used some data-layers from the 2011 plan. The 2022 plan's map data will be provided to the PDCs, so the data can be easily integrated into other local government emergency management and planning documents. The Crater Planning District Commission Director of Planning and Information Technology provides GIS technical support to any Crater PDC jurisdictions so will ensure integration of hazard information. The Hazus flood analysis is expected to be used for resiliency planning, especially in coastal jurisdictions.

The region's experienced floodplain program administrators conduct activities on a regular basis to make certain local floodplain management ordinances are administered in accordance with the NFIP. Building officials are partners in working to ensure adherence to hazard-related regulations and criteria in the VUSBC.

Community Rating System (CRS): FEMA's CRS program provides flood insurance premium reductions in five-percent increments following a rigorous, comprehensive floodplain management program review by FEMA and FEMA's partners. The City of Richmond enjoys a CRS rating of Class 8, meaning NFIP policyholders in the SFHA receive a 10% reduction on their annual flood insurance premiums. The Town of Ashland has a CRS Rating of Class 9, giving its policyholders a 5% annual flood insurance policy reduction. Henrico County is actively preparing an application to the CRS.

Critical and Public Facilities Protection: Due to increased power outages from more frequent severe storms with high winds causing tree loss, the region's local governments have intensified efforts to provide redundant power to critical facilities such as public safety buildings, 911 communications centers, health care facilities, as well as schools and other buildings to be used as shelters. Additionally, redundant power or backflow wiring or "quick connects" so that public buildings are able to accept temporary generators have become a local priority. While sometimes eligible for FEMA HMA grant support, most of the generator quick connects and installations have been done through local funding. Most new critical facilities are pre-wired for generator acceptance if a permanent generator is not installed. Communities typically have programs in place to test and fuel the generators on a regular basis to ensure dependability. The trend toward smaller shelters or opening community resource centers in lieu of sheltering has introduced new considerations in determining which facilities are critical and expanding the options for modern disaster sheltering.

6.6.3 Local Government Highlights

Local jurisdictions within the Richmond-Crater region have had numerous successes with mitigation actions that reduce vulnerability from a variety of hazards. The following list of programs, projects and policy changes highlight both successfully completed mitigation actions and illustrate how the mitigation planning process and plan itself have been integrated into other community plans, policies and regulations.

Ashland

Ashland officials report considerable progress with Continuity of Operations (COOP) planning, a need identified in the 2017 plan. The new threat assessment, COOP and EOP have been prepared jointly with the county, although each department will have their own operational plans. The COOP is substantially complete, but must be finalized and implemented with the county in the next planning period.

Charles City County

Charles City County is now considered an ingestion pathway community for Surry nuclear power plant emergencies and participates in appropriate testing. All community critical facilities have adequate generator capabilities. The county has established an effective emergency operations center within its Judicial Center. Emergency communications are being enhanced by the addition of a communication tower in the vicinity of the Judicial Center.

Chesterfield County

Chesterfield County has acquired four repetitive loss properties along Beach and Old Beach Road in the central part of the county. FEMA mitigation grant funds were used for this project.

More recently, the county was successful in implementing a recommended action in the previous plan regarding incorporating the 2017 Mitigation Action Plan into the comprehensive plan update being conducted simultaneously. Mitigation actions are similar throughout the two documents. The county also has a new COOP that will aid in the process of identifying needs for protecting critical facility infrastructure, an action in the previous mitigation plan that is retained in this update.

The county strives to provide a variety of emergency management—related training opportunities to county staff on an annual basis. Emergency Management is currently revising their recovery training and developing new best practices. Simultaneously, they have expanded their public outreach efforts to focus on the whole community concept of including seniors, people with disabilities, civic associations and faith-based organizations.

County officials report that through coordination with Virginia Department of Energy and use of the agency's maps of abandoned mines, the county has modified their development review process to include consideration of physical abandoned mine and related sinkhole hazards.

City of Colonial Heights

City officials report that two mitigation actions identified in the previous plan have been completed in the past five years. The city has completed a project to purchase and distribute NOAA weather radios for public facilities. They have also worked with Crater PDC to obtain and begin using GIS data regarding building footprint data to enable more precise flood hazard analysis for a variety of purposes.

Dinwiddie County

COVID-19 created a number of lessons learned that will inform the refinement of the county's new COOP over the next several years. The COOP was finalized, as recommended in the 2017 plan, just before COVID impacted the globe. The county also implemented their new Debris Management Plan in the past five years as called for the in the 2017 plan. Also, the county's Computer Aided Dispatch system has been improved with regard to road and railroad crossings, better correlating the crossing numbers to geographic locations.

Goochland County

Goochland County has been working with VDOF to promote best management practices among landowners in the county. The department and the county have offered joint courses on forestry management and wetlands protection. In addition, the county has thinned more than 160 acres of flammable pine plantations vulnerable to wildfire and insect infestation while instituting best management practices on county-owned property.

Greensville County

In 2009, the USACE, Norfolk District, completed a stream and rain gauging network study within the Chowan River Basin. The study identified gauging station needs that would improve flood forecasts by the NWS. An additional study in 2009 evaluated water resource issues, such as environmental restoration, flood risk management, navigation, and water quality. These two studies helped to determine Risk Mapping, Assessment, and Planning (Risk MAP) program activities implemented in the Chowan River Basin. The three Risk MAP activities included:

- Assessment of basin flood hazard data.
- Establishment of local community officials' knowledge and understanding of flood risk management concepts and increasing public awareness of flood hazards and the NFIP.
- Support to state and local governments to engage in risk-based mitigation planning.

The Chowan River Basin report provides an in-depth assessment of the river basin and mitigation activities for understanding flood risk. Areas of concern are highlighted throughout the report, which should be used to identify future mitigation actions.

Hanover County

Fire Station #5, the location of the Hanover County EOC, has been updated since the first regional hazard mitigation plan to address its electrical power capacity issues. The county also used the proceeds of a bond issuance to improve the communication system and interoperability. The basement of the Hanover County Sheriff's Office is still subject to flooding through the windows. This flooding could affect the emergency communications ability of the Sheriff's Office. Hanover County has also used FEMA mitigation funds for minor, localized drainage improvement projects. County officials indicate that, per the mitigation actions in the previous plan, needs related to electrical hook-ups, wiring and switches for connections to emergency power generation at key critical facilities has been substantially completed.

Henrico County

Henrico County has implemented higher standards in floodplain management, including a prohibition on new residential structures in identified floodplains. As a FEMA Cooperating Technical Partner, the county has mapped floodplain drainage areas in 100 acre units, providing far more discrete floodplain modeling than industry standards of 1 square mile (640 acres). Development or redevelopment is prohibited if it will cause a rise in the base flood elevation (or 100-year flood level). In addition, the lowest floor of new development and substantially improved structures must be two foot above the BFE if within the SFHA, and one foot above the BFE if within the 500-

year floodplain or within 40 feet of the SFHA. Finally, through the Chesapeake Bay Preservation Act ordinance, a mandatory stream buffer further prohibits development adjacent to streams and wetlands.

In 2005, the county purchased several properties in the Bloomingdale neighborhood along with the property at the intersection of Brook and Lakeside Avenues that were high flood risk, repetitive damage sites.

More recently, the county implemented a mitigation action from the previous plan regarding enhanced water availability for wildfire fighting in the eastern portion of the county. As sheltering needs evolve in this century, the county is focusing more on multi-hazard vulnerability assessments and mitigation planning for all schools to determine their suitability as temporary shelters during tornadoes and earthquakes, for example. Henrico County is also currently developing a floodplain acquisition program.

Hopewell

A 2017 mitigation action involving stream channel and road embankment stabilization along the City's primary emergency route is substantially complete. Work along Winston Churchill Drive between High Avenue and Arlington Road to protect adjacent residences is substantially complete.

New Kent County

As recommended in the 2017 plan, the county has applied for and will retain StormReady certification from the NWS. A prior mitigation action related to continuing participation in the NFIP and CRS, to include training and CFM certifications and other related actions, is echoed in the county's comprehensive plan. County officials report that road construction in the Fannies Creek area is mitigated as suggested in the previous plan. The county has also completed measures that requires substantial coordination with regional stakeholders, including coordination with various state agencies regarding traffic management concerns related to a Hampton Roads evacuation. The county has also assessed earthquake vulnerability in the area as recommended by the previous plan.

Prince George County

A mitigation action in the 2017 plan called for construction of a new burn building for the Fire Department to conduct exercises. As of late fall 2021, the designs are complete and construction is expected to begin shortly. The county also constructed a new fire station at Route 10 and Moody Road.

City of Richmond

Following numerous floods from the 1970's through 1990's, the USACE performed a study and ultimately constructed a flood wall to protect the Shockoe Bottom area and a small area of the south bank from James River flooding. The City of Richmond has been very active since 2011 with new mitigation projects and programs to help reduce its vulnerability to future events. The city received about 14 inches of rain from Tropical Storm Gaston, which the stormwater system was not able to manage effectively. Drainage features such as the East Gravity Outlet, which are part of the floodwall project, were found to contribute to increased damages on the protected side of the floodwall. The occurrence of back-to-back flooding brought attention to the city's older infrastructure system and its need for a dedicated source of funding. Using Capital Improvement Plan (CIP) funds in 2008–2010, the city completed many improvements to the Shockoe Bottom area.

During the additional budget cycles, the City of Richmond added three gate structures on the Northeast Interceptor to prevent the transfer of flow from the Arch Sewer to the main Box Sewer, which is the primary sewer collector in the Shockoe Bottom area. The city also installed or modified approximately 100 curb inlets to improve the capture of stormwater from the steeper slopes leading to the Shockoe Bottom watershed, helping to prevent flooding in the lowest parts of the Shockoe Bottom area. In addition, the city redesigned the storm drainage system in Pine Alley to capture a significant portion of the stormwater that would normally enter the alley and flood area businesses. Separation of the East Gravity Outlet from the combined sewer overflow system was also done to eliminate the need for gate operations to minimize interior flooding, increase the reliability of both the flood-reduction system and environmental protection system, and allow the operation of the system with a fail-safe mode. City contractors also connected the Box Sewer to the East Gravity Outlet to provide a high-rate overflow, and restored the Upper Shockoe Creek Retention Basin to further improve the capacity of the Shockoe Bottom Drainage system.

The major improvements in the Shockoe Bottom area were facilitated by the creation of a stormwater utility controlled by the Department of Public Utilities in 2009. This new utility transferred maintenance and improvements of the city's stormwater system from Public Works to Public Utilities and created a long-term source of funding. The new utility now creates an annual CIP list of projects and has begun working to improve the various systems throughout the city to reduce the potential loss of life and damages from future events.

Tropical Storms Gaston and Ernesto led the City of Richmond to complete two large residential mitigation projects that helped reconstruct and remove homes from the floodplain. The first was Broad Rock Creek Floodway Mitigation Project. This project included the acquisition, demolition, and relocation of several homes. The project also identified other structures in the city that were then reconstructed to move their systems out and above the BFE. All properties were located in the Broad Rock Creek floodway and were adjacent to a 100-year floodplain where structures sustained severe damage as a result of the remnants of Tropical Storm Gaston in 2004.

The second project occurred with the acquisition and relocation of structures in the Battery Park community. The historic city park and several homes immediately adjacent to it sustained heavy damage during Tropical Storm Ernesto in 2006. The project resulted in the removal of homes from the floodplain and the creation of new parkland.

Richmond successfully used HMGP grant funds to add several stream monitoring gaging stations to augment its flood warning system. These are tied to the Commonwealth's Integrated Flood Observing and Warning System (IFLOW) system. Recently, Richmond has distributed NOAA weather radios to residents to expand their communication capabilities when power is out after disaster events, and they have successfully integrated GIS capabilities with emergency management needs, although additional opportunities remain. Emergency managers indicate the City has conducted wind studies on many City-owned facilities as part of a more comprehensive inventory assessment identified in Richmond 300.

Sussex County

Following the early 2016 tornado which killed three in Waverly, a Waverly Tornado Recovery Urgent Needs Study was conducted, which focused on long-term recovery efforts for the area. Meetings were conducted in late 2016 with the objective of submission of HUD grant applications to support neighborhood recovery and manufactured housing rehabilitation/mitigation. Mitigation action 11 in the MAP (in Section 7) was developed for the previous Hazard Mitigation Plan. Although some progress has been made, the action is retained in this plan with additional action expected in partnership with HUD in the future.

6.6.4 Emergency Operations Plans (EOP)

A comprehensive emergency management operations plan (or emergency operations plan) sets out a series of actions to be taken by government agencies and private organizations in response to an emergency or disaster event. The plan describes the jurisdiction's capabilities to respond to emergencies and establishes the responsibilities and procedures for responding effectively to the actual occurrence of a disaster.

Emergency operations plans in the Richmond-Crater region typically reference the Richmond-Crater PDC mitigation plan rather than including a mitigation section to the EOP. EOPs describe the responsibilities of various departments and agencies, private businesses, and the public in a post-disaster scenario. Importantly, I EOP outlines a concept of operations that explains and supports activities to be undertaken before and during a disaster. Specific tasks are assigned to the local governing body and various agencies, such as Emergency Services, Health, Building Officials/County Engineer/Planning and Zoning, Law Enforcement, Fire Department and Emergency Crew, Superintendent of Schools, and the Public Information Officer. Each of the operational subplans is part of a total response plan typically overseen by the Director of Emergency Management or a comparable division lead. Emergency Managers for each city and county were included preparation of the MAP because their knowledge of their jurisdiction's EOP and its strengths and weaknesses is a valuable component of this planning process. In this way, the EOP was integrated into the update to the hazard mitigation plan.

In addition to local EOPs, VDOT and VDEM have worked with the localities to develop incident plans that include evacuation routes. When an event occurs, the Emergency Alert System (EAS) provides the latest information on evacuation. The majority of the Richmond and Crater regions are within the Richmond Extended EAS area. Surry County is an exception and is part of the Eastern Virginia EAS area.

Many of the region's community emergency operations plans outline the concerns surrounding mass evacuation, in terms of jurisdictional evacuation, evacuation of other areas in which the locality acts as a "host," or as a transit route locale. In addition to EOPs, many jurisdictions without comprehensive COOPs for all internal agencies were interested in supplementing their existing EOP or existing COOP with additional planning, and this insight was included in the MAP planning process.

6.6.5 Floodplain Management

Communities that regulate development in floodplains are able to participate in the NFIP. In return, the NFIP makes federally-backed flood insurance policies available for properties in the community. In Virginia, local governments are provided the power to regulate land use through Code of Virginia, Title 15.2 Counties, Cities and Towns, Subtitle II Powers of Local Government. Floodplain management in the study area communities is administered as a zoning overlay in the Zoning Ordinance (§ 15.2-2280) or through a standalone Floodplain Management ordinance (§ 15.2-984). Table 5.5 summarizes the history of NFIP participation for the study area jurisdictions. The table also provides the current FIRM effective date for each community.

The Towns of Surry, McKenney and Waverly did not have initial identified SFHA boundaries on the FIRMs; however, McKenney has chosen to adopt an ordinance and participate to make flood insurance available. **Table 6.3** below provides additional information for the study area jurisdictions. Community floodplain management ordinances were reviewed by the consultant as part of the preparation for Workshop #3; analysis from the review was discussed and incorporated into the planning process through recommendations for mitigation actions.

Each community has designated staff who enforce their floodplain management ordinance. The staff of the DCR Floodplain Management Program, including the NFIP State Coordinator, serve as state level administrators of the program, providing assistance to communities upon request.

DCR's Virginia Dam Safety Program operates under the authority of the Virginia Soil and Water Conservation Board. The division regulates impounding structures in the Commonwealth to ensure that they are 'properly and safely constructed, maintained and operated.' The Virginia Dam Safety Act, Article 2, Chapter 6, Title 10.1 (10.1-604 et seq) of the Code of Virginia and Dam Safety Impounding Structure Regulations (Dam Safety Regulations), were established and published by the Virginia Soil and Water Conservation Board. Virginia's Dam Safety Regulations were last updated on March 23, 2016.

Ongoing dam inspections and Virginia's participation in the National Dam Safety Program administered by FEMA and the USACE serve as a preventative measure against dam failures. Disaster recovery programs include assistance to dam owners and local officials in assessing the condition of dams following a flood disaster and assuring the repairs and reconstruction of damaged structures in compliance with the NFIP regulations.

6.6.7 Comprehensive Plans

Virginia law requires that all communities have a comprehensive land use plan and that it be updated every five years. A community's comprehensive plan provides the future vision for the community regarding growth and development; not by coincidence, many of the study area plans include land use or environmental protection goals that could support future mitigation efforts. For example, limiting development in the floodplain (which is considered mitigation) may also help meet open space goals laid out in a comprehensive plan. Several comprehensive plans in the study area address mitigation, green space, resiliency and long-term community sustainability. These are relatively new inclusions, and as communities continue to update their comprehensive plans and to create separate resilience plans, mitigation and resiliency issues will likely be more comprehensively addressed.

For the most part, these strategies address development in the floodplain or otherwise flood-prone areas. In addition, the plans indicate that communities in the Richmond-Crater region are experienced with and willing to use growth management tools such as zoning, subdivision regulations, and preferential tax assessment. In many cases, demographic information, land use characteristics and growth projections found in the most current available local comprehensive plans were used to update Section 4.0 Community Profile. Comprehensive plans for the communities were also consulted during the development of mitigation actions to identify areas of potential overlap or synergy, where previously-identified recommendations in the comprehensive plan could be integrated into new or modified mitigation actions that address specific hazard vulnerabilities. This practice also helps prevent conflict between community planning efforts.

Table 6.3 summarizes the local planning mechanisms used by the jurisdictions in the study area.

Table 6.3: Local Planning Mechanisms

Locality	Disaster Recovery Plan	Comprehensive Plan	Floodplain Management Ordinance	Stormwater Management Plan	Emergency Operations Plan	Other
Charles City County	✓	✓	✓		✓	Chesapeake Bay Preservation Program
Chesterfield County	✓	✓	✓		✓	Continuity of Operations (COOP); Evacuation Plan; Wetlands Preservation Program; Open Space Program; Riparian Buffers Program
City of Colonial Heights	✓	✓	✓	✓	✓	Historic preservation ordinance; Chesapeake Bay Preservation Program (wetlands)
Dinwiddie County		✓	✓		✓	
City of Emporia		✓	✓		✓	Transportation plan, 1984
Hanover County	✓	✓	✓	✓	✓	Chesapeake Bay Preservation Program
Town of Ashland		✓	✓		✓	CRS
Henrico County	✓	✓	✓	✓	✓	Chesapeake Bay Preservation Program
Goochland County	✓	✓	✓	✓	✓	

Table 6.3: Local Planning Mechanisms						
Locality	Disaster Recovery Plan	Comprehensive Plan	Floodplain Management Ordinance	Stormwater Management Plan	Emergency Operations Plan	Other
Greensville County	✓	✓	✓		✓	Erosion control and sediment ordinance
City of Hopewell	✓	✓	✓	✓	✓	COOP, 2001 Evacuation plan
New Kent County		✓	✓	✓	✓	Chesapeake Bay Preservation Program
City of Petersburg	✓	✓	✓	✓	✓	Transportation plan; Chesapeake Bay Preservation Program Riparian buffers Open space program and plan
Powhatan County	✓	✓	✓	✓	✓	Open Space; Natural Resources Inventory; Debris Management Plan
Prince George County	✓	✓	✓	✓	✓	Chesapeake Bay Preservation Program Riparian buffers
City of Richmond	✓	✓	✓	✓	✓	Chesapeake Bay Preservation Program; CRS
Town of Surry		✓ (through county)			✓ (through county)	Chesapeake Bay Preservation Program Evacuation plan
Sussex County		✓	✓		✓	Evacuation plan Transportation plan, 1997
Town of Wakefield		✓ (through county)	✓		✓ (through county)	Chesapeake Bay Preservation Program Evacuation plan
Town of Waverly		✓ (through county)			✓ (through county)	Chesapeake Bay Preservation Program Evacuation plan

Table 6.4 summarizes how individual communities expect to continue integrating hazard mitigation actions into other planning tools, regulations and activities beyond those activities listed above. Check marks indicate which planning mechanisms are targeted for existing or future coordination and integration with that community's mitigation action plan. None of the communities currently participating in the NFIP are considering a change in status at this time.

Table 6.4: Integration Of Hazard Mitigation Actions Into Other Planning Mechanisms

Locality	Regulations	Administrative & Technical Procedures	Fiscal Planning (CIP, grants, budgeting)	Land Use Planning (comprehensive, resilience, transportation)	Other (public information, activities, etc)
Charles City County	✓	✓	✓	✓	✓
Chesterfield County	✓	✓	✓	✓	✓
City of Colonial Heights	✓	✓	✓	✓	✓
Dinwiddie County	✓	✓	✓	✓	✓
City of Emporia	✓	✓	✓	✓	✓
Hanover County	✓	✓	✓	✓	✓
Town of Ashland	✓	✓	✓	✓	✓
Henrico County	✓	✓	✓	✓	✓
Goochland County	✓	✓	✓	✓	✓
Greensville County	✓	✓	✓	✓	✓
City of Hopewell	✓	✓	✓	✓	✓
New Kent County	✓	✓	✓	✓	✓
City of Petersburg	✓	✓	✓	✓	✓
Powhatan County	✓	✓	✓	✓	✓
Prince George County	✓	✓	✓	✓	✓
City of Richmond	✓	✓	✓	✓	✓
Town of Surry	✓	✓		✓	
Sussex County	✓	✓	✓	✓	✓
Town of Wakefield	✓		✓	✓	
Town of Waverly	✓		✓	✓	

6.7 Legal Authority

Local governments in Virginia, including those in the Richmond-Crater region, have a wide range of tools available to them for implementing mitigation programs, policies, and actions. A hazard mitigation program can use any or all of the four broad types of government powers granted by the Commonwealth of Virginia, which are (a) regulation, (b) acquisition, (c) taxation, and (d) spending. The scope of this local authority is subject to constraints; however, as all of Virginia's political subdivisions only have the power to act with proper delegation from the state. All power is vested in the state and can only be exercised by local governments to the extent it is delegated (in accordance with Dillon's Rule). Thus, this portion of the capabilities assessment will summarize Virginia's enabling legislation that grants the four types of government powers within the context of available hazard mitigation tools and techniques.

6.7.1 Regulation

General Police Power

Virginia's local governments have been granted broad regulatory powers in their jurisdictions. Virginia State Statutes bestow the general police power on local governments, allowing them to enact and enforce ordinances that define, prohibit, regulate or abate acts, omissions, or conditions detrimental to the health, safety, and welfare of the people, and to define and abate nuisances (including public health nuisances). Since hazard mitigation can be included under the police power (as protection of public health, safety, and welfare), towns, cities, and counties may include requirements for hazard mitigation in local ordinances. Local governments may use their ordinance-making power to abate "nuisances," which could include, by local definition, any activity or condition making people or property more vulnerable to any hazard.

All of the jurisdictions located in the Richmond-Crater region have enacted and enforce regulatory ordinances designed to promote the public health, safety, and general welfare of its citizenry.

Land Use

Regulatory powers granted by the state to local governments are the most basic manner in which a local government can control the use of land within its jurisdiction. Through various land use regulatory powers, a local government can control the amount, timing, density, quality, and location of new development. All these characteristics of growth can determine the level of a community's vulnerability in the event of a natural hazard. Land use regulatory powers include the power to plan, enact and enforce zoning ordinances, floodplain ordinances, and subdivision controls. Each local community in the Richmond-Crater region possesses legal authority to prevent unsuitable development in hazard-prone areas.

Planning

According to state statutes, local governments in Virginia may create or designate a planning agency. The planning agency may perform a number of duties, including:

- making studies of the area;
- determining objectives;
- preparing and adopting plans for achieving those objectives;
- developing and recommending policies, ordinances, and administrative means to implement plans; and
- performance of other related duties.

The importance of the planning powers of local governments is illustrated by the requirement that zoning regulations be made in accordance with a comprehensive plan. While the ordinance itself may provide evidence that zoning is being conducted "in accordance with a plan," the existence of a separate planning document ensures that the government is developing regulations and ordinances that are consistent with the overall goals of the community.

The cities and counties within the Richmond-Crater region all have planning departments and comprehensive plans. Most of the towns in the region, with the exception of Ashland, have no formal planning and limited zoning authority; these small towns rely on the county in which they are located to enforce most planning and zoning regulations. For purposes of the NFIP, towns are required to have their own floodplain management ordinances, but may rely on the county for help with administration, preferably through a mutual aid agreement.

Zoning

Zoning is the traditional and most common tool available to local governments to control the use of land. Broad authority is granted for municipalities and counties in Virginia to engage in zoning. Land "uses" controlled by zoning include the type of use (e.g., residential, commercial, and industrial), as well as minimum specifications that control height and bulk such as lot size, building height and setbacks, and density of population. Local governments are authorized to divide their territorial jurisdiction into districts, and to regulate and restrict the erection, construction, reconstruction, alteration, repair or use of buildings, structures, or land within those districts. Districts may include general-use districts, overlay districts (such as for floodplains), and special-use or conditional-use districts. Zoning ordinances consist of maps and written text.

Subdivision Regulations

Subdivision regulations control the division of land into parcels for the purpose of building development or sale. Flood-related subdivision controls may prohibit the subdivision of land subject to flooding unless flood hazards are identified and addressed. Subdivision regulations may also require that developers install adequate drainage facilities or stormwater controls, address erosion and sediment control, and design water and sewer systems to minimize flood damage and contamination.

All PlanRVA jurisdictions continue enforcement of their adopted subdivision ordinances and in many instances, have updated those ordinances during the past ten years. Some of the ordinances contain floodplain-specific provisions. For instance, Powhatan County requires a 100-foot natural vegetative buffer along all perennial streams as well as setbacks for residential structures from the floodplain. In New Kent County, new subdivisions with 50 or more homes are required to have at least two ingresses and egresses. This requirement will allow an alternate route if one is blocked in case of emergency. Since subdivisions of four lots or more trigger major subdivision review standards in Charles City County, most subdivisions are smaller to avoid these more rigorous standards.

Likewise, the jurisdictions in the Crater PDC have adopted subdivision ordinances. Many of the ordinances require that land be suited for development, and specifically, that land platted for residential use not be subject to flooding. The City of Emporia and Surry County require that utilities be buried underground.

Floodplain Management

All communities with a FEMA-designated SFHA in the Richmond-Crater region have adopted floodplain management regulations. Powhatan County's regulations have been in place since 1973, prior to joining the NFIP. The other jurisdictions adopted floodplain regulations as part of joining the NFIP.

In several cases, the regulations adopted by the study communities go beyond the minimum standards of the NFIP. Goochland and Powhatan Counties restrict uses in the floodplain. Henrico County prohibits new residential development in the floodplain and the county has developed, mapped and regulates their own floodplains that extend beyond the boundaries of the FEMA SFHA. The majority of communities set design criteria for utilities and other public infrastructure.

Goochland County and the City of Richmond prohibit manufactured homes in all or portions of the floodplain. Chesterfield County prohibits new manufactured home parks, while Greensville County prohibits new manufactured homes unless located in an existing park.

Twelve of the ordinances in the Richmond-Crater region describe procedures for structures built before the regulations were in place. While the ordinances must, at a minimum, require that lowest floors of new and improved structures in the SFHA be constructed with the lowest floor at or above the base, or 100-year, flood elevation, freeboard refers to an extra level or protection that some communities incorporate into their regulations above the minimums. All localities that allow development in the floodplain require at least a 1-foot freeboard for development with some localities having higher freeboard requirements. The City of Hopewell and Henrico County require a 2-foot freeboard for all new and substantially reconstructed homes in the floodplain, Greensville County requires 18 inches of freeboard in its ordinance, and Surry County includes a 1-foot freeboard. Goochland County has the highest freeboard with a level of 3 feet above the base flood elevation for construction within the regulated floodplain.

Effective January 1, 2022, a new flood disclosure requirement of Virginia Code Section 55.1-708.2, requires that an owner of residential real property who knows that the dwelling unit is a repetitive risk loss structure must disclose such fact to the purchaser. A "repetitive risk loss structure" is defined as a property for which two or more claims of more than $1,000 were paid by the National Flood Insurance Program within any rolling 10-year period since 1978. The law further requires that the owner of a property subject to the disclosure requirement must provide notification to the purchaser of any disclosure before the ratification of a contract.

Resiliency

In 2021, the Commonwealth began working with 2,000 stakeholders to build the *Coastal Resilience Master Plan*. This plan documents which land is exposed to coastal flooding hazards now and into the future, as well as the impacts of future flooding scenarios on coastal Virginia's community resources and manmade and natural infrastructure.

The Master Plan concluded that between 2020 and 2080:

- the number of residents living in homes exposed to extreme coastal flooding is projected to grow from approximately 360,000 to 943,000, an increase of 160%;
- the number of residential, public, and commercial buildings exposed to an extreme coastal flood is projected to increase by almost 150%, from 140,000 to 340,000, while annualized flood damages increase by 1,300% from $0.4 to $5.1 billion;
- the number of miles of roadways exposed to chronic coastal flooding is projected to increase from 1,000 to nearly 3,800 miles, an increase of nearly 280%; and
- an estimated 170,000 acres, or 89%, of existing tidal wetlands and 3,800 acres, or 38%, of existing dunes and beaches may be permanently inundated, effectively lost to open water.

The Commonwealth intends to develop successive updates of the Master Plan on at least a five-year cycle, managed by DCR in consultation with the Chief Resilience Officer, the Special Assistant to the Governor for Coastal Adaptation and Protection, and the Technical Advisory Committee.

The next phase of the Master Plan anticipated by 2024, will aim to address recommendations of the Technical Advisory Committee to broaden the analysis of natural hazards by including rainfall-driven, riverine, and compound flooding, expand and improve the inventory of resilience projects by continuing to add efforts and working with project owners to better understand the benefits of projects, and extend this critical work beyond the coastal region to encompass statewide resilience needs.

Projects identified in the Master Plan must go through a specified resiliency planning process to be funded through the Community Flood Preparedness Fund (CFPF), also launched in 2021. Several communities in the Richmond-Crater region are beginning initial stages of the planning process. CFPF is a statewide program maintained by DCR that fills pressing needs by prioritizing low-income communities and provides a permanent funding stream to finance flooding resilience projects, studies, and capacity-building initiatives. The Regional Greenhouse Gas Initiative (RGGI) is an initiative made up of eleven states that aims to reduce greenhouse gas emissions. RGGI holds carbon dioxide auctions, which will fund the Virginia CFPF.

North Atlantic Coast Comprehensive Study

The USACE recently completed a report detailing the results of a two-year study to address coastal storm and flood risk to vulnerable populations, property, ecosystems, and infrastructure affected by Hurricane Sandy in the North Atlantic region of the United States.

The *North Atlantic Coast Comprehensive Study* is designed to help local communities better understand changing flood risks associated with climate change and to provide tools to help those communities better prepare for future flood risks. It builds on lessons learned from Hurricane Sandy and attempts to bring to bear the latest scientific information available for state, local, and tribal planners.

The conclusions of the study, as detailed in the final report, include several findings, outcomes, and opportunities, such as the use of a nine-step Coastal Storm Risk Management Framework that can be customized for any coastal watershed. The study ranked localities risk impacts as to High, Medium or Low Impact. Within the Richmond-Crater region, Henrico, Charles City, Chesterfield, Prince George and Sussex Counties were ranked “Low” and Surry County was ranked “Medium.” This comprehensive study can provide planners with additional information on long-term impacts of coastal storms.

Stormwater Management

A stormwater management plan is designed to address flooding associated with stormwater runoff. The stormwater management plan is typically focused on design and construction measures that are intended to reduce the impact of frequent urban nuisance flooding.

Virginia Department of Environmental Quality (VDEQ) is the lead agency for developing and implementing statewide stormwater management and nonpoint source pollution control programs to protect the Commonwealth's water quality and quantity. Currently, three laws apply to land disturbance activity in Virginia: the Stormwater Management Act (§ 62.1-44.15:24 et seq.), Erosion and Sediment Control Law (§ 62.1-44.15:51 et seq.), and Chesapeake Bay Preservation Act (§ 62.1-44.15:67 et seq.). These laws evolved at different times, have been administered by different agencies throughout the years, and created three distinct regulatory programs with varying requirements. At the request of the Chairs of the Virginia House and Senate Natural Resources committees, VDEQ pulled together a group of stakeholders to consider ways to streamline and possibly combine these programs. The goal is to make the requirements clearer, more consistent and more "user-friendly", while continuing to ensure the protection of the Commonwealth's water quality. The Department asked representatives of all affected constituencies to take part in this important effort – including local governments, the development community, environmental organizations, agriculture, and others.

Local governments in Virginia are required to administer the stormwater management and erosion and sediment control laws and regulations promulgated by the State through local ordinances. Surry County's program is administered directly by VDEQ.

Chesapeake Bay Preservation Act (CBPA)

The Virginia General Assembly enacted the Chesapeake Bay Preservation Act in 1988, requiring local governments statewide to include water quality protection measures in their zoning and subdivision ordinances and in their comprehensive plans. Although the Act was developed with the intent of improving water quality throughout Virginia, the regulations have the additional benefit of controlling or restricting development in floodplain areas. The CBPA Overlay District consists of three components: Resource Protection Area (RPA) that includes a 100 foot RPA buffer, a Resource Management Area (RMA), and the Intensely Developed Areas (IDA). The lands that make up Chesapeake Bay Preservation Areas are those that have the potential to impact floodplains and water quality most directly. Generally, there are two main types of land features: those that protect and benefit water quality (RPAs); and those that, without proper management, have the potential to damage water quality (RMAs). Areas with intensive waterfront industrial land uses and activities are categorized as IDAs.

Localities within the plan update region that are within the Chesapeake Bay watershed and thus enforce the CBPA regulations include: Charles City, Chesterfield, Hanover, Henrico, New Kent, Prince George, and Surry Counties, the cities of Colonial Heights, Hopewell, Petersburg and Richmond and the towns of Ashland, and Surry.

Building Codes and Building Inspection

Building codes regulate design and construction standards. Permits are issued and work is inspected on new construction and building alterations. Permitting and inspection processes both before and after a disaster can affect the level of hazard risk faced by a community.

Under Virginia law, the Department of Housing and Community Development (DHCD) has authority to promulgate building regulations and a regulatory process for development and adoption of a statewide mandatory mini/maxi construction code that all 167 units of local government (counties and incorporated cities) must adopt and implement. As stated above, the VUSBC is administered by the Virginia Board of Housing and Community Development and regulates construction and maintenance of buildings and structures. Effective July 1, 2021, Virginia adopted the 2018 I-codes as referenced in the Virginia Construction Code Part 1, the 2018 Statewide Fire Prevention Code; and the 2017 National Electrical Code. Implementation for state colleges and universities is the responsibility of the Virginia General Services Department. The State Fire Marshal within DHCD is responsible for statewide implementation of the Fire Code unless localities elect to adopt this code at the local level. Localities can and do adopt the Property Maintenance Code, which is within the scope of the statewide code. Enforcement of the VUSBC is the responsibility of the local government's building inspections department. Many of the towns in the study area rely upon the county building department for code-related functions.

DHCD has a resiliency subcommittee on codes that met and made recommendations for the 2018 code, and each code change had to have a resiliency impact considered. The 2018 version of the codes incorporates several resiliency measures, including: a requirement for 3 Elevation Certificates at various stages of construction for structures built in the SFHA; various freeboard requirements based on building characteristics (1 foot minimum for residential); and coastal high hazard area requirements for Coastal A Zones, or areas seaward of the LiMWA. The resiliency subcommittee is doing the same for the 2021 update currently underway.

Radon Exposure Remediation

The Code of Virginia requires that Radon testers and mitigators be currently certified by either the National Radon Proficiency Program or the National Radon Safety Board. The program is administered by VDH, Office of Radiological Health, Indoor Radon Program. In 1993, the Virginia General Assembly passed legislation that requires all schools in the Commonwealth to be tested for radon after July 1, 1994, and also any new school buildings or additions built after that date. Each school is required to maintain files of their radon test results. Upon request, the Department's Radon Coordinator can present a course on radon for real estate transactions in Virginia. The department has a limited supply of radon test devices that are distributed annually, free upon request.

6.7.2 Acquisition

The power of acquisition can be a useful tool for pursuing local mitigation goals. Local governments may find that the most effective method for completely "hazard-proofing" a particular piece of property or area is to acquire the property (either in fee simple or a lesser interest, such as an easement), thus removing the property from the private market and eliminating or reducing the possibility of inappropriate development. Virginia legislation empowers jurisdictions to acquire property for public purpose by gift, grant, devise, bequest, exchange, purchase, lease, or eminent domain.

The City of Richmond completed acquisition projects after 2006 Tropical Depression Ernesto, in both the Broad Rock Creek and Battery Park neighborhoods. All projects were completed without using FEMA mitigation funds. Virginia CDBG Urgent Needs funds were used following Ernesto to acquire and demolish flood-damaged properties. Once the structures were demolished, the lots were dedicated to permanent open space. In some instances, Richmond has used city funds available to the Building Official to acquire and demolish disaster-impacted properties, such as with some trailer park communities and a residence impacted by the landslide on Church Hill following Tropical Depression Gaston. Chesterfield County acquired several repetitive loss properties along Beach and Old Beach Roads using FEMA HMGP funds following Hurricane Isabel. Development of an acquisition program is proposed in the City of Petersburg Comprehensive Plan. The City of Colonial Heights continues to consider a voluntary acquisition program along high-risk creeks to eliminate repetitive flood claims in the city. Henrico County is currently developing a floodplain acquisition program, as well.

6.7.3 Taxation

Real estate taxes are a significant source of local revenue. Code of Virginia §58.1-3201 requires that a structure be assessed at 100% of fair market value. A building that increases in value of more than $500 due to repairs or additions must be assessed as new (Code of Virginia §58.1-3291), also at 100% of fair market value. At the same time, the code allows the abatement of local real estate taxes for buildings unusable for at least 30 days during the year (Code of Virginia §58.1-3222); however, the abatement is prorated based on what portion of the year the property was impacted.

Specified local governments in the Commonwealth have the ability to levy special assessments on property owners for all or part of the costs of acquiring, constructing, reconstructing, extending, or otherwise building or improving flood protection works within a designated area (Code of Virginia §15.2-2404(D)); however, none of the specified communities are within the Richmond-Crater study area. Special assessments for flood control structures can serve to increase the cost of building in such areas, thereby effectively discouraging development. Because the usual methods of apportionment seem mechanical and arbitrary, and because the tax burden on a particular piece of property is often quite large, the major constraint in using special assessments is policy-oriented. Special assessments seem to offer little in terms of control over land use in developing areas. They can, however, be used to finance the provision of necessary services within municipal or county boundaries. In addition, they are useful in distributing the costs of the infrastructure required by new development to new property owners.

The State Corporation Commission collects communication taxes in Virginia, including a 75 cent E911 tax on landlines and Voice Over Internet Protocol phones, a 94 cent postpaid wireless E-911 tax for mobile phones, and a 63 cent prepaid wireless E-911 tax for mobile phones. These taxes pay for the cost of an emergency response communications system that identifies both the caller and the location of the call.

6.7.4 Spending

The fourth major power that has been delegated from the Virginia General Assembly to local governments is the power to make expenditures in the public interest. Hazard mitigation principles should be made a routine part of relevant spending decisions made by the local government, including the adoption of annual budgets and the CIP.

A CIP is a schedule for the provision of municipal or county services during a specified period of time. Capital programming, by itself, can be used as a growth management technique, with a view to hazard mitigation. By tentatively committing itself to a timetable for the provision of capital to extend services, a community can control growth to some extent, especially in areas where the provision of on-site sewage disposal and water supply are unusually expensive.

In addition to formulating a timetable for the provision of services, a local community can regulate the extension of and access to services. A CIP that is coordinated with extension and access policies can provide a significant degree of control over the location and timing of growth. These tools can also influence the cost of growth. If the CIP is effective in directing growth away from environmentally-sensitive or high-hazard areas, for example, it can reduce environmental costs.

The majority of the jurisdictions in the Richmond-Crater region have some form of a CIP. The construction or renovation of capital facilities, such as schools, municipal offices, and police/fire stations is often a highlight of their capital improvements. Investments in stormwater and sewer systems are included in the capital improvements program for most municipalities. Some jurisdictions also have included open space and other park acquisition costs as part of their CIP.

6.8 Summary

Most of the information in the capability assessment was provided by the jurisdictions in the study area through a capability assessment survey. **Table 6.5** summarizes the self-reported capability and priority assessment; note that several jurisdictions have not returned the 2016 or 2021 update capability assessment surveys.

Table 6.5: Mitigation Capability & Priority Self-Assessment by Jurisdiction

Jurisdiction	Planning and Regulatory Capability	Administrative Capability	Technical Capability	Fiscal Capability	Overall Capability
PlanRVA	Planning High	Moderate	Moderate	Moderate	Moderate
Crater PDC	Planning High	Moderate	Moderate	Moderate	Moderate
Charles City County	Moderate	Moderate	Moderate	Moderate	Moderate
Chesterfield County	High	High	High	High	High
City of Colonial Heights	Moderate	Moderate	Moderate	Moderate	Moderate
Dinwiddie County	Moderate	Moderate	Moderate	Moderate	Moderate
Town of McKenney	Limited	Limited	N/A	Limited	Limited
City of Emporia	Moderate	Moderate	Moderate	Moderate	Moderate
Goochland County	Moderate	Moderate	Moderate	Moderate	Moderate
Greensville County	Moderate	Moderate	Moderate	Moderate	Moderate
Town of Jarratt	Limited	Limited	N/A	Limited	Limited
Hanover County	Moderate	Moderate	Moderate	Moderate	Moderate
Town of Ashland	Moderate	High	Moderate	Limited	Moderate
Henrico County	High	High	High	High	High
City of Hopewell	Moderate	Moderate	Moderate	Limited	Moderate
New Kent County	Moderate	High	Moderate	Moderate	Moderate
City of Petersburg	Limited	Limited	Moderate	Limited	Limited
Powhatan County	Moderate	High	Moderate	Moderate	Moderate
Prince George County	Moderate	Moderate	Moderate	Moderate	Moderate
City of Richmond	Moderate	Moderate	Moderate	Limited	Moderate
Town of Surry	Limited	Limited	Limited	Limited	Limited
Sussex County	Moderate	Limited	Limited	Limited	Limited
Town of Stony Creek	Limited	Limited	Limited	Limited	Limited
Town of Wakefield	Moderate	Moderate	Limited	Moderate	Moderate
Town of Waverly	Limited	Limited	Limited	Limited	Limited

High: No increase in capability needed (e.g., extensive regulations on development in place).

Moderate: Increased capability desired but not needed (e.g., funding exists for mitigation but availability fluctuates).

Limited: Increased capability needed (e.g., additional staff are needed to successfully implement mitigation projects).

7.0 Mitigation Strategy

7.1 Updates for 2022

During the 2022 update, Section 7 was updated to reflect the Committee's work to update the Goals and Objectives. The following major changes were incorporated:

1. All tables were added or updated to reflect new information, including the new goals and objectives;
2. Mitigation actions were reviewed, completed actions were deleted; and, new mitigation actions were revised and added as directed by Committee members; and
3. Mitigation actions were modified to include a ranking for social vulnerability.

7.2 Introduction

This section of the Plan provides the "blueprint" for the Richmond-Crater region to become less vulnerable to natural hazards. It is based on the general consensus of the Committee along with the findings and conclusions of the Capability Assessment and Risk Assessment. The Mitigation Strategy section consists of the following four subsections:

7.1 Mitigation Goals

7.2 Identification and Analysis of Mitigation Techniques

7.3 Selection of Mitigation Techniques

7.4 Mitigation Action Plan

The intent of the Mitigation Strategy is to provide participating communities with the goals that will serve as the guiding principles for future mitigation policy and project administration, along with a list of proposed actions available to meet those goals and reduce the impact of natural hazards. It is designed to be comprehensive and strategic in nature.

The development of the strategy included a thorough review of all natural hazards and identified policies and projects intended to not only reduce the future impacts of hazards, but also to assist the region in achieving compatible economic, environmental, and social goals. The development of this section is also intended to be strategic, in that all policies and projects are linked to established priorities assigned to specific departments responsible for their implementation and assigned target completion deadlines. Funding sources are identified when possible, that can be used to assist in project implementation.

The first step in designing the Mitigation Strategy includes the identification of mitigation goals. Mitigation goals represent broad statements that are achieved through the implementation of more specific, action-oriented tasks listed in the Mitigation Action Plan (MAP). These actions include both hazard mitigation policies (such as the regulation of land in known hazard areas), and hazard mitigation projects that seek to address specifically targeted at-risk properties (such as the acquisition and relocation of flood-prone structures). Additional mitigation measures are then considered over time as new mitigation opportunities are identified, new data become available, technology improves, and mitigation funding becomes available.

The last step in designing the Mitigation Strategy is the creation of a set of jurisdictionally specific MAPs. The MAPs represent the key outcome of the mitigation planning process. MAPs include a prioritized list of proposed hazard mitigation actions (policies and projects), including accompanying information such as those agencies or individuals responsible for their implementation, potential funding sources, and an estimated target date for completion. The MAPs provide those individuals or agencies responsible for implementing mitigation actions with a clear roadmap that also serves as an important tool for monitoring progress over time. The collection of actions listed in the MAP also serves as a synopsis of activities for local decision makers.

In preparing the MAPs, committee members considered their overall hazard risk and capability to mitigate natural hazards, in addition to the mitigation goals. The prioritization of mitigation actions was based on the following five factors: (1) effect on overall risk to life and property; (2) ease of implementation; (3) political and community support; (4) a general economic cost/benefit review; and (5) funding availability.

A separate ranking for each MAP's impact on socially vulnerable populations is also included. This High, Moderate or Low impact rating is based on the NRI vulnerability information provided in Section 5. Where projects were identified in a specific location and/or tied to reducing vulnerability from a single hazard, the hazard-specific ranking for that Census tract and hazard was used. Projects geared toward reducing risk community-wide, such as general outreach, were evaluated based on the relative NRI social vulnerability of that community versus the percent of counties/cities with lower social vulnerability in Virginia (–ow - less than 40% of other counties/cities have lower social vulnerability; Moderate – 41-75%; High –75-100%). In cases where an action was specifically geared toward highly socially vulnerable populations within a community, the NRI risk was overridden, and the action was rated High.

7.3 Mitigation Goals

The goals of the Richmond-Crater Hazard Mitigation Plan were crafted as part of Workshop #3, a facilitated discussion and brainstorming session with committee members (see Section 3: Planning Process). As part of the 2022 update, the planning consultant reviewed the goals and objectives of the previous plan as well as pertinent goals and objectives from Virginia Beach's Sea Level Rise: Adaptation Strategy, Virginia's Coastal Resilience Master Planning Framework, the most recent Hampton Roads Hazard Mitigation Plan (2021 draft), the 2016 Middle Peninsula Hazard Mitigation Plan, and the 2018 Commonwealth of Virginia Hazard Mitigation Plan. In this way, the committee was able to incorporate some important regional resilience goals and work to find common ground in statewide, regional and local mitigation programming.

The group reassessed each goal word for word, reprioritized the list, and edited overall for brevity. The original document ("2017 Plan Goals and Objectives") and updated ("2022 Plan Goals and Objectives") goals are provided in **Table 7.1** below, with notes about the discussion leading to the changes. Each of the following updated goal statements represents a broad target to achieve through associated objectives which are fulfilled through implementation of specific Mitigation Action Plans, both for the region as a whole and for each community.

Table 7.1: Updated Goals and Objectives

2017 Plan Goals and Objectives	2022 Plan Goals and Objectives
~~**Goal 1:** Reduce risk exposure and vulnerabilities to hazards ranked "medium" and "high" by focusing on regional and local mitigation actions on priority hazards.~~	Deleted **Why the Change:** The goal was worded so broadly as to encompass the purpose of the whole plan.
Goal 2: Prepare and protect the whole community within the Central Virginia Emergency Management Alliance (EMACV) region through all-hazards planning staff, outreach publications and activities, and through training, and exercising volunteers and the general public.	**Goal 1: Equitably prepare and protect the whole community against natural hazards** 1.1 Increase staff capabilities regarding multi-hazard management and mitigation 1.2 Conduct outreach and educational opportunities for diverse groups of citizens 1.3 Share mitigation successes with citizens and stakeholders 1.4 Reduce disparities in how communities prepare for, respond to, and recover from hazards. **Why the Change:** Previous goal was divided into several objectives to show how the goal can be achieved. The EMACV does not cover the entire study area. The word "equitably" was added to reflect group's desire to identify mitigation actions for socially vulnerable areas of their communities.
Goal 3: Strengthen and sustain response coordination and collaboration through planning, equipment, training, and exercises to increase interoperability between all stakeholders in the EMACV region and other regions/entities that impact interoperability within the region, to include, but not limited to voice, video, and data.	**Goal 2: Strengthen and develop partnerships for mitigating and reducing hazard impacts** 2.1 Include stakeholders and other regions in planning and training actions. 2.2 Expand outreach and educational opportunities to influence and inform a broad spectrum of stakeholders. 2.3 Collaborate on public safety and support effective system redundancies

Table 7.1: Updated Goals and Objectives	
2017 Plan Goals and Objectives	**2022 Plan Goals and Objectives**
	Why the Change: The focus on stakeholders was retained, but goal was divided into several manageable objectives to fulfill of overall goal. The EMACV does not cover entire study area.
~~**Goal 4:** Provide support for public health and human service needs of the whole community through robust and coordinated sheltering capability, to include planning, resources, equipment, training, and exercises to include support of client needs tracking, family reunification services, information sharing, and public health response support.~~	Deleted **Why the Change:** The concepts captured in the action were similar to old Goal 5, and thus were merged into new Goal 3.
Goal 5: In the aftermath of a catastrophic incident, provide restoration of basic services, long term housing, and revitalization of a sustainable economy that includes the health, social, cultural, historic, and environmental fabric of the community, through planning, staffing, equipment, training, and exercises.	**Goal 3: Encourage sustainable government practices that support the short- and long-term health, safety and welfare of citizens** 3.1 Identify and protect important elements of the economic, social, cultural, historic, and environmental fabric of the community and neighborhoods 3.2 Address restoration of long-term housing and continuity of basic government services for affected populations, especially socially vulnerable communities, during recovery from hazard events **Why the Change:** The focus on sustainability was retained as was the concept of community “fabric”, but the goal was broken down into several manageable objectives to show how to attain the overall goal.
~~**Goal 6:** Enhance and maintain public safety and incident management response capabilities to all hazard emergencies including acts of terrorism, through planning, staffing, equipment, training, and exercises.~~	Deleted **Why the Change:** The concepts captured in the previous action were similar to old Goal 5, and thus were merged into new Goal 3.
Goal 7: Protect the critical infrastructure of the CVEMA region, and enhance the capability to disrupt criminal or terrorist threats through effective information and intelligence gathering and sharing, outreach, planning, equipment, training, and exercises.	**Goal 4: Protect critical infrastructure** 4.1 Identify opportunities for information- and intelligence-sharing regarding threats and hazards 4.2 Collaborate on utility management and support effective system redundancies 4.3 Identify and assist owners to maintain and upgrade high hazard potential dams, and protect the people and property downstream **Why the Change:** The focus on critical infrastructure was retained, but overall goal was divided into several objectives to show how to attain goal. The EMACV does not cover entire study area. Added high hazard potential dam protection.

7.4 Identification and Analysis of Mitigation Techniques

> **44 CFR Requirement**
>
> **Part 201.6(c)(3)(ii):** The mitigation strategy shall include a section that identifies and analyzes a comprehensive range of specific mitigation actions and projects being considered to reduce the effect of each hazard, with particular emphasis on new and existing buildings and infrastructure.

In formulating the Richmond-Crater Mitigation Strategy, a wide range of activities was considered in order to help achieve the goals and address specific hazard concerns. At the third workshop, committee members considered six broad categories of mitigation techniques. Committee discussions regarding each category are summarized beneath each category, including notes on the appropriateness and applicability of each as it applies to the region.

1. Prevention

Preventative activities are intended to reduce the impact of future hazard events, and are typically administered through government programs or regulatory actions that influence the way land is developed and buildings are constructed. They are particularly effective in reducing a community's future vulnerability, especially in areas where development has not occurred or capital improvements have not been substantial. Examples of preventative activities include:

- Planning and zoning
- Building codes
- Open space preservation
- Floodplain regulations
- Stormwater management regulations
- Drainage system maintenance
- Capital improvements programming
- Shoreline/riverine setbacks

Committee Discussion: Prevention activities have been implemented in the past in the region, are ongoing, and will continue to be included in this and future mitigation action plans. Many communities will mitigate flood damage through planning and zoning actions, such as amendments to their floodplain management ordinances which are viewed as very effective mitigation tools locally. Most communities in the region are continually updating zoning ordinances, especially for flood zones. The statewide building code is viewed as a rather static mitigation tool; it has components that mitigate especially for wind and flood, but is not a product that local governments exert a great deal of influence upon regularly. Appendix F of the building code could be adopted by communities concerned about protecting future construction from the impacts of radon exposure.

Open space preservation strategies are contained in most of the regional comprehensive plans, and some communities such as Richmond, have targeted planning in place for protecting green spaces and adding to their inventory. In the more urbanized areas of the region, open space preservation is also addressed in subdivision regulations. Several communities have integrated information from their existing hazard mitigation plans into Comprehensive Plan revisions, and vice versa.

Stormwater management regulations and drainage system maintenance rules promulgated at the state level are viewed as quite robust and not in need of additional local action at this time, although several communities are considering adopting more stringent regulations to require use of better future precipitation levels (similar to Virginia Beach); in addition, VDOT performs much of the drainage system maintenance in the region. Similarly, the state's Chesapeake Bay Act regulations governing shoreline setbacks are enforced locally in the Chesapeake Bay watershed communities. Capital improvements programming is seen as a useful tool in the implementation of high priority mitigation activities across the participating communities.

2. Property Protection

Property protection measures involve the modification of existing buildings and structures or the removal of the structures from hazardous locations. Examples include:

- Acquisition
- Relocation
- Building elevation
- Critical facilities protection
- Retrofitting (i.e., windproofing, floodproofing, seismic design)
- Safe rooms, shutters, shatter-resistant glass
- Insurance

Committee Discussion: Property protection measures have been implemented in the past in the region and across the state, and are ongoing primarily through HMGP projects. These measures will continue to be included in this and future mitigation action plans. Communities expressed various priorities for acquisition versus elevation versus relocation of flood-prone structures. Critical facilities protection and floodproofing/retrofitting are popular alternatives with the region's emergency managers, and many communities continually seek ways to increase insurance coverage for vulnerable property owners. The Community Rating System and related activities encompass and highlight several property protection measures ongoing in the participating communities of Richmond and Ashland.

The Committee decided to continue acquisition, relocation, and elevation measures for repetitively flooded properties, including critical facilities retrofits, in the Mitigation Action Plan, but did not act on any measures specifically for safe rooms or shatter-resistant glass as tornadoes are not a high risk critical hazard. Some communities had discussions about providing safe rooms in designated areas, particularly in manufactured home parks, but only Sussex County expressed interest in pursuing that action at this time.

Existing building code requirements are seen as sufficient with regard to wind and tornado protection; however, hurricane shutters and shatter-resistant glass may be an option for critical facility or emergency shelter retrofits as necessary. Many of the study area communities have installed or are considering installation of back-up generators for specific critical facilities, although some communities prefer mobile and some communities prefer permanent generators.

With regard to insurance, many of the communities have produced community flyers regarding the importance of having insurance coverage on structures.

3. Natural Resource Protection

Natural resource protection activities reduce the impact of natural hazards by preserving or restoring natural areas and their protective functions. Natural areas could include floodplains, wetlands, steep slopes, barrier islands and sand dunes. Parks, recreation or conservation agencies and organizations often implement these measures. Examples include:

- Land acquisition
- Floodplain protection
- Watershed management
- Beach and dune preservation
- Riparian buffers
- Forest and vegetation management (i.e., fire resistant landscaping, fuel breaks)
- Erosion and sediment control
- Wetland preservation and restoration
- Habitat preservation

- Slope stabilization
- Historic properties and archaeological site preservation

Committee Discussion: Natural resource protection measures remain commonly-used throughout the state. Many state programs discussed in Section 6, such as the Chesapeake Bay Act, are long-established natural resource protection measures considered effective and pro-active. The most important of these measures in relation to the region's critical hazards are floodplain protection, erosion and sediment control, and watershed management. Several communities indicated the cost of flood-prone land mitigation is often prohibitive for their local governments due to the level of administrative oversight required for grant programs.

Several rivers in the study area are designated scenic rivers and that designation has positively impacted watershed management efforts. Forest management in conjunction with VDOF is important in parts of the region, and affects vulnerability for wildfire. Beach and dune preservation is another state-promulgated program that requires permitting for impacts in the eastern or coastal portions of the study area. Friends of the Lower Appomattox River (FOLAR) participated in Committee discussions And expressed interest in partnering with riverside communities in protecting open space floodplains through land acquisition, and other eco-tourism related measures.

Several communities decided to continue floodplain protection measures and land acquisition in the MAP, but did not act specifically on other natural resource protection measures as those are considered to be sufficiently addressed through state regulations. Slope stabilization is important along the James River, although individual projects are not identified in the MAP. Abandoned mines are mapped by the state and development in relation to them is strictly regulated at the local level to ensure natural land cover disturbances are minimized.

4. Structural Projects

Structural mitigation projects are intended to lessen the impact of a hazard by modifying the hazard itself through construction. These projects are usually designed by engineers and managed or maintained by public works staff. Examples include:

- Reservoirs
- Dams/levees/dikes/floodwalls/seawalls
- Diversions/detention/retention
- Channel modification
- Beach nourishment
- Storm sewers

Committee Discussion: New large-scale reservoirs are not under consideration at this time in the region. Dam regulations at the state level are considered sufficient and communities are not considering additional regulation. Several structural protection measures are in place and must be maintained by the communities or private owners. Channel modifications, diversions, detention/retention, and stream restoration have been effective in reducing flood hazards in some areas and will remain viable mitigation actions in the future, especially for reducing the compounding effects of increased precipitation, floods and sea level rise. Stream restoration was recently included as a best management practice (BMP) in the State's BMP clearinghouse and some committee members believe that this may result in this method being considered and possibly used more in the future. Dry hydrants, and smoke testing of sanitary sewers, and the stormwater management preventive maintenance schedule are potential structural projects, with dry hydrants particularly important in wildfire control in the rural counties, including Charles City County. Beach nourishment is not being considered for limited beaches in the study area's eastern counties; erosion is typically on private proper

5. Emergency Services

Although not typically considered a "mitigation" technique, emergency services can minimize the impacts of a hazard event on people and property. These actions are often taken prior to, during, or in response to an emergency or disaster. Examples include:

- Warning systems
- Evacuation planning and management
- Emergency response training and exercises
- Sandbagging for flood protection
- Installing temporary shutters for wind protection

Committee Discussion: Riverine warning systems are being considered to help address some of the region's flood hazards. Several communities have recently implemented unified critical communications software to deliver messages to targeted audiences, and most communities have some form of reverse 911. Leveraging the various communities' flood warning systems to create a more regional approach would aid the people who live and commute through multiple jurisdictions. Regional cooperation on this front could benefit residents and visitors to the region and may result in savings to communities. Some communities with industrial waterfronts are concerned with hazardous materials in the floodplain and storm surge zones, and this generated discussion on actions related to business resilience and readiness in communities such as the City of Hopewell.

Evacuation planning is aided at the regional and state levels, but local planners use many tools to continually manage and improve the program; several are now considering more use of targeted evacuations in accordance with an evacuation plan that includes timed evaluation of road elevations and predicted flood elevations. Evacuation and sheltering plans for vulnerable populations are a high priority for the region's emergency planners at this time, and planners continue to express concerns about mass evacuation from coastal Virginia, North Carolina and the Washington D.C. area, which can have devastating impacts on the region's infrastructure.

Sandbagging for flood protection is generally considered helpful, but local governments are not typically involved in helping property owners sandbag. Individual property owners may decide to sandbag for protection, but this is not an action committee members want to include in the MAP, as longer-term retrofit protection methods are deemed preferable. Adding generator electrical circuits to support critical operations during power outages was discussed by almost every community. This activity is both an Emergency Services action and a Property Protection measure.

6. Public Education and Awareness

Public education and awareness activities are used to advise residents, elected officials, business owners, potential property buyers, and visitors about hazards, hazardous areas, and mitigation techniques they can use to protect themselves and their property. Examples of measures used to educate and inform the public include:

- Outreach projects
- Speaker series/demonstration events
- Hazard mapping
- Real estate disclosure
- Library materials
- School children educational programs
- Hazard expositions
- Inter-governmental coordination

Committee Discussion: Public education and outreach activities are a particular focus of emergency planners in the region and are ongoing, particularly through existing web sites, social media outlets and several CRS-related activities. Speaker series and demonstration events are supported by several of the local governments throughout the year, but may not rise to the importance of being included in the MAP for each of these communities. Many of these activities are supported or promoted by the PDCs, such as annual preparedness days. Some of these activities have been on hold because of COVID-19.

FEMA, working with the USACE, has revised many of the Flood Insurance Rate Maps for the region as studies are completed. Additional hazard mapping has been done by Henrico County in particular. Real estate disclosure, particularly for flood risk and radon risk, is guided by current State regulations and not influenced by local government. Library materials, school programs, and open houses are included in the MAP for interested communities.

Committee members discussed use of Community Emergency Response Teams (CERT) and potential existing actions; however, in several cases CERTs have altered functions or been reduced or eliminated during the COVID-19 disaster. The PDCs support several efforts at inter-governmental coordination, including the Emergency Management Alliance of Central Virginia, a voluntary association of government and key stakeholder organizations that manage emergency preparation, response, relief, recovery and mitigation in Central Virginia. There is also a CRS User's Group, facilitated by Wetlands Watch, that is very active among CRS and CRS-interested communities in some parts of the study area.

7.5 Selection of Mitigation Techniques

In order to determine the most appropriate mitigation techniques, committee members reviewed and considered the findings of the Capability Assessment and Risk Assessment. Other considerations included each mitigation action's effect on overall risk reduction, its ease of implementation, its degree of political and community support, its general cost-effectiveness and funding availability.

FEMA guidance for meeting the planning requirements of the Disaster Mitigation Act of 2000 also specifies that local governments should prioritize their mitigation actions based on the level of risk a hazard poses to the lives and property of a given jurisdiction. A Mitigation Technique Matrix (**Table 7.2**) shows that those hazards posing the greatest threat are addressed by the updated MAP.

The matrix provides the committee with the opportunity to cross-reference each of the priority hazards (as determined through the Risk Assessment) with the comprehensive range of available mitigation techniques, including prevention, property protection, natural resource protection, structural projects, emergency services, and public education and awareness. The Mitigation Action Plan includes an array of actions targeting multiple hazards, not just those classified as either high or moderate risk.

As part of the 2022 update, the committee reviewed several documents to assist with the development of new mitigation actions and the assessment of existing actions. Review documents included: 1) a spreadsheet of each community's capabilities and any mitigation program gaps subsequently identified; 2) each community's Comprehensive Plan, specifically components that may be compatible with mitigation goals, or that may be appropriate as mitigation actions; 3) contractor review of local floodplain regulations; 4) the mitigation action items from the existing plans with 2022 status information; and 5) several recommended publications, including FEMA Publication *Mitigation Ideas: A Resource for Reducing Risk to Natural Hazards*, January 2013, FEMA's *Mitigation Best Practices* and *Mitigation Action Portfolio* web site, and resilience design guidelines for Miami Beach, Boston and New York City.

Table 7.2: Mitigation Technique Matrix

Mitigation Technique	HIGH RISK HAZARDS			MODERATE RISK HAZARDS		
	Flooding	Severe Wind Events	Tornadoes	Severe Winter weather	Droughts and Extreme Heat	Thunderstorms
Prevention	✓	✓	✓	✓	✓	✓
Property Protection	✓	✓	✓	✓		✓
Natural Resource Protection	✓				✓	
Structural Projects	✓	✓	✓	✓		
Emergency Services	✓	✓	✓	✓	✓	✓
Public Education and Awareness	✓	✓	✓	✓	✓	✓

The mitigation actions proposed for local adoption are listed in the MAP on the pages that follow. They will be implemented according to the plan maintenance procedures established for the Richmond-Crater Hazard Mitigation Plan (see Section 8: Plan Maintenance Procedures). The action items have been designed to achieve the mitigation goals and priorities established by the committee.

Each proposed mitigation action has been identified as an effective measure to reduce hazard risk in the Richmond-Crater region. Each action is described with available background information such as the location of the project and general cost benefit information.

Other information provided includes data on cost estimates and potential funding sources to implement the action should funding be required (not all proposed actions are contingent upon funding). Most importantly, implementation mechanisms are provided for each action, including the designation of a lead agency or department responsible for carrying the action out, as well as a timeframe for its completion. These implementation mechanisms ensure that the Richmond-Crater Hazard Mitigation Plan remains a functional document that can be monitored for progress over time. Proposed actions are not listed in exact priority order though each has been assigned a priority level of "high," "moderate" or "low" as described in the previous section.

Table 7.3 describes the key elements of the Mitigation Action Plan, and **Table 7.4** lists the additional considerations that were evaluated for each proposed action once selected for inclusion in the Mitigation Action Plan. This includes social, technical, administrative, political, legal, economic, and environmental considerations collectively known as "STAPLEE" evaluation criteria.

As part of the plan update process, the committee reviewed the list of recommended actions included in their respective existing plans to determine if the actions should be deleted because they are completed, cancelled, or retained, and made recommendations regarding modified and new actions. Summary results of this review are included in Appendix G.

Table 7.3: Key Elements of the Mitigation Action Plan	
Proposed Action	Identifies a specific action that, if accomplished, will reduce vulnerability and risk in the impact area. Actions may be in the form of local policies (i.e., regulatory or incentive-based measures), programs or structural mitigation projects and should be consistent with any pre-identified mitigation goals and objectives.
Site and Location	Provides details with regard to the physical location or geographic extent of the proposed action, such as the location of a specific structure to be mitigated, whether a program will be Citywide, countywide or regional, etc.
Cost Benefit	Provides a brief synopsis of how the proposed action will reduce damages for one or more hazards.
Hazard(s) Addressed	Lists the hazard(s) the proposed action is designed to mitigate for.
Goal(s) Addressed	Indicates the Plan's established mitigation goal(s) the proposed action is designed to help achieve.
Priority	Indicates whether the action is a "high" priority, "moderate" priority, or "low" priority based on the established prioritization criteria.
Impact on Socially Vulnerable Populations	Indicates whether the action has a "high" impact, "moderate" impact , or "low" impact based on the established ranking criteria.
Estimated Cost	Indicates what the total cost will be to accomplish this action. This amount will be an estimate until actual final dollar amounts can be determined.

Table 7.3: Key Elements of the Mitigation Action Plan	
Potential Funding Sources	If applicable, indicates how the cost to complete the action will be funded. For example, funds may be provided from existing operating budgets or general funds, a previously established contingency fund, or a cost-sharing federal or state grant program.
Lead Agency/Department Responsible	Identifies the local agency, department or organization that is best suited to implement the proposed action.
Implementation Schedule	Indicates when the action will begin and when it is estimated to be completed. Some actions will require only a minimal amount of time, while others may require a long-term or continuous effort.

Table 7.4: STAPLE/E Prioritization Criteria for Actions to be Taken

Socially Acceptable

- Is the proposed action socially acceptable to the community(s)?
- Are there equity issues involved that would mean that one segment of a community is treated unfairly?
- Will the action cause social disruption?

Technically Feasible

- Will the proposed action work?
- Will it create more problems than it solves?
- Does it solve a problem or only a symptom?
- Is it the most useful action in light of other community(s) goals?

Administratively Possible

- Can the community(s) implement the action?
- Is there someone to coordinate and lead the effort?
- Is there sufficient funding, staff, and technical support available?
- Are there ongoing administrative requirements that need to be met?

Politically Acceptable

- Is the action politically acceptable?
- Is there public support both to implement and to maintain the project?

Legal

- Is the community(s) authorized to implement the proposed action? Is there a clear legal basis or precedent for this activity?
- Are there legal side effects? Could the activity be construed as a taking?
- Is the proposed action allowed by a comprehensive plan, or must a comprehensive plan be amended to allow the proposed action?
- Will the community(s) be liable for action or lack of action?
- Will the activity be challenged?

Table 7.4: STAPLE/E Prioritization Criteria for Actions to be Taken
Economically Sound
• What are the costs and benefits of this action? • Do the benefits exceed the costs? • Are initial, maintenance, and administrative costs taken into account? • Has funding been secured for the proposed action? If not, what are the potential funding sources (public, non-profit, and private)? • How will this action affect the fiscal capability of the community(s)? • What burden will this action place on the tax base or local economy? • What are the budget and revenue effects of this activity? • Does the action contribute to other community goals, such as capital improvements or economic development? • What benefits will the action provide?
Environmentally Sound
• How will the action affect the environment? • Will the action need environmental regulatory approvals? • Will it meet local and state regulatory requirements? • Are endangered or threatened species likely to be affected?

The following is a list of current funding sources and their acronyms as may be indicated in the mitigation actions. Additional acronyms used throughout this plan are interpreted in Appendix H. The pool of potential funding mechanisms is changing very rapidly as a result of COVID-19 and other Federal and state legislative priorities at the time of this update.

Key to Potential Funding Source Acronyms:

DHS U.S. Department of Homeland Security

- BRIC – Building Resilient Infrastructure and Communities
- HMGP – Hazard Mitigation Grant Program
- FMA – Flood Mitigation Assistance Program
- HHPD – Rehabilitation of High Hazard Potential Dams (HHPD) grant program

ARPA American Rescue Plan Act

USACE U.S. Army Corps of Engineers

- SFCP – Small Flood Control Projects
- FPMS – Flood Plain Management Services Program
- CAP – Continuing Authorities Program

DOI **U.S. Department of the Interior**

- LWCF – Land and Water Conservation Fund Grants

EDA **U.S. Economic Development Administration**

- DMTA – Disaster Mitigation and Technical Assistance Grants

EPA **U.S. Environmental Protection Agency**

- CWA – Clean Water Act Section 319 Grants

HUD **U.S. Department of Housing and Urban Development**

- CDBG – Community Development Block Grant Program

USDA **U.S. Department of Agriculture**

- EWP – Emergency Watershed Protection
- WPFP – Watershed Protection and Flood Prevention
- WSP – Watershed Surveys and Planning

Virginia

CFPF – Virginia Community Flood Preparedness Fund

Table 7.5 provides a matrix indicating that each critical and noncritical hazard affecting communities is addressed in the Mitigation Action Plan. Section 7.4 contains the Mitigation Action Plan for the Richmond-Crater region.

Table 7.5: Mitigation Actions for Critical and Non-Critical Hazards	Flooding	Severe Wind Events	Tornadoes	Severe Winter Weather	Droughts and Extreme Heat	Thunderstorms	Wildfires	Infectious Diseases	Earthquakes	Shoreline Erosion	Flooding Due to Impoundment Failure	Radon Exposure
Regional Actions	M*	M	M	M	M	M	M	M	M	M	M	M
Charles City Co	M	M	M	M	2	M	M	2	M	2	M	1,2
Chesterfield Co	M	M	M	M	M	M	M	M	M	M	M	M
Colonial Heights	M	M	3, 5	M	3	M	M	3	M	7	M	2,3
Dinwiddie Co	M	M	M	M	M	M	M	M	M	M	M	M
Town of McKenney	M	M	M	M	3,4	M	M	3	M	3	M	3,5
City of Emporia	M	M	M	M	4,8	M	M	4,8	M	4,8	M	M
Goochland Co	M	M	M	M	M	M	M	M	M	M	M	M
Greensville Co	M	M	M	M	M	M	M	M	M	1,9	M	M
Town of Jarratt	1, 2	1, 2	1	1, 2		1, 2	1		1, 2		1,2	1
Hanover Co	M	M	M	M	M	M	M	M	M	M	M	M
Town of Ashland	M	M	M	M	M	M	M	M	M	M	M	M
Henrico Co	M	M	M	M	M	M	M	M	M	M	M	M
City of Hopewell	M	M	M	M	M	M	M	M	M	M	M	M
New Kent Co	M	M	M	M	M	M	M	M	M	M	M	M
City of Petersburg	M	M	M	M	M	M	M	M	M	M	M	M
Powhatan Co	M	M	M	M	M	M	M	M	M	M	M	M
Prince George Co	M	M	M	M	M	M	M	M	M	M	M	M
City of Richmond	M	M	M	M	M	M	M	M	M	M	M	M
Town of Surry	1, 2	1, 2	1	1, 2		1, 2	1		1, 2		1,2	1
Sussex Co	M	M	M	M	M	M	M	M	M	M	M	M
Town of Stony Creek	1, 2	1, 2	2	1, 2		1, 2	1		1, 2		1,2	1
Town of Wakefield	1, 2	1, 2	2	1, 2		1, 2	1		1, 2		1,2	1
Town of Waverly	1, 2	1, 2	2	1, 2		1, 2	1		1, 2		1,2	1

** "M" indicates that 3 or more actions address this hazard.*

7.6 Mitigation Actions

REGIONAL MITIGATION ACTIONS

REGIONAL MITIGATION ACTION 1	
Strengthen regional strategy for incoming evacuees, to include plan development, traffic management, sheltering, and information sharing.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Richmond-Crater study area
Benefit Cost:	No single community can effectively assess and address the impacts of mass evacuations alone. Regional participation in the analysis and planning can reduce redundant resource expenditures and streamline the approach. Communities with fewest resources are most likely to benefit.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Wildfires, Earthquakes, Infectious Diseases
Goal(s) Addressed:	Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	DHS: BRIC, HMGP
Lead Agency/Department Responsible:	PDCs with local Emergency Managers
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

REGIONAL MITIGATION ACTION 2	
Continue to improve the quality, detail and availability of data used to prepare effective hazard assessments and vulnerability analyses. Data may include, but are not limited to, gauging systems, inundation mapping using existing gauges, GIS data, flood insurance coverage and loss data, assessor data and other structure-specific information, landslide- and radon-related geological data, and pandemic-related economic impact data. Local reports that are fed into NCEI are also important for calculating event frequency and total losses. Hazard data are multi-purpose and may be used to support evacuation mapping and planning. The PDCs should consider serving as administrator(s) of a regional hazard data hub.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Richmond-Crater study area
Benefit Cost:	Economies of scale can be realized with the regional PDCs acting as data hubs. Better data on hazard frequency and impacts improve BCR calculations for other hazard mitigation projects, and in cases such as evacuation planning, make the planning more effective.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All Hazards
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	DHS; USACE
Lead Agency/Department Responsible:	PlanRVA and Crater PDC
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
An example of a related project might be improving critical infrastructure data in coastal communities, and more critically examining the relationship of critical facilities to projected flood risk and sea level rise.	

REGIONAL MITIGATION ACTION 3	
Integrate mitigation goals and actions into other regional planning mechanisms, for example regional economic development, resiliency, transportation, parks and trail, and watershed plans.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Richmond-Crater study area
Benefit Cost:	The PDCs play a large role in local and regional level planning in the study area. Their knowledge and expertise regarding the various planning efforts underway will create low-cost synergies among each community's plans, and among regional efforts as a whole.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 2: Objective 2.1; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	PlanRVA and Crater PDC
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

REGIONAL MITIGATION ACTION 4	
Work with state partners and neighboring localities to monitor and implement Next Generation 911 GIS data standards.	
BACKGROUND INFORMATION	
Site and Location:	Crater PDC region
Benefit Cost:	Improvements to 911 GIS data reduce response times and reduce hazard impacts.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 2: Objective 2.1; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS
Lead Agency/Department Responsible:	Crater PDC
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

REGIONAL MITIGATION ACTION 5	
Identify communities that need more current NFIP repetitive flood loss data for CRS and other planning purposes. **1. Request data from FEMA for all NFIP-participating communities on a regular basis, to include repetitive flood loss data and minus-rated policies;** **2. Update repetitive flood loss area polygons every 2 years;** **3. Rank repetitive flood loss areas by social vulnerability and provide areas and rankings to communities; and** **4. Identify areas subject to future flooding due to climate change and sea level rise.**	
BACKGROUND INFORMATION	
Site and Location:	Throughout the PlanRVA and Crater regions
Benefit Cost:	Handling these data requests at the regional level and on a regular basis will help communities be more prepared to examine the data for useful analysis. Mitigation projects to address repetitive flood loss properties are more likely to have positive BCRs.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Variable across the region
Estimated Cost:	Staff time
Potential Funding Sources:	HMGP, State funds
Lead Agency/Department Responsible:	PDCs with VaDCR and VDEM
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	
The PDCs and VDEM may also be able to support development of Substantial Damage Management Plans and Repetitive Flood Loss Area Analyses (RLAAs), which are creditable for CRS communities. Data may also be integrated with data from the State's Crisis Track software post-disaster.	

REGIONAL MITIGATION ACTION 6	
Provide Community Rating System (CRS) support for interested communities, to include: application assistance, Plans for Public Information (PPI), Substantial Damage Management Plans, Repetitive Flood Loss Area Analyses (RLAAs), web site development, and library resources.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the PlanRVA and Crater regions
Benefit Cost:	The time investment to apply for and participate in the CRS is substantial. Regional assistance through provision of application assistance, templates for certain activities, and labor assistance with some of the record keeping could increase the number of participating communities, which reduces costs of flood insurance and keeps premium money *in the community*.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding; Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate to High; variable across the region
Estimated Cost:	Staff time
Potential Funding Sources:	USACE; existing resources
Lead Agency/Department Responsible:	PDCs with VaDCR and Wetlands Watch
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

REGIONAL MITIGATION ACTION 7		
Address high and significant hazard dam safety in the region. Assist Virginia DCR with investigating significant hazard dams region-wide for possible reclassification as high hazard. Inspect high hazard potential dams for necessary retrofits/repairs. Implement retrofits in partnership with dam owners. This action includes outreach to: 1) private dam owners to either provide or offer to collect data, and to provide additional guidance and resources; and 2) the public, to build awareness through signage installation and other media regarding the dangers associated with low-head dams.		
BACKGROUND INFORMATION		
Site and Location:	High and significant hazard dams throughout the PlanRVA and Crater regions	
Benefit Cost:	Local engineering expertise and regional knowledge may prove effective in supplementing existing, limited state resources for inspecting and rating dams. Dam inundation planning is similarly impacted.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding due to Impoundment Failure, Flooding
Goal(s) Addressed:		Goal 1: Objectives 1.1, 1.2, 1.4; Goal 2; Goal 4: Objectives 4.1, 4.2, 4.3
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		High, if dams in areas with high NRI risk for flooding are prioritized
Estimated Cost:		TBD
Potential Funding Sources:		DHS: HHPD, BRIC, HMGP; USACE
Lead Agency/Department Responsible:		Virginia DCR, Crater PDC, PlanRVA
Implementation Schedule:		Continuously over next 5 years
ADDITIONAL COMMENTS		

			REGIONAL MITIGATION ACTION 8
Use commercially available radon test kits to determine radon levels in structures. Evaluate radon data against known geological formations in the region to determine geographic variability in vulnerability. End product will be a refined map of radon zones.			
BACKGROUND INFORMATION			
Site and Location:	Throughout the PlanRVA and Crater regions, particularly areas of suspected high radon concentration over the western extent of the Yorktown Formation.		
Benefit Cost:	Radon exposure has a high cost; it is a known cause of lung cancer, especially in smokers. Radon tests are inexpensive (<$50) and structural mitigation is inexpensive. The results of additional testing and map refinement will provide local and state officials with additional tools to advise homeowners when testing is advised, resulting in mitigation of lung cancer. Leaders at the local, regional and State level will gain valuable information to determine if a change in capabilities is warranted (e.g., building code requirements, real estate transaction disclosures, or testing).		
MITIGATION ACTION DETAILS			
Hazard(s) Addressed:		Radon Exposure	
Goal(s) Addressed:		Goal 1; Goal 2; Goal 3	
Priority (High, Moderate, Low):		Moderate	
Impact on Socially Vulnerable Populations:		Variable across region; more data required to make determination	
Estimated Cost:		Estimated $30/structure, plus mapping costs	
Potential Funding Sources:		EPA, DHS: HMGP, BRIC	
Lead Agency/Department Responsible:		PDCs, College of William & Mary	
Implementation Schedule:		Begin project within 2 years of plan adoption; project may extend beyond 2027 planning horizon	

REGIONAL MITIGATION ACTION 9	
Provide assistance to communities and residents regarding Risk Rating 2.0, the NFIP's new flood insurance rating policy standards. This action includes assistance with: **1) Evaluation of rating methodology and accuracy;** **2) Messaging and outreach to homeowners and renters;** **3) Elevation Certificate correction; and** **4) Mitigation assistance for property protection, including retrofit guidance and physical alterations to structures or structure components.**	
BACKGROUND INFORMATION	
Site and Location:	Flood-prone areas throughout the region
Benefit Cost:	The rollout of Risk Rating 2.0 is likely to introduce uncertainty in the flood insurance market. The state and region have an interest in helping ensure that property owners retain flood insurance, so good information available locally will help alleviate uncertainty.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding; Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 3: Objective 3.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Variable across the region; High, if effort is focused on areas with high NRI flood risk such as portions of Dinwiddie and Sussex counties
Estimated Cost:	<$5,000
Potential Funding Sources:	HMGP, BRIC
Lead Agency/Department Responsible:	VaDCR, PDCs
Implementation Schedule:	Within 1 year of plan adoption

REGIONAL MITIGATION ACTION 10	
Work with private companies to advance continuity of operations, including but not limited to power, gas, and water service restoration. Mitigation actions may include implementation of system redundancies, mutual aid agreements or other partnerships to address critical capability gaps. Physical retrofits may increase resilience of critical infrastructure, such as burying power lines and provision of dependable backup power to water and wastewater treatment facilities.	
BACKGROUND INFORMATION	
Site and Location:	Throughout Richmond-Crater region
Benefit Cost:	Damages are reduced when critical lifelines are returned to service promptly after a disaster. By creating partnerships between private utility providers, the region can expect a faster return to full operations, thereby reducing losses to business and property owners.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	ARPA; DHS
Lead Agency/Department Responsible:	Dominion Energy, public and private utility providers, PDCs
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	

REGIONAL MITIGATION ACTION 11	
Partner with VDOF on sharing Wildland Urban Interface data in support of efforts to develop local tools (ordinances, outreach templates, etc.) to determine impacts of fire and climate change as well as potential local projects. **Partner with Virginia Department of Wildlife Resources (VDWR) regarding Wildlife Action Plan climate change assessment and development of Wildlife Climate Change Adaptation Committee.**	
BACKGROUND INFORMATION	
Site and Location:	Throughout Richmond-Crater region
Benefit Cost:	Builders and property owners benefit when regional and state plans set out clear, concise direction for planning and policy.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Wildfire, Severe Wind Events; Droughts and Extreme Heat
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	PDCs, VDOF, VDWR
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Existing Capabilities at VDOF include: Forest Action Plan, FireWise, Ready Set Go – includes mitigation planning guidance at community level and grant fund guidance. The PDCs can support these capabilities by taking part in planning committees as regional stakeholders, and by disseminating information to their respective community partners.	

REGIONAL MITIGATION ACTION 12	
Convene interested parties to discuss NFIP status of the Town of Waverly, and encourage participation. Notify FEMA that town boundaries are incorrect on the FIRM.	
BACKGROUND INFORMATION	
Site and Location:	Town of Waverly
Benefit Cost:	NFIP participation would benefit Waverly property owners by making flood insurance available, and opening up some types of disaster assistance.

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 3: Objective 3.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	
Estimated Cost:	Staff time only
Potential Funding Sources:	n/a
Lead Agency/Department Responsible:	PlanRVA, with assistance from VDCR, Sussex County and Waverly
Implementation Schedule:	Immediately

ADDITIONAL COMMENTS
FEMA FIRM for Waverly/Sussex County does not show the town's current boundaries correctly. The town does not participate in the NFIP. The town's sewage treatment plant is also located near the SFHA.

REGIONAL MITIGATION ACTION 13		
Strengthen community resilience planning and project implementation through: 1) Public Education/Awareness – Create resilience dashboard to share information and data with the general public about resilience issues, including flood risk. Enhance other outreach efforts to educate the public about hazard risk and regional resilience. 2) Engage communities in Resilience Adaptation Feasibility Tool (RAFT) process and support training and implementation. 3) Combine elements of regional resilience efforts into regional plan to satisfy DCR and CFPF requirements. 4) Resilience Program and Project Cobenefit Connector - expand current PDC staff capacity, web presence and guidance documents to better understand and educate localities on fully harnessing existing and future grant programs given the cobenefits of resilience-related projects. 5) Business resiliency training.		
BACKGROUND INFORMATION		
Site and Location:	Throughout Richmond-Crater region	
Benefit Cost:	Community resilience measures that permeate all facets of local and regional government save resources in post-disaster scenarios.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		All hazards
Goal(s) Addressed:		Goal 1; Goal 2; Goal 3: Objective 3.1
Priority (High, Moderate, Low):		Moderate
Impact on Socially Vulnerable Populations:		Moderate
Estimated Cost:		~$100,000
Potential Funding Sources:		CFPF
Lead Agency/Department Responsible:		PlanRVA & Crater PDC, DCR, UVA, W&M, ODU, Chambers of Commerce, Economic Development departments
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		

CHARLES CITY COUNTY MITIGATION ACTION 1	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on floodprone areas.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate in eastern half of the county
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Planning and Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Generators, in particular, are identified as a high priority need at: Roxbury Pumping Stations (generator failed); Kimages Well #1 (generator failed); Animal Shelter (no generator); Mt Zion Vacuum Station (no generator); and Ruthville Fire & EMS (no generator).	

CHARLES CITY COUNTY MITIGATION ACTION 2	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, and earthquakes.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases, Shoreline Erosion
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CHARLES CITY COUNTY MITIGATION ACTION 3	
Work with private utilities to keep right-of-way clear.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on evacuation routes
Benefit Cost:	Right of ways must remain clear of debris that clogs drains and trees that block roads so that drainageways and roads continue to operate as designed.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CHARLES CITY COUNTY MITIGATION ACTION 4		
Reduce rural wildfire risk by increasing resources used to fight wildfires. Equipment needs may include, but are not limited to: dry hydrants, drafting equipment, personnel and tankers.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	Rural wildfire risk and raze risk to rurally-located structures can be reduced by strategically locating and maintaining dry hydrants, and having sufficient personnel, drafting equipment and tanker trucks available to deploy quickly.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Wildfire
Goal(s) Addressed:		Goal 1: Objectives 1.1, 1.4: Goal 4: Objectives 4.1, 4.2
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		TBD
Potential Funding Sources:		Existing budgets; DHS: HMGP;ARPA
Lead Agency/Department Responsible:		Administration
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		
Dry hydrants are currently located in just 3 areas of the county: the Industrial Park area, near Kimages Road and Wayside Road (State Route 607) in the southwest part of the county, and in the southeast along Wilcox Neck Road. The Charles City County Fire Department has identified the following needs: 2 engines with 1000 gallons of water on each side; 1 tanker (2200 gallons); 12 firefighters working 24/7, 3 shifts; and, 3 ambulances (1 ALS, 2 BLS). The Charles City County Volunteer Fire Department has identified the following needs: 1 engine with 1000 gallons of water; 2 ambulances BLS; and, 1 rescue truck.		

CHARLES CITY COUNTY MITIGATION ACTION 5	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Examples include the *Virginia Hurricane Evacuation Guide* and data collected through VDEM's Crisis Track after a disaster.	

CHESTERFIELD COUNTY MITIGATION ACTION 1	
Conduct regular review of repetitive loss and severe repetitive loss NFIP data. Continue to work with VDEM and FEMA to mitigate repetitive and SRL properties as owners demonstrate interest in participation. Projects may include acquisition, relocation, elevation or retrofits.	
BACKGROUND INFORMATION	
Site and Location:	Repetitively flooded areas in the county
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance. Helping these owners, in particular, will have a positive impact on the flood vulnerability of the county.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Moderate – 2 rep loss areas along Falling Creek, near Newby's Bridge Rd, 1 rep loss area near Screamersville, and1 rep loss area near Mt Blanco Low – all other rep loss areas
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Environmental Engineering – Floodplain Manager
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CHESTERFIELD COUNTY MITIGATION ACTION 2	
Enhance and centralize use of GIS to gather damage assessment information by all county agencies including establishing naming conventions and data categories.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objectives 4.1 and 4.3
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time and associated software
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	GIS, Risk Management, Building Inspections
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CHESTERFIELD COUNTY MITIGATION ACTION 3	
Protect critical facility infrastructure through quick connects for generator power, wind and snow retrofits, and other protective measures, which may include permanent generators, elevation, or relocation. This action may include minor flood control structures and stormwater system modifications.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Radon Exposure
Goal(s) Addressed:	Goal 3, Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC, FMA; ARPA; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
The county's new COOP will aid in the process of identifying needs.	

CHESTERFIELD COUNTY MITIGATION ACTION 4	
Provide training opportunities to educate all county staff with a role in disaster recovery regarding mitigation principles and long term recovery best practices, particularly related to housing options.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Preparing all county staff to assist citizens and themselves in the event of a disaster reduces damages and allows faster recovery. If staff are also able to incorporate mitigation principles during recovery/rebuilding, future damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3: Objective 3.2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Annually/Ongoing
ADDITIONAL COMMENTS	
Introduction to EM provided to all interested county staff, annually. EM is revising recovery training and developing new best practices, restructuring the EOC and developing new training techniques/priorities.	

CHESTERFIELD COUNTY MITIGATION ACTION 5		
Encourage whole community preparedness through education regarding hazards affecting the community and steps to reduce vulnerability.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	Sharing mitigation priorities with a broad group of stakeholders encourages multiple small steps that reduce vulnerability to individual businesses, homes and families.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		All hazards
Goal(s) Addressed:		Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		High
Estimated Cost:		$12,000/yr for materials plus staff costs
Potential Funding Sources:		DHS: HMGP; ARPA; Virginia CFPF
Lead Agency/Department Responsible:		Emergency Management
Implementation Schedule:		Annually/Ongoing
ADDITIONAL COMMENTS		
County has expanded public outreach to focus on the whole community, including seniors, populations with medical, functional, and access needs, lesser served populations, civic associations, youth, and faith-based organizations.		

CHESTERFIELD COUNTY MITIGATION ACTION 6	
Use abandoned mines mapping to guide zoning, development, and building inspection decisions. Work with Virginia Department of Energy to continue to refine the Locations of Abandoned Mines in the Greater Richmond Area maps.	
BACKGROUND INFORMATION	
Site and Location:	See maps in Section 5
Benefit Cost:	Measures that discourage or prohibit new development in areas over or near abandoned minds reduce vulnerability to dangerous sinkholes or other land movements that may affect structural stability, especially to underground components.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Sinkholes, Landslides, Earthquakes
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 3: Objective 3.2; Goal 4: Objectives 4.1, 4.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Inspections; Environmental Engineering; Planning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Mapping is part of development review process. Both the physical hazard and historical significance are considered.	

CHESTERFIELD COUNTY MITIGATION ACTION 7	
Enhance processes and procedures in building permit application system within Enterprise Land Management System (ELM) to comprehensively capture damage assessment data.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 3: Objective 3.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	GIS; Inspections
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CHESTERFIELD COUNTY MITIGATION ACTION 8	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes. Consider development of a standalone floodplain ordinance.	
BACKGROUND INFORMATION	
Site and Location:	Flood prone areas countywide
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Inspections, Planning, Environmental Engineering
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CHESTERFIELD COUNTY MITIGATION ACTION 9		
Maintain StormReady certification (last certification 2020).		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	StormReady helps arm communities with the communication and safety skills needed to save lives and property--before, during and after the event. StormReady helps community leaders and emergency managers strengthen local safety programs.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Extreme Heat
Goal(s) Addressed:		Goal 1; Goal 2
Priority (High, Moderate, Low):		Low
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		Staff time
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Emergency Management
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		

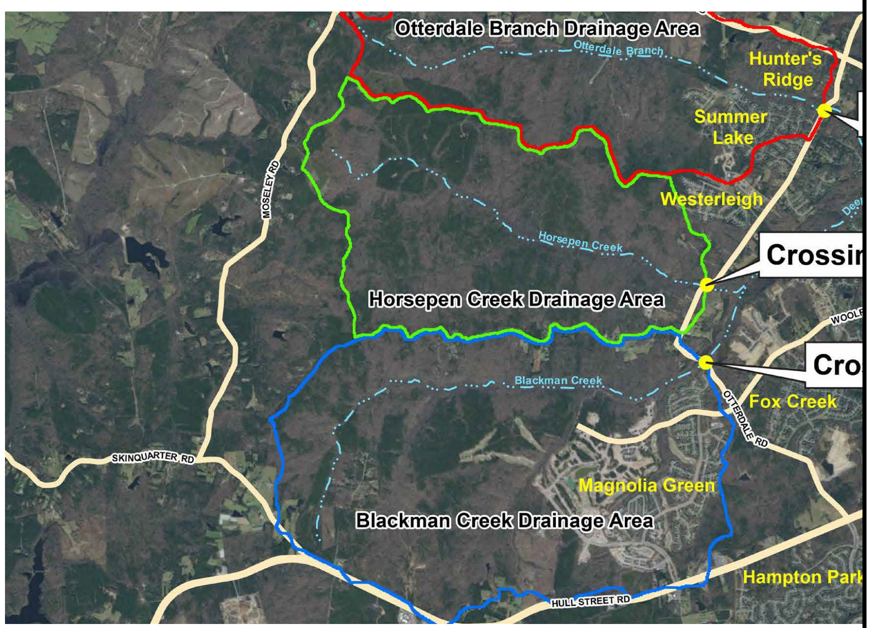
CHESTERFIELD COUNTY MITIGATION ACTION 10	
Incorporate hazard mitigation potential in decision making for acquiring new park land and open space easements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Strategic acquisition of land by Parks and Recreation can reduce vulnerability to a variety of hazards.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Wildfires, Droughts and Extreme Heat, Landslides, Shoreline Erosion, Sinkholes
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3: Objective 3.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC, FMA; ARPA; Virginia CFPF
Lead Agency/Department Responsible:	Parks and Recreation; FOLAR
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CHESTERFIELD COUNTY MITIGATION ACTION 11		
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.		
BACKGROUND INFORMATION		
Site and Location:	Countywide, with particular emphasis on floodprone areas.	
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:		Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		TBD
Potential Funding Sources:		DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:		Community Development; Planning; Environmental Engineering
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		

CHESTERFIELD COUNTY MITIGATION ACTION 12		
Apply hazard mitigation concepts across development project review, capital improvement planning and all other community planning efforts.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	Hazard mitigation is forward-thinking, and thus requires application across disciplines in order to reduce damages.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		All hazards
Goal(s) Addressed:		Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):		Moderate
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		Staff time
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Community Development; Planning
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		

CHESTERFIELD COUNTY MITIGATION ACTION 13	
Install new monitoring systems for county-owned dams.	
BACKGROUND INFORMATION	
Site and Location:	County-owned dams, high and significant hazard potential, countywide
Benefit Cost:	Real-time monitoring is necessary for early notification of dam/impoundment problems, information that can be used to notify the public to take protective action. Public information helps arm citizens with the communication and safety skills needed to save lives and property--before, during and after a flood event.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	>$330,000
Potential Funding Sources:	DHS: HHPD; CIP
Lead Agency/Department Responsible:	Department of Utilities
Implementation Schedule:	Within 3 years of funding
ADDITIONAL COMMENTS	

CHESTERFIELD COUNTY MITIGATION ACTION 14	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in the event of a hazard event. Acquire additional resources to build components of a flood warning system and local evacuation plan.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE; USGS
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Incorporate any manufactured home park evacuation plans promulgated in response to the floodplain management ordinance at Sec. 19.1-503(10).	

CHESTERFIELD COUNTY MITIGATION ACTION 15	
Improve stormwater management system to reduce flooding, particularly in neighborhoods. Projects may include raising roads and regrading to eliminate 100-year flood hazard, redesign and installation of infrastructure to more properly handle current and future flows.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, but with particular emphasis on Otterdale Road improvements at Otterdale Branch, Horsepen Creek and Blackman Creek. 
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses. In some cases, the risk of flooding is so great that relocation, demolition or elevation is the only cost effective and safe solution.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Moderate

Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	$25,000,000
Potential Funding Sources:	100% county funded
Lead Agency/Department Responsible:	Environmental Engineering
Implementation Schedule:	Ongoing; Construction of all Otterdale Road crossings expected complete by 2024.
ADDITIONAL COMMENTS	
County funding has been identified to address existing drainage issues on Otterdale Road between Woolridge Road and Genito Road. Preliminary engineering to address the Blackman Creek, Horsepen Creek, and Otterdale Branch crossings is underway. Project brochure available online at: https://www.chesterfield.gov/DocumentCenter/View/21384/Otterdale-Rd-Drainage-CIM---Project-Brochure-PDF	

CHESTERFIELD COUNTY MITIGATION ACTION 16	
Develop and expand use of mass notification tool. Final system should have four audiences for messaging: 1) residents; 2) employees; 3) IPAWS all hazard notifications; and 4) a community engagement tool. Include notification system for dam inundation area dwellers, as identified on recorded plats.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Droughts and Extreme heat, Earthquakes, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.2, 1.4; Goal 4: Objectives 4.1, 4.3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	$71,000/year plus staff time
Potential Funding Sources:	USGS; USACE; DHS: HMGP; Virginia CFPF; ARPA; existing budget
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	
Investigate the possibility of using NWS weather radio for non-weather related messaging, as well.	

CHESTERFIELD COUNTY MITIGATION ACTION 17	
Finalize and implement county COOP. Coordinate implementation across all county departments.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	An effective COOP helps identify and reduce vulnerabilities in the county's operational procedures. The plan requires continuous refinement and updating.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate (it keeps critical human services going)
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	within 2 years of plan adoption
ADDITIONAL COMMENTS	
COOP is substantially complete.	

CITY OF COLONIAL HEIGHTS MITIGATION ACTION 1	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas throughout the city
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objective 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate to High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing budgets and staff
Lead Agency/Department Responsible:	Building Inspection Department
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF COLONIAL HEIGHTS MITIGATION ACTION 2

Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.

BACKGROUND INFORMATION	
Site and Location:	Citywide, but with particular emphasis on Newcastle Apartments in the Old Town Creek floodway and floodplain. Safe evacuation of these buildings during flood events is problematic.  *Source: Virginia Flood Risk Information System*
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses. In some cases, the risk of flooding is so great that relocation, demolition or elevation is the only cost effective and safe solution.

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High – Newcastle Apartments rep loss area Moderate – 2 rep loss areas along Swift Creek west of Jefferson Davis Highway Low – rep loss area east of I-95 and north of Temple Ave, along Old Town Creek
Estimated Cost:	Depends on method selected to address the problem.
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Fire and EMS; Planning and Community Development; Economic Development; PDC
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	
Additional projects include projects to repair/replace/retrofit aging infrastructure, such as: shelter retrofits; protection for Lakeview Elementary which is in the SFHA; repairs to flood-damaged stormwater components; protection for sewer pump stations; and aging sewer and water lines and components (Conjure's Neck and Boulevard north of Temple).	

CITY OF COLONIAL HEIGHTS MITIGATION ACTION 3	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, earthquakes, and tornado. Customize messaging to address: repetitive flood loss areas, importance of flood insurance coverage, and the high vulnerability of certain populations.	
BACKGROUND INFORMATION	
Site and Location:	Citywide, with particular emphasis on repetitive flood loss areas.
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	~$5,000
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 1 year of plan adoption

ADDITIONAL COMMENTS
The current messaging/outreach the City is deploying is not reaching the targeted populations. Officials are optimistic about reworking the current system to address more people and measuring the number of people reached.

CITY OF COLONIAL HEIGHTS MITIGATION ACTION 4	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Repetitively flooded areas in the city
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance, and for targeting flood risk messaging per action #4 above.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Fire and EMS, PDC and VDEM
Implementation Schedule:	Within 2 years of plan adoption and regularly thereafter as new data are provided
ADDITIONAL COMMENTS	

CITY OF COLONIAL HEIGHTS MITIGATION ACTION 5	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to build components of a flood warning system and local evacuation plan, including: new IFLOWS gauges (especially, Swift Creek, Swift Creek dam and Old Town Creek), road crossing elevations for county, city and state-owned roads, a flood alert system, and an additional tornado siren for the north end of the City near Tussing Elementary and Conjure's Neck.	
BACKGROUND INFORMATION	
Site and Location:	Citywide, with particular emphasis on the Swift Creek floodplain, Sherwood Hills, and Conjure's Neck, as described above
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Fire and EMS
Implementation Schedule:	Within 4 years of plan adoption

CITY OF COLONIAL HEIGHTS MITIGATION ACTION 6	
Repair flood gates on Lakeview Dam, as identified in after action report from the last flood event that impacted the dam.	
BACKGROUND INFORMATION	
Site and Location:	Lakeview Dam is located in a meander bend of Swift Creek in the northwest portion of the City.
Benefit Cost:	Critical infrastructure requires regular upkeep, maintenance and repairs to operate at design capacity. Repairs to the dam are far less expensive than the potential flooding that could result should the flood gates fail.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HHPD, HMGP; USACE
Lead Agency/Department Responsible:	Emergency Management, VaDCR
Implementation Schedule:	Immediately; identify funding source within 1 year of
ADDITIONAL COMMENTS	
Lakeview Dam is privately-owned and was built in 1920; it is considered a high hazard potential dam. Although no structures are listed as potential impact structures on the Dam Safety Data Sheet, the dam impounds water above the Sherwood Hills neighborhood and access/egress to that neighborhood during flood events on Swift Creek is very limited.	

CITY OF COLONIAL HEIGHTS MITIGATION ACTION 7		
Include additional reviewers on Design Review Committee for new development, specifically to review projects for hazard-related vulnerabilities. Include staff training for decision making tools, such as those developed by VIMS Center for Coastal Resources Management for shoreline development and the Certified Floodplain Manager program from the Association of State Floodplain Managers.		
BACKGROUND INFORMATION		
Site and Location:	Citywide	
Benefit Cost:	Early review of projects to reduce existing and future hazard vulnerabilities reduce future damages.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Flooding due to Impoundment Failure, Wildfires, Landslides, Shoreline Erosion, Sinkholes
Goal(s) Addressed:		Goal 1; Goal 4
Priority (High, Moderate, Low):		Moderate
Impact on Socially Vulnerable Populations:		High
Estimated Cost:		Minimal
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Planning and Community Development, Emergency Management
Implementation Schedule:		Within 2 years of plan adoption
ADDITIONAL COMMENTS		
This action includes elements from the Comprehensive Plan Environment Policies section.		

DINWIDDIE COUNTY MITIGATION ACTION 1	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas of the county
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance, and for targeting flood risk messaging.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Moderate – Single rep loss area east of Namozine Creek, north of New Cox Road
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning/Zoning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Dinwiddie County currently has 1 repetitive loss area identified in Section 5.	

DINWIDDIE COUNTY MITIGATION ACTION 2	
Address road flooding in the county. Appropriate measures may include elevation of bridges, maintenance of roadside ditches, and improvements to BMPs.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Road flooding impacts safety and welfare of citizens and travelers. Impassable roads present a dangerous hazard for drivers, and for first responders.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate to High
Estimated Cost:	TBD
Potential Funding Sources:	VDOT; county CIP
Lead Agency/Department Responsible:	Emergency Management, VDOT
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 3	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, tornados and earthquakes.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Minimal
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 4		
Continue to refine and update Continuity of Operations Plan (COOP) with lessons learned from COVID-19 pandemic.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	An effective COOP helps identify and reduce vulnerabilities in the county's operational procedures. The plan requires continuous refinement and updating, especially post-disaster when memories are fresh regarding how the plan can be improved.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		All hazards
Goal(s) Addressed:		Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):		Moderate
Impact on Socially Vulnerable Populations:		Moderate
Estimated Cost:		Staff time
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Emergency Services
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		

DINWIDDIE COUNTY MITIGATION ACTION 5	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes. Ensure easy access to FEMA floodplain maps by citizens and property owners.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas throughout the county
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objective 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate to High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning/Zoning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 6	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, and stormwater management system improvements. Conduct countywide facilities assessment, including schools, to determine vulnerability to multiple hazards, continuous power availability and utility redundancies.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Critical facilities operated by the wastewater authority and the Dinwiddie County Water Authority are of particular concern.	

DINWIDDIE COUNTY MITIGATION ACTION 7	
Increase water/wastewater treatment systems resiliency with County, McKenney and two private subdivisions with their own water systems. Measures may include generators and additional wells.	
BACKGROUND INFORMATION	
Site and Location:	Stony Springs and Lew Jones Village are the private subdivisions.
Benefit Cost:	Safe drinking water in post-disaster scenarios is a basic necessity both for recovery and for safety of citizens.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Wildfires, Severe Winter Weather, Droughts and Extreme Heat, Earthquakes
Goal(s) Addressed:	Goal 4: Objectives 4.1 and 4.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP
Lead Agency/Department Responsible:	Dinwiddie County Water Authority, wastewater authority
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 8	
Integrate mitigation plan goals and actions into other appropriate planning mechanisms such as comprehensive plans and capital improvement plans.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Mitigation actions that are represented in various plans, budgets and programming are more likely to be funded sufficiently and implemented because the number of people engaged in making the actions happen increases.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Planning; Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 9	
Integrate Health Department and Emergency Management operations in the event of a health-related event, such as pandemic. Address Incident Command Services at both departments; coordinate with the PDC and other regional entities, and prepare post-incident review of COVID response.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Aligning agency goals within county government helps ensure a better-coordinated response process.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Infectious Diseases, Radon Exposure
Goal(s) Addressed:	Goal 2; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate to High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Emergency Management, Health Department, PDC
Implementation Schedule:	Within 1 year of plan adoption
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 10	
Fill and train GIS/addressing staff and planner level position. Expand the Planning Department staff to more effectively and efficiently address short-term and long-term planning needs.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; ARPA
Lead Agency/Department Responsible:	Emergency Management, Planning/Zoning
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 11	
Design any new county schools to current shelter standards.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	New schools that can also serve as shelters benefit the county in numerous ways because stringent design requirements ensure protection from a variety of hazards.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts & Extreme Heat, Earthquakes
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Design costs
Potential Funding Sources:	CIP
Lead Agency/Department Responsible:	Emergency Management, County Administration
Implementation Schedule:	Long-term
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 12	
Develop methods for encouraging private property owners to properly maintain BMPs.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, several locations
Benefit Cost:	Ill-maintained BMPs can contribute to flooding problems and disturb valuable ecosystem.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Winter Weather, Shoreline Erosion, Landslides, Sinkholes
Goal(s) Addressed:	Goal 1, Goal 2, Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Methodology development requires staff time, but maintenance will cost landowners.
Potential Funding Sources:	TBD
Lead Agency/Department Responsible:	Environmental
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	

DINWIDDIE COUNTY MITIGATION ACTION 13	
Study capacity of existing stormwater system components, including culverts and other structures, to determine if sizing is sufficient for current and future flooding and precipitation conditions. Identify and replace vulnerable or undersized structures with bridges, larger culverts or other measures to reduce flood hazards. Implement program for regular inspections and maintenance of roadside ditches and stream channels.	
BACKGROUND INFORMATION	
Site and Location:	Countywide study
Benefit Cost:	Stormwater conveyances are necessary in urbanized areas to alleviate flooding. Improvements over time are necessary to retrofit incorrectly sized systems, and to accommodate changes in precipitation rates and frequency.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate to High
Estimated Cost:	TBD
Potential Funding Sources:	Virginia CFPF
Lead Agency/Department Responsible:	Environmental, VDOT
Implementation Schedule:	Within 1 year of plan adoption
ADDITIONAL COMMENTS	
The county plans to build these measures into the county resilience plan in order to become eligible for CFPF money for planning and implementation.	

TOWN OF MCKENNEY MITIGATION ACTION 1	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA, if any.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Although the town does not have a mapped SFHA through FEMA, they do participate in the NFIP and flood insurance is available. Town officials should monitor the flood insurance loss list for any claims to determine if reconsideration of flood hazard areas is or may become advisable.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Mayor and Administration
Implementation Schedule:	
ADDITIONAL COMMENTS	

TOWN OF MCKENNEY MITIGATION ACTION 2	
Continue to work with VDOT to evaluate and mitigate at-risk roads.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Roads are critical infrastructure in this town.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Earthquakes, Landslides
Goal(s) Addressed:	Goal 4: Objectives 4.1, 4.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	Dinwiddie County, VDOT
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF MCKENNEY MITIGATION ACTION 3	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, tornado, and earthquakes.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases, Shoreline Erosion
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF MCKENNEY MITIGATION ACTION 4	
Increase water/wastewater treatment systems resiliency between Dinwiddie County, the Town of McKenney and two private water systems.	
BACKGROUND INFORMATION	
Site and Location:	Town and surrounding county
Benefit Cost:	Critical infrastructure resiliency can be a low-cost way to supplement existing systems and help ensure the utilities stay online during a disaster.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Wildfires, Severe Winter Weather, Droughts and Extreme Heat, Earthquakes
Goal(s) Addressed:	Goal 4: Objectives 4.1 and 4.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; ARPA
Lead Agency/Department Responsible:	Town officials, Dinwiddie County Water Authority, private system owners
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

TOWN OF MCKENNEY MITIGATION ACTION 5	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, mapping to determine detailed flood hazards, and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Town Administration
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF MCKENNEY MITIGATION ACTION 6	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Town Administration
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 1	
Investigate all public utility lines to evaluate their resistance to flood, wind, and winter storm hazards.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Provision of public utilities during and after disasters is critical to public safety.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	$75,000 for inspection & report; retrofit costs TBD
Potential Funding Sources:	DHS: HMGP, BRIC; ARPA
Lead Agency/Department Responsible:	Public Utilities
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 2	
Complete replacement of Halifax Street Bridge.	
BACKGROUND INFORMATION	
Site and Location:	Halifax Street crosses Metcalf Branch southeast of the intersection of Routes 58 and 301. Area is identified as Zone A on the FIRM.
Benefit Cost:	The bridge is aging and in disrepair and may be a culprit in the repetitive flooding reported in the area.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	$150,000 (2016/17)
Potential Funding Sources:	CIP
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Within 10 years of plan adoption
ADDITIONAL COMMENTS	
Building adjacent to the bridge (north side) is in SFHA and contains numerous hazardous materials.	

CITY OF EMPORIA MITIGATION ACTION 3	
Continue to review and make recommendations for improvements to the stormwater system.	
BACKGROUND INFORMATION	
Site and Location:	Citywide; improvements at industrial park and Emporia Shopping Center were budgeted to 2020/2021.
Benefit Cost:	Stormwater conveyances are necessary in urbanized areas to alleviate flooding. Improvements over time are necessary to retrofit incorrectly sized systems, and to accommodate changes in precipitation rates and frequency.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	$400,000 budgeted 2020/21
Potential Funding Sources:	ARPA; DHS: HMGP, BRIC
Lead Agency/Department Responsible:	Emergency Services, Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 4	
Finalize Continuity of Operations Plan.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Plans that reduce the impacts of ongoing disasters save taxpayer dollars by bringing businesses back online sooner and providing normal services to citizens in need.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources, CIP; VDEM
Lead Agency/Department Responsible:	Administration; Emergency Services
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 5	
Improve gauging and warning system. Install additional flood gauges on the Meherrin River. Integrate data from all new flood gauges into citizen notification system, including a siren system. Use gauging and warning system data and existing flood depth data to begin developing targeted evacuation plan for flood-prone areas.	
BACKGROUND INFORMATION	
Site and Location:	Flood-prone areas Citywide, particularly Falling Run and the Meherrin River
Benefit Cost:	The state hurricane evacuation plan does not take all local factors into account and may not be sufficient for some residents of Emporia, especially if flooding isn't caused by hurricane. Local planning will facilitate evacuation when needed and better focus evacuation messaging to reduce confusion, speed evacuation and reduce the number of people in danger.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	$50,000 - $125,000
Potential Funding Sources:	DHS: HMGP, FMA; USACE: FPMS; ARPA
Lead Agency/Department Responsible:	Emergency Services
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 6	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Hazard prone areas Citywide, especially repetitive flood loss areas as discussed in Section 5
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Services
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 7	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objective 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Zoning Administrator
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 8	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, and earthquakes.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases, Shoreline Erosion
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Services
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF EMPORIA MITIGATION ACTION 9	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the city who have to pay for flood insurance.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Zoning Administrator
Implementation Schedule:	Every 2 years
ADDITIONAL COMMENTS	

GOOCHLAND COUNTY MITIGATION ACTION 1	
Continue coordination with VDEM on incoming evacuee issues.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, particularly along the I-64 corridor along the northern edge of the county.
Benefit Cost:	Evacuees from the Washington DC and Hampton Roads metropolitan areas place a burden on local infrastructure. Coordination with VDEM keeps local officials informed and aware of potential impacts.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Earthquakes
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GOOCHLAND COUNTY MITIGATION ACTION 2	
Continue to coordinate with City of Richmond and Department of Corrections to address wastewater capacity issues.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, but particularly near Goochland Courthouse
Benefit Cost:	There are critical capacity issues with wastewater that impact the ability of the utility to continue operating throughout a disaster event.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Sinkholes
Goal(s) Addressed:	Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Coordination costs are minimal; future costs for infrastructure retrofits TBD
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Utilities
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GOOCHLAND COUNTY MITIGATION ACTION 3	
Continue to provide training opportunities to county staff. Hazard-related topics may include: floodplain management training, conferences and certification through VaDCR and the Association of Floodplain Managers; conferences and training for emergency managers regarding wildfire mitigation and other hazards; conferences and training for county officials regarding mitigation grant availability and processes.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Funds to provide county official with training can reduce damages from hazard events in the future by helping to reduce exposure of new development and identify grant opportunities for retrofitting existing structures and infrastructure.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.3; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	$2500/year
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Emergency Management & Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GOOCHLAND COUNTY MITIGATION ACTION 4	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Customize approach to provide outreach to large group of citizens with regard to broad spectrum of hazards, including flood, radon and wildfire. Continue the floodplain map-related outreach to support county's new FEMA FIRMs.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases, Shoreline Erosion
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GOOCHLAND COUNTY MITIGATION ACTION 5	
Strengthen system of coordinating, collecting, storing and transmitting damage assessment data for each natural hazard event which causes death, injury, and/or property damage.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Sinkholes
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 2; Goal 3: Objective 3.2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time and data storage costs
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management/ IT
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
VDEM has Crisis Track system for this purpose, as well, which meet community needs for post-disaster data collection.	

GOOCHLAND COUNTY MITIGATION ACTION 6	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Flood-prone areas Countywide
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objective 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GOOCHLAND COUNTY MITIGATION ACTION 7	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, mapping to determine detailed flood hazards, and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, particularly in the repetitive flood loss area identified in Section 5 of this plan and the existing Fire Training Center.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Services, Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
County has outgrown existing Fire Training Center and is examining locations and designs for a new building.	

GOOCHLAND COUNTY MITIGATION ACTION 8		
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to build components of a flood warning system and local evacuation plan, including: new IFLOWS gauges, high hazard water crossing elevations for county and state-owned roads, and a flood alert system.		
BACKGROUND INFORMATION		
Site and Location:	Countywide, particularly flood-prone areas and the repetitive flood loss area just south of Westview on the James River.	
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:		Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		TBD
Potential Funding Sources:		DHS: HMGP; ARPA; USACE: FPMS
Lead Agency/Department Responsible:		Emergency Management
Implementation Schedule:		Within 2 years of plan adoption
ADDITIONAL COMMENTS		

GOOCHLAND COUNTY MITIGATION ACTION 9		
Hire full time Environmental Planner to support stormwater management, PlanRVA coordination, environmental planning, conservation easements, community outreach and awareness of various hazards. Add a second Environmental Inspector.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	These positions support the policies and regulations already in place in the County. Administration of existing policies and providing assistance to citizens are important components in the mitigation process.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		All hazards
Goal(s) Addressed:		Goal 1; Goal 2: Objective 2.2; Goal 3
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		$175,000 per year
Potential Funding Sources:		ARPA; Virginia CFPF
Lead Agency/Department Responsible:		Environmental and Land Development
Implementation Schedule:		Within 2 years of plan adoption
ADDITIONAL COMMENTS		

GOOCHLAND COUNTY MITIGATION ACTION 10	
Support Virginia DCR in its efforts to bring all regulated dams into compliance with the Dam Safety Regulations Implement projects and assign responsibility to ensure maintenance/retrofit needs are addressed.	
BACKGROUND INFORMATION	
Site and Location:	Dams throughout the county
Benefit Cost:	Local engineering expertise and regional knowledge may prove effective in supplementing existing, limited state resources for inspecting and rating dams.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Contracted cost for inspections TBD.
Potential Funding Sources:	DHS: HHPD, HMGP; ARPA; USACE
Lead Agency/Department Responsible:	Community Development and Public Safety
Implementation Schedule:	Within 5 years of plan adoption
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 1	
Complete development of Continuity of Operations plan.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Plans that reduce the impacts of ongoing disasters save taxpayer dollars by bringing businesses back online sooner and providing normal services to citizens in need.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	CIP; DHS; VDEM
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 2	
Complete implementation of citizen notification system.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Other methods of notifying citizens require massive amounts of staff time which exceeds budgetary restraints. Reverse 911 quickly and efficiently uses existing infrastructure to notify property owners of appropriate pre- and post-disaster mitigation actions.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Infectious Disease
Goal(s) Addressed:	Goal 1; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 3	
Consider participating in "Turn Around, Don't Drown" public education campaign.	
BACKGROUND INFORMATION	
Site and Location:	Flood-prone road crossings throughout the county
Benefit Cost:	Public information helps arm citizens with the communication and safety skills needed to save lives and property--before, during and after a flood event. Reminders via social media are free of charge and require only staff time.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.3; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Immediately upon plan adoption
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 4	
Improve GIS layers and track storm damages.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Landslides, Shoreline Erosion, Sinkholes
Goal(s) Addressed:	Goal 3: Objective 3.1; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	DHS: HMGP; ARPA
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
VDEM Crisis Track can be used by localities to obtain, record and share storm damages from the field immediately following disaster events.	

GREENSVILLE COUNTY MITIGATION ACTION 5	
Install high water mark signage along bridges and other structures to indicate dangerous water levels along creeks and rivers in flood-prone areas.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone stream crossings throughout the county
Benefit Cost:	Signage that notifies drivers about how high the water is helps reduce water rescues and save lives. Combined with a “Turn Around, Don’t Drown” campaign, this action could be very effective at minimizing dangerous water rescues.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.2; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	$15,000
Potential Funding Sources:	DHS: HMGP, FMA; USACE: FPMS; ARPA
Lead Agency/Department Responsible:	Public Safety, with VDOT
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 6	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the county
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objective 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Zoning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 7	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, and earthquakes.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases, Shoreline Erosion
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 8		
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.		
BACKGROUND INFORMATION		
Site and Location:	Repetitively flooded areas in the county	
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:		Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):		Low
Impact on Socially Vulnerable Populations:		Moderate
Estimated Cost:		Staff time
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Planning and Zoning
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		

GREENSVILLE COUNTY MITIGATION ACTION 9	
Work with state partners and neighboring localities to monitor and implement Next Generation 911 GIS data standards. Explore 911 consolidation with Emporia.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; existing resources
Lead Agency/Department Responsible:	GIS Manager, PDC
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 10	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on floodprone areas.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Services, Planning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

GREENSVILLE COUNTY MITIGATION ACTION 11	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Emergency Services, Planning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF JARRATT MITIGATION ACTION 1	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Zoning and Planning; Fire Department
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF JARRATT MITIGATION ACTION 2	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Zoning and Planning; Fire Department
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Examples include the Virginia Hurricane Evacuation Guide and data collected via VDEM's Crisis Track post-disaster.	

HANOVER COUNTY MITIGATION ACTION 1	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event: • **Develop a more advanced flood warning system to increase the ability to locally and specifically forecast flood events and flood depths. Partner with other organizations including the NWS, U.S. Geological Survey (USGS), and local watershed organizations.** • **Acquire additional resources to build components of a local evacuation plan, including: new IFLOWS gauges, high hazard water crossing elevations for county and state-owned roads, and a flood alert system (using GIS, CodeRed and reverse 911).** • **Create more targeted flood messages and planning that can be conveyed to citizens. Include dam owners and downstream property owners.**	
BACKGROUND INFORMATION	
Site and Location:	Countywide, especially in floodprone areas and communities downstream of the dam
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced and lives are saved.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD

Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

HANOVER COUNTY MITIGATION ACTION 2	
Promote the "Turn Around, Don't Drown" public education campaign.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone road crossings countywide
Benefit Cost:	Public information helps arm citizens with the communication and safety skills needed to save lives and property--before, during and after a flood event. Reminders via social media are free of charge and require only staff time.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.2; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Public Safety and National Weather Service
Implementation Schedule:	Ongoing and frequently
ADDITIONAL COMMENTS	

HANOVER COUNTY MITIGATION ACTION 3	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes. Develop plan to improve flood insurance coverage in the county, similar to the CRS Plan for Public Involvement. Consider updating flood ordinance from 2008.	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the county
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.2, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	

HANOVER COUNTY MITIGATION ACTION 4		
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, tornado, and earthquakes.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases, Shoreline Erosion
Goal(s) Addressed:		Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):		Moderate
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		Minimal
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Emergency Management
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		
This is an ongoing action. The county's CERT and Medical Reserve Corps (MRC) distribute literature at multiple public events and work with Emergency Management on general preparedness training program that includes hazard information, at least twice per year.		

HANOVER COUNTY MITIGATION ACTION 5	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Repetitive flooded areas in the county, particularly the area identified in Section 5 near Pegway Lane and Route 642 (Bell Creek Road)
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Ongoing as data are provided
ADDITIONAL COMMENTS	
IMPORTANT: Officials noted that they need to determine if the repetitive flood loss area identified in Section 5 is included on the new preliminary FEMA SFHA maps.	

HANOVER COUNTY MITIGATION ACTION 6	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on floodprone areas and repetitive flood loss area.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management, Public Works, Planning and Community Development
Implementation Schedule:	Ongoing

ADDITIONAL COMMENTS
Action may include stormwater management conveyance improvements, stream cleanouts with VDOT, storage management and communications with dam owners, and coordination with Va Department of Forestry regarding the hydrologic impacts of mass timber clearing. County has made and continues to make significant progress addressing generators for critical facilities, including switching from diesel to natural gas generators at fire stations, replacing the Wickham Building generator, adding a generator at Town Hall and the new terminal in the airport, and replacing units at the Police Department, and Fire Training Center.

HANOVER COUNTY MITIGATION ACTION 7	
Improve community interoperability when cell services are interrupted. Work with cell service providers and electric utility to ensure power redundancies at cell towers.	
BACKGROUND INFORMATION	
Site and Location:	All regional cell towers that affect county communications
Benefit Cost:	Cell service is critical to management of emergencies and for communicating messages to the public.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS, Dominion Energy
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	

HANOVER COUNTY MITIGATION ACTION 8	
Assemble pre-approved messaging plans for various hazard events. Include focus audience, message, and plan for dissemination. Assemble resources required to execute plans for each hazard.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Time is precious in post disaster scenarios, and having the tools available and pre-approved messaging agreed upon can help save lives and reduce damage.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.2, 1.3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	<$25,000; electronic messaging boards range from $13,000 - $35,000 each
Potential Funding Sources:	DHS: HMGP; ARPA
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	
Messaging will address a variety of hazard events and identify conflicts in messaging, such as from online apps (e.g., Waze) that send information to residents and visitors. Methods of dissemination may vary, but may include electronic messaging boards and door stickers or door hangers.	

TOWN OF ASHLAND MITIGATION ACTION 1	
Continue to identify areas of existing development where drainage is of significant concern, and implement a drainage improvement program, where feasible. Evaluate and make improvements, as needed, to stormwater system to ensure adequacy to handle major rain events.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Ashland is generally flat and has poorly drained soils. Much of the town was developed prior to current standards for stormwater quantity control. Drainage studies can identify sites where undersized structures contribute to flooding and propose projects to reduce flooding now and in the future.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate (in southern portion of town) to Low
Estimated Cost:	TBD
Potential Funding Sources:	CIP; DHS: HMGP; ARPA
Lead Agency/Department Responsible:	Planning & Utilities
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
This action is also in the town's comprehensive plan, as policy recommendation E.14.	

TOWN OF ASHLAND MITIGATION ACTION 2	
Continue NFIP Community Rating System activities to reduce flood risk. Consider development of a Plan for Public Involvement per *CRS User's Manual* that is coordinated with other community outreach programs.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas throughout the town
Benefit Cost:	Currently rated as a Class 8 in the CRS, property owners in the town's SFHA receive a 10% discount on premiums.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate (in southern portion of town) to Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF ASHLAND MITIGATION ACTION 3	
Finalize Continuity of Operations plan. New County/Town THIRA, COOP, and EOP are being completed together. Each department will have their own operational plans.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town, and coordinated with Hanover County
Benefit Cost:	All of these plans help identify and reduce vulnerabilities in the town's operational procedures.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Costs of implementation are TBD.
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Police
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
These plans are substantially complete. COOP is awaiting approval.	

TOWN OF ASHLAND MITIGATION ACTION 4	
Continue to enhance capabilities to use GIS for emergency management.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Town
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF ASHLAND MITIGATION ACTION 5	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town, with particular emphasis on floodprone areas
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Planning and Community Development; Department of Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Potential projects include stream restorations, debris cleanup and the equipment necessary to assist, identification and removal of hazardous trees before wind and winter weather events.	

TOWN OF ASHLAND MITIGATION ACTION 6	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the town
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate (in southern portion of town) to Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF ASHLAND MITIGATION ACTION 7	
Distribute brochures and use other means (e.g., local media) to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, tornados, wind, and earthquakes.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Police
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Activities focus on flooding, stormwater management, hurricanes, winter weather and other "stay safe" messaging.	

TOWN OF ASHLAND MITIGATION ACTION 8		
Coordinate emergency management plans and practices with Hanover County and Randolph-Macon College, including plans for debris management.		
BACKGROUND INFORMATION		
Site and Location:	Throughout the town	
Benefit Cost:	Coordinated responses and pre-event planning reduce impacts and damages.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		All hazards
Goal(s) Addressed:		Goal 1, Goal 2, Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):		Low
Impact on Socially Vulnerable Populations:		High
Estimated Cost:		Staff time
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Public Works
Implementation Schedule:		Within 3 years of plan adoption
ADDITIONAL COMMENTS		

TOWN OF ASHLAND MITIGATION ACTION 9	
Integrate mitigation plan goals and actions into other appropriate planning mechanisms for the town and county, such as comprehensive plans and capital improvement plans. Add hazard mitigation discussion to the town's comprehensive plan, and include pertinent mitigation actions.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Mitigation actions that are represented in various plans, budgets and programming are more likely to be funded sufficiently and implemented because the number of people engaged in making the actions happen increases.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF ASHLAND MITIGATION ACTION 10	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Police, Planning and Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF ASHLAND MITIGATION ACTION 11	
Continue coordination between Planning and Community Development and County Building Services to ensure no structures are constructed in the SFHA without proper permitting.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Code compliant designs are proven to reduce damage from flood, wind, snow and earthquake. The NFIP requires that all development in the SFHA is compliant with local floodplain management requirements implemented specifically to reduce flood damages.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate (in southern portion of town) to Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development, Hanover County
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 1	
Implement all-inclusive hazard mitigation planning for schools, to include: 1) continue annual site multi-hazard inspections of schools to identify areas for use as tornado safe rooms, assessment of structure vulnerability to earthquake and flood based on floor elevations; 2) prepare Emergency Action Plan for each school; 3) incorporate building plans into GIS to enable first responders entering the schools for any reason; and 4) ensure sheltering sites meet all national shelter standards, have generator power, and are protected from wind and flood. Fund and fulfill required retrofits upon identification.	
BACKGROUND INFORMATION	
Site and Location:	All county schools
Benefit Cost:	Schools house a large number of people everyday, which increases exposure to a variety of hazards. Pre-disaster planning and structural inspections, as well as detailed knowledge about the school layout and construction, enable first responders to quickly respond to events and minimize damage.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Sinkholes, Infectious Diseases
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4: Objectives 4.1, 4.3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	Existing budgets; DHS: HMGP, BRIC
Lead Agency/Department Responsible:	Emergency Management & Henrico County Public Schools

Implementation Schedule:	within 4 years of plan adoption, with ongoing annual inspections
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 2	
Continue to implement drainage and stream channel maintenance program.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Conveyances that are kept clean and maintained appropriately are less likely to cause flooding during periods of extreme precipitation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 4: Objective 4.2
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
This program is currently complaint-based.	

HENRICO COUNTY MITIGATION ACTION 3		
Expand existing comprehensive Public Outreach program through coordination of several ongoing efforts related to hazards: 1) operationalize Community Emergency Resource Team resources to enhance training availability to targeted populations; 2) continue participating in Great Shakeout (workplace safety drills) and other wide-scale disaster drills; 3) continue participation in the StormReady program; 4) continue outreach through brochure distribution and other means (e.g., utility bill messaging, local media, social media) to educate the public regarding preparedness and mitigation; 5) coordinate all messaging with CRS Plan for Public Information (PPI), which focuses on increasing flood insurance countywide; and 6) rebrand Dept. of Public Works outreach for flood and dam safety and tie into other EM initiatives.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Extreme Heat
Goal(s) Addressed:		Goal 1; Goal 2
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		$10,000/year, plus staff time
Potential Funding Sources:		Existing resources, CERT
Lead Agency/Department Responsible:		Emergency Management, Finance, Public Works, Public Utilities, Public Relations
Implementation Schedule:		Ongoing

ADDITIONAL COMMENTS
Consider addition of Public Information Officer on staff of DPW to manage outreach on flood and dam safety. With proper training, CERT members can be used to help administer vaccine clinics, lead volunteer efforts, conduct damage assessments, provide information dissemination, canvas communities, prepare IEPs, serve as radio team leaders.

HENRICO COUNTY MITIGATION ACTION 4	
Upgrade/retrofit existing EOC and identify viable temporary EOCs that would suit the county's purposes. Expand options for public facilities that can receive generator backup and be used as temporary emergency shelters.	
BACKGROUND INFORMATION	
Site and Location:	Existing EOC and potential county-owned facilities countywide
Benefit Cost:	EOCs require sufficient protection from weather and manmade hazards to provide a safe operational platform for executing emergency response. Temporary EOCs for particular events may provide a lower cost way to address the vulnerabilities of the existing facility.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 4: Objective 4.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	Existing resources; DHS, VDEM
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 10 years of plan adoption
ADDITIONAL COMMENTS	
Second floor of existing EOC building is vulnerable to wind damage and is located near major road and hospital with potential for hazardous materials exposure. Existing EOC is not a dedicated facility.	

HENRICO COUNTY MITIGATION ACTION 5	
Install electrical hook-ups, wiring, and switches to allow quick connects at county-owned critical facilities, including for example, shelters and pump stations.	
BACKGROUND INFORMATION	
Site and Location:	Critical facilities throughout the county
Benefit Cost:	Shelters and pump stations can stay operational throughout disaster events with provision of dependable generator power.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	Existing resources; DHS: HMGP, UASI; ARPA
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 6	
Provide continuous, ongoing training on hazard mitigation and the county's related initiatives to all county staff. Training will enhance ability to integrate mitigation objectives in all county programs.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Available materials for training are readily available from state and Federal agencies free of charge. The benefits of hazard-focused training may be realized in small ways over a long period of time as mindsets change to think about the impact of everyday actions on long-term vulnerability.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 2: Objective 2.2; Goal 3: Objective 3.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Works, Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 7	
Expand existing local, regional, and county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, including: 1) build a comprehensive stream gauge network that includes data on water elevation, water quality, precipitation measurement, and dam impoundment levels; 2) updated Emergency Action Plans based on rain gauge data; 3) warning system(s) that alert citizens; and 4) detailed evacuation planning tied to warning system and based on critical road elevations or other road obstructions.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on county- and FEMA-identified flood hazard areas
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1, Goal 2
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE; USGS
Lead Agency/Department Responsible:	Public Utilities, Public Works, and Emergency Management, USGS
Implementation Schedule:	
ADDITIONAL COMMENTS	
USGS rain gauges have been installed at 5 of the county-owned dams, and USACE/NWS have completed inundation mapping on the James River.	

HENRICO COUNTY MITIGATION ACTION 8	
Maintain relationships with Dominion Energy, Comcast, Verizon (and other utility service providers), and VDOT to ensure swift removal of debris and continued maintenance of lines to minimize future debris.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	The critical element in maintaining these relationships is keeping contacts and contact information current and up to date on the county's actions. Cooperation with utility providers in post-disaster scenarios protects consumers and reduces damages.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Dominion Energy, DPW, DPU, Fire and Police
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 9	
Conduct annual review of repetitive loss, severe repetitive loss and all NFIP claims and policy coverage data from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Data analysis will inform other community mitigation efforts.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas countywide
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance. Data analysis will inform PPI which targets underinsured, flood-prone areas of the county in an effort to increase flood insurance coverage.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low to Moderate; Rep loss areas on Horsepen Branch, Rocky Branch, North Run, Trumpet Branch and along West Nine Mile Road near Highland Springs have highest relative NRI risk for flood in the county and should be prioritized to increase impacts of mitigation on socially vulnerable populations.
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Works, FEMA Region III

Implementation Schedule:	Annual, or as data are provided
ADDITIONAL COMMENTS	
Each rep loss and severe rep loss structure will be assigned a flood risk score (using social vulnerability info) and ranked in order to prioritize areas for flood mitigation	

HENRICO COUNTY MITIGATION ACTION 10	
Continue participating in the National Flood Insurance Program and Community Rating System, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the county
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation. CRS participation reduces flood insurance premiums for property owners in the SFHA.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 11	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on floodprone areas.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate to Low for flood: Each rep loss and severe rep loss structure will be assigned a flood risk score (using social vulnerability info) and ranked in order to prioritize areas for flood mitigation
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management, Public Utilities, Public Works, Planning, Permit Center, Building Inspections, Police, Schools, Rec & Parks

Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Acquisition of floodprone structures is the county's current priority for mitigation. Strategic acquisition of properties on the open market or available through trustee's sale is a long-term tactic.	

HENRICO COUNTY MITIGATION ACTION 12	
Prepare countywide hazard-related communications plan. Include general outreach regarding risk, county programs and dam safety. Provide information on regulations and permitting requirements. Tie messaging into the PPI focusing on flood insurance coverage. Prepare an annex to the Emergency Operations Plan that includes prescribed messages for pre- and post-disaster scenarios.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Pre-prepared and pre-approved messages save precious moments in post-disaster scenarios when citizens need answers and officials need to disseminate information. The costs of preparing communications methodology and messaging ahead of time are minimal.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management, Public Works, Public Relations
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 13	
Provide training to realtors, insurance agents, builders, and surveyors, who operate in the county regarding floodplain management policies and procedures. Provide business resilience training to business owners, especially SWaM businesses. Tie messaging into the PPI.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Effective floodplain management reduces future damages in floodprone areas but only if regulations are enforced. There are many measures businesses can implement to reduce damage from a variety of hazards.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundments
Goal(s) Addressed:	Goal 1, Objectives 1.2, 1.3, 1.4; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources; DHS: HMGP, FMA;
Lead Agency/Department Responsible:	DPW
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

HENRICO COUNTY MITIGATION ACTION 14	
Provide infrastructure upgrades (roads, water supply, sanitary sewer service) to improve emergency services response times in the county's east end. Ensure water supply is sufficient to meet firefighting needs, and water quality remains safe for residents.	
BACKGROUND INFORMATION	
Site and Location:	Eastern portion of the county, east and south of Richmond
Benefit Cost:	Response times for wildfire and other hazard events can reduce damage by removing people from harm's way.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Wildfires, Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Severe Winter Weather, Earthquakes
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	Capital budgeting
Lead Agency/Department Responsible:	DPW, Public Utilities, Fire
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 1	
Integrate mitigation goals into future capital improvement plans to ensure that new city facilities are located out of identified hazard areas. Relocate Fire Station 1/EOC/Headquarters outside of 0.5 mile evacuation zone for industrial plans and as far as possible from train yards/tracks.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	The vulnerability of public safety buildings and the location of the city's operational facilities in areas outside of high hazardous risk zones is a key element in reducing risk and increasing operational capabilities.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Hazardous materials release secondary to surrounding facilities impacted by natural disasters, i.e. tornado, hurricane, high winds.
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 2 years of plan adoption and then ongoing
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 2	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building ordinances. Update Article XV, Floodplain District, ordinance. Research joining the NFIP Community Rating System.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas Citywide
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Development
Implementation Schedule:	Ongoing. Update floodplain ordinance within 2 years of plan adoption.
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 3	
Target FEMA's repetitive loss property, and those in the surrounding repetitive loss area, for specialized outreach and mitigation activities.	
BACKGROUND INFORMATION	
Site and Location:	Structures are in an area outside the detailed-study 100-year floodplain and floodway of Bailey Creek, a tributary of the James River. Bailey Creek, in general, has a relatively flat watershed; the lower reaches are swampy, and flow is very sluggish.
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring structures designated as repetitive loss have flood insurance is important for protecting citizens occupying those structures.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1; Goal 3: Objective 3.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
As of 2021, there is only 1 confirmed repetitive loss in Hopewell.	

CITY OF HOPEWELL MITIGATION ACTION 4	
Inspect and clear debris from stormwater drainage system. Increase capacity of Cabin Creek drainage system, including: 1) debris clearing and revetment, and 2) if necessary, re-alignment of channel. Increase capacity of Cattail Creek channel and culverts crossing CSX and Norfolk Southern Railroad to address repeated flooding and damage to infrastructure.	
BACKGROUND INFORMATION	
Site and Location:	Cabin Creek, and Cattail Creek at railroad crossing
Benefit Cost:	Benefits of improving the stormwater conveyances accrue to infrastructure and homes in the area flooded by undersized bridges and culverts. Ensuring culverts are sized appropriately for current and future conditions will help address climate change and increased precipitation in the future, as well.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; ARPA; Virginia CFPF
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Cattail Creek improvements have been funded (partially by grant funding) and are substantially complete. Additional improvements to stabilize the stream channel and road embankment of the city's primary emergency route, Winston Churchill Dr, between High Ave & Arlington Rd, and to protect adjacent residences, is also substantially complete.	

CITY OF HOPEWELL MITIGATION ACTION 5	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, and an engineering study to identify retrofits to address critical infrastructure vulnerabilities such as the need for generators, and quick-connects at the schools.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management, Public Works
Implementation Schedule:	
ADDITIONAL COMMENTS	
City Hall generator is under-sized to fulfill radio & other needs during disaster.	

CITY OF HOPEWELL MITIGATION ACTION 6	
Engage owners of the city's industrial businesses to discuss opportunities for retrofitting/hardening their facilities against flooding and severe weather, and developing business resilience plans.	
BACKGROUND INFORMATION	
Site and Location:	The City's floodprone industrial waterfront
Benefit Cost:	Targeted mitigation opportunities in this area can help dramatically reduce vulnerability by reducing damage to structures and infrastructure, and prepare businesses for managing disaster events.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Severe Winter Weather, Shoreline Erosion, Earthquakes
Goal(s) Addressed:	Goal 1: Objectives 1.3, 1.4; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal planning costs; project/retrofit costs TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; ARPA; USEDA: DMTA
Lead Agency/Department Responsible:	Emergency Management, private owners
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 7	
Develop a debris removal plan.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Both pre- and post-disaster debris removal is a key component in managing recovery and getting infrastructure (such as roads) back online.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Shoreline Erosion
Goal(s) Addressed:	Goal 1: Objectives 1.1; Goal 3: Objective 3.1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Planning costs minimal; fees associated with on call contractors to perform services
Potential Funding Sources:	DHS; VDEM
Lead Agency/Department Responsible:	Public Works, Emergency Management
Implementation Schedule:	Within 1 year of plan adoption
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 8	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
City distributed FEMA brochures during COVID disaster.	

CITY OF HOPEWELL MITIGATION ACTION 9	
Install NWS-grade tide gauge at confluence of James and Appomattox Rivers. Include acoustic water-level sensor, protective well components, data collection platform, GOES satellite telemetry, enclosure, stand, batteries, antenna, and solar panels. Integrate IPAWS sensors with CodeRed alert system.	
BACKGROUND INFORMATION	
Site and Location:	Confluence of James and Appomattox Rivers
Benefit Cost:	The gauge data will be used to increase predictive capability, to build historical data to use for more reliable future predictions for industrial area and marina that will increase protective measures taken and aid evacuation efforts.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; NWS; USACE; ARPA; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 10		
Implement continuity of operations plan.		
BACKGROUND INFORMATION		
Site and Location:	Citywide	
Benefit Cost:	COOP helps identify and reduce vulnerabilities in the city's operational procedures.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:	All hazards	
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4	
Priority (High, Moderate, Low):	Moderate	
Impact on Socially Vulnerable Populations:	High	
Estimated Cost:	Minimal	
Potential Funding Sources:	Existing resources	
Lead Agency/Department Responsible:	Emergency Management	
Implementation Schedule:	Within 1 year of plan adoption	
ADDITIONAL COMMENTS		
Since previous plan, City has completed the COOP.		

CITY OF HOPEWELL MITIGATION ACTION 11	
Integrate VDEM Crisis Track software (for post-disaster damage assessment) into local GIS platforms for data collection, storage and sharing. Add building plans from critical facilities into GIS to benefit first responders.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Development
Implementation Schedule:	Within 1 year of plan adoption
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 12	
Retrofit Hopewell Marina infrastructure to minimize potential impacts from flooding and shoreline erosion, to include: power equipment, pumpout facility, and docks. Develop plan for debris management at the site. Ensure marina rules and regulations require boats to be operational and regularly-maintained, with insurance policies up to date.	
BACKGROUND INFORMATION	
Site and Location:	Hopewell Marina, on the south bank of the Appomattox River, just west of the Route 10 bridge
Benefit Cost:	Marina is vulnerable to flooding and shoreline erosion; retrofitting components and infrastructure will reduce future flood damages.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Shoreline Erosion, Severe Wind Events
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	ARPA; DHS: HMGP
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 13	
Formalize process for tax sale properties, with special focus on those in hazardous locations (SFHA, 500-year floodplain, hazardous materials, etc.).	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Determining best practices for divesting the city of hazardous properties and minimizing future private investment in those properties can reduce damages in the long-term.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Shoreline Erosion, Earthquakes, Severe Wind Events
Goal(s) Addressed:	Goal 1; Goal 3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal cost for planning; future acquisition/disposal/demolition costs TBD. Demolition/rebuild may allow future, protected development.
Potential Funding Sources:	DHS: HMGP, BRIC, FMA, RFC
Lead Agency/Department Responsible:	Commissioner of Revenue, Emergency Management, Risk Management
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 14	
Develop local stormwater management resilience plan and incorporate identified upgrades into the State's Coastal Resilience Plan.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	A broad review and study of the city's stormwater conveyances is needed to identify upgrades/maintenance/retrofits necessary to ensure the system can perform as designed to handle existing and future precipitation conditions.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	Virginia CFPF
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Within 1 year of plan adoption
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 15	
Implement State Code requirement to adopt Capital Improvement Budget. As outlined in the Comprehensive Plan, a CIP would identify and prioritize projects for environmental protection, including funding for: critical RPA maintenance, mitigation and remediation; stormwater retrofits on City-owned properties; development of Small Area Plans in key areas of environmental vulnerability, and grant and investment support for high priority pollutant reduction projects.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	CIP is needed in order to determine City priorities for mitigation and to outline what local funds are available to support the most cost beneficial initiatives.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure; Shoreline Erosion, Severe Wind Events, Earthquakes
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	City Manager, Finance, Public Works
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF HOPEWELL MITIGATION ACTION 16	
Enact additional regulations to govern shoreline development, to include: require vegetation as an alternative to manmade structures; require all new shoreline development applications are accompanied by a Shoreline Protective Plan, in accordance with the *Virginia Department of Conservation and Recreation Chesapeake Bay Local Assistance Riparian Buffers Modification and Mitigation Guidance Manual*; ensure all newly delineated wetlands (resulting from review of development proposals) are added to the city's wetland resource inventory.	
BACKGROUND INFORMATION	
Site and Location:	Shorelines citywide
Benefit Cost:	Shoreline erosion is caused by a variety of forces in Hopewell, but controlling new development is an important element in reducing future damages.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Shoreline Erosion
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Development
Implementation Schedule:	Within 5 years of plan adoption
ADDITIONAL COMMENTS	
This action is also recommended in the comprehensive plan.	

CITY OF HOPEWELL MITIGATION ACTION 17	
Install comprehensive atmospheric monitoring equipment, including but not limited to: air temperature, road temperature, wind speed & direction, rainfall, lightning strike, humidity, road surface and bridge surfaces conditions. This comprehensive weather monitoring system includes remote monitoring of these sensors and conditions, and receives data from all monitors as well as cameras. Remote and automatic activation of automatic early warning system must also be included.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Improved situational awareness of atmospheric conditions which allows for improved preparation, response and recovery before during and after inclement weather conditions. This allows City officials to make accurate informed decisions for the planning preparation and response to natural disasters, early warning and notification, orders of emergency evacuation/shelter in place.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Severe Winter Weather, Droughts and Extreme Heat, Thunderstorms
Goal(s) Addressed:	Goal 1: Objective 1.1, 1.2,1.4; Goal 2: Objective 2.1, 2.2, 2.3; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; NWS; USACE; ARPA; Virginia CFPF
Lead Agency/Department Responsible:	Public Works, Emergency Management
Implementation Schedule:	Within 2 years of adoption
ADDITIONAL COMMENTS	
As a waterfront community we must monitor the conditions of roadways, bridges, the shoreline as well as current air temperatures, surface temperatures, wind and tidal activity. The City	

maintains over 276 miles of roadways; cost savings and waste reductions would be secondary benefits of implementing this program. Accurate atmospheric monitoring or air and road surface temperature information allows the personnel responsible for surface pre-treatment, treatment, repairs, and maintenance to respond appropriately to the current conditions, monitor trends, and respond accordingly. This prevents waste and the misapplication of treatment products.

CITY OF HOPEWELL MITIGATION ACTION 18	
Implement the projects identified in the local stormwater resilience plan. Projects are categorized from short range to long range based on size, cost, complexity and risk area.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	This effort will address potential climate hazards that are not only felt today but also will affect every aspect of life over the coming decades. Project implementation will mitigate risk areas identified in stormwater resilience plan, reducing the occurrence of flood damage to public infrastructure and private property.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	VDOT Revenue Sharing Program, Virginia DCR CFPF, Virginia DEQ Stormwater Local Assistance Fund
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Within 5 Years of plan adoption
ADDITIONAL COMMENTS	
The local stormwater resilience plan is a living document that will be updated each year to account for completed projects and new projects added as categorized.	

NEW KENT COUNTY MITIGATION ACTION 1	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Repetitively flooded areas in the county
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Moderate – 2 rep loss areas in the southeastern part of county along the Chickahominy River
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

NEW KENT COUNTY MITIGATION ACTION 2	
Maintain floodplain protection ordinances and policies that allow the county to fully participate in the National Flood Insurance Program..	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the county
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3, Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Inspections
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Floodplain management ordinance was updated in September 2021. A floodplain manager position was created and staffed in Environmental in 2019. This action is also expressed in the county's comprehensive plan.	

NEW KENT COUNTY MITIGATION ACTION 3

Distribute brochures and other literature to educate the public regarding preparedness and mitigation. Use a variety of means to disseminate hazard-related information, including social media and workshops. Prepare transferable lesson plans for delivery in schools and summer camps (Storm Camp). Incorporate the NWS "Turn Around, Don't Drown" campaign.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time + materials (~$2500/year printing costs)
Potential Funding Sources:	DHS: HMGP; NWS; ARPA
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
County currently distributes information at all special events, such as Grand Illumination, National Night Out, and the County Fair.	

NEW KENT COUNTY MITIGATION ACTION 4	
Encourage new community support facilities, such as banks, gas stations, and pharmacies, to have back-up generators, cell phone charging stations, and electric vehicle charging stations as they are developed.	
BACKGROUND INFORMATION	
Site and Location:	Countywide population centers
Benefit Cost:	Long-term power outages can have impacts beyond climate control. Emergency Management disseminates post-disaster messaging via social media, which requires cell service. Citizens need urgent access to money, gas and medicines.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD. If mandated, cost is minimal. If incentives are provided, county could cover part of the cost.
Potential Funding Sources:	DHS; Dominion Energy
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

NEW KENT COUNTY MITIGATION ACTION 5		
Identify and replace vulnerable or undersized structures with bridges, larger culverts or other measures to reduce flood hazards.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	Benefits of improving the stormwater conveyances accrue to infrastructure and homes in the area flooded by undersized bridges and culverts.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure	
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4	
Priority (High, Moderate, Low):	Moderate	
Impact on Socially Vulnerable Populations:	Low to Moderate	
Estimated Cost:	~$175,000-$250,000 for single stormwater master plan	
Potential Funding Sources:	DHS: HMGP; ARPA; USDA: WPFP	
Lead Agency/Department Responsible:	Planning, Environmental, General Services	
Implementation Schedule:	Ongoing	
ADDITIONAL COMMENTS		

NEW KENT COUNTY MITIGATION ACTION 6

Pursue opportunities and funding to harden local utilities and infrastructure to improve recovery time, including fulfilling any equipment and heavy machinery needs to accomplish this, and retrofitting critical facilities and systems.

BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Infrastructure can often be retrofitted at low to moderate cost to provide additional protection from hazards such as flood, thereby reducing average annual losses.

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Landslides, Shoreline Erosion, Sinkholes, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4: Objectives 4.1 and 4.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Public Utilities, Emergency Management
Implementation Schedule:	Ongoing

ADDITIONAL COMMENTS

Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects.

BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on floodprone areas and repetitive loss areas as identified in Section 5
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

NEW KENT COUNTY MITIGATION ACTION 8

Identify additional shelter mass care locations.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Sheltering requirements are evolving and communities must adjust to meet the needs of citizens for a variety of short- and longer-term disaster duration events in order to minimize adverse impacts when evacuation is necessary.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS; VDEM
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Annual needs assessment
ADDITIONAL COMMENTS	
Shelter demand, availability and options are reviewed annually. COVID impacted mass care options requiring Federal and state agencies to adopt interim strategies including non-congregate shelter options.	

Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required. Consider countywide flood warning system and evacuation plan.

BACKGROUND INFORMATION	
Site and Location:	Countywide; I-Flow gauges particularly needed for Colonies and campground areas near Chickahominy River
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE; USGS
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing

ADDITIONAL COMMENTS

NEW KENT COUNTY MITIGATION ACTION 10

Create a culture within New Kent County government focused on hazard mitigation objectives: 1) integrate mitigation plan goals and actions into other appropriate planning mechanisms, such as the comprehensive plan and capital improvement plan; 2) review processes and procedures across all functions to ensure objectives are met (Development Review Committee hazard reviews, for example); and 3) regularly brief elected officials on mitigation plan status and priorities. Within Emergency Management, conduct and receive training to stay current on grant opportunities and identify new opportunities for data sharing within the county, region and state. Work to focus mitigation actions on specific structures, neighborhoods and problem areas. Incorporate mitigation objectives into recovery planning and regular exercises.

BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Mitigation actions require integration with other county functions to be implemented effectively.

MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal; some training costs may be incurred
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing

ADDITIONAL COMMENTS

NEW KENT COUNTY MITIGATION ACTION 11	
Periodically inventory existing dams in the county, assess their hazard potential, and seek funding for preparation of dam inundation zone maps. Ensure Emergency Action Plans (EAPs) are up to date, identify necessary maintenance or retrofits, and conduct exercises to reinforce EAP procedures.	
BACKGROUND INFORMATION	
Site and Location:	All dams countywide
Benefit Cost:	Local engineering expertise and regional knowledge may prove effective in supplementing existing, limited state resources for inspecting and rating dams. Dam inundation planning is similarly impacted.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HHPD; USACE; VaDCR
Lead Agency/Department Responsible:	Environmental; Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
This action is also expressed in the county's comprehensive plan. There are no high hazard potential dams in New Kent County.	

NEW KENT COUNTY MITIGATION ACTION 12	
Promote native and drought-tolerant grass species and landscaping as an alternative to traditional fescue-based lawns.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	This measure provides protection from a variety of hazards; reduced runoff and erosion, and more cooling on high temperature days are advantages of these alternatives.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Shoreline Erosion, Extreme Heat
Goal(s) Addressed:	Goal 3
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management and County Extension Services
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	
This action is also expressed in the county’s comprehensive plan.	

CITY OF PETERSBURG MITIGATION ACTION 1	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the city
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Building Department
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 2	
Partner with parent-teacher associations and local schools to implement existing curriculum related to natural hazards (e.g., Masters of Disaster, Risk Watch).	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Children and parents that are informed and know what actions to take in the event of hazard events can help reduce damages and save lives.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 3	
Complete application for StormReady Program.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	StormReady helps arm communities with the communication and safety skills needed to save lives and property--before, during and after the event. StormReady helps community leaders and emergency managers strengthen local safety programs.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Extreme Heat
Goal(s) Addressed:	Goal 1; Goal 2
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	
City is not certified StormReady as of January 2022.	

CITY OF PETERSBURG MITIGATION ACTION 4	
Consider participating in FEMA's Community Rating System.	
BACKGROUND INFORMATION	
Site and Location:	Citywide, with particular benefits to flood prone areas
Benefit Cost:	CRS actions help reenforce existing floodplain management initiatives, including the floodplain zoning overlay ordinance. These measures reduce average annual damages from flooding in the future, and participation in the CRS results in premium savings that stay in homeowners' pockets.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Considerable staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 5	
Inspect and clear debris from stormwater drainage system. Partner with VDOT to ensure non-City owned ROWs are also clear.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Clear drainage systems help to alleviate local or urban flooding and associated damage resulting from severe precipitation events.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	$20,000/year
Potential Funding Sources:	Existing CIP; DHS: BRIC, HMGP; VDOT
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 6	
Finish implementation of Reverse 911 system.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Other methods of notifying citizens require massive amounts of staff time which exceeds budgetary restraints. Reverse 911 quickly and efficiently uses existing infrastructure to notify property owners of appropriate pre- and post-disaster mitigation actions.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.2, 1.4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 7	
Install high water mark signage along bridges and other structures to indicate dangerous water levels along creeks and rivers in flood-prone areas.	
BACKGROUND INFORMATION	
Site and Location:	Flood-prone crossings Citywide
Benefit Cost:	Signage that notifies drivers about how high the water is helps reduce water rescues and save lives.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding; Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.2, 1.4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	$15,000
Potential Funding Sources:	DHS: HMGP, FMA; USACE: FPMS; ARPA; FOLAR
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 8	
Investigate all public utility lines to evaluate their resistance to flood, wind, and winter storm hazards. Retrofit or relocate lines, as necessary, to reduce vulnerabilities.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Provision of public utilities during and after disasters is critical to public safety.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Shoreline Erosion, Sinkholes
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	$75,000 for inspection & report; retrofit costs TBD
Potential Funding Sources:	DHS: HMGP, BRIC; ARPA
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 9	
Work with VDOT, private utilities, and/or private homeowners to trim or remove trees that could down power lines.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Provision of utilities during and after disasters is critical to public safety.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Shoreline Erosion, Sinkholes
Goal(s) Addressed:	Goal 2; Goal 4
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	$25,000
Potential Funding Sources:	ARPA; DHS: HMGP;
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 10	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal
Potential Funding Sources:	DHS: HMGP
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 11		
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.		
BACKGROUND INFORMATION		
Site and Location:	Repetitive flood loss areas throughout the City as discussed in Section 5 of this plan	
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the City who have to pay for flood insurance.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure	
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1	
Priority (High, Moderate, Low):	Low	
Impact on Socially Vulnerable Populations:	Low to Moderate	
Estimated Cost:	Staff time	
Potential Funding Sources:	Existing resources	
Lead Agency/Department Responsible:	Planning Department, Tax Assessor	
Implementation Schedule:	Ongoing	
ADDITIONAL COMMENTS		

CITY OF PETERSBURG MITIGATION ACTION 12	
Install quick connects for generators at critical facilities. Ensure existing generators are working at all times with regular maintenance and inspections. Replace generators, as necessary.	
BACKGROUND INFORMATION	
Site and Location:	Citywide facilities
Benefit Cost:	Continuity of operations after a hazard event is dependent upon operational utilities, shelters, communications and medical services.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	$8000/year
Potential Funding Sources:	DHS: HMGP; Existing CIP budgets
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 13	
Work with state partners and neighboring localities to monitor and implement Next Generation 911 GIS data standards.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; existing resources
Lead Agency/Department Responsible:	GIS Manager, Crater PDC
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 14	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Citywide, with particular emphasis on the city's repetitive flood loss areas as identified in Section 5
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Fire-Rescue
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF PETERSBURG MITIGATION ACTION 15	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Fire-Rescue
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

POWHATAN COUNTY MITIGATION ACTION 1	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, mapping to determine detailed flood hazards, and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Quick connects for all permanently-installed generators on critical facilities are needed.	

POWHATAN COUNTY MITIGATION ACTION 2	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes. Continue to require minimum non-disturbance (vegetated) buffers from the edge of all wetlands and streams.	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the county
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low, to Moderate in the eastern two-thirds of the county
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
County does not allow new development in the SFHA. The buffer continuance is also expressed in the existing comprehensive plan, which is currently being updated.	

POWHATAN COUNTY MITIGATION ACTION 3	
Maximize use of VDEM's Crisis Track system to collect and transmit damage assessment information post-disaster.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	

POWHATAN COUNTY MITIGATION ACTION 4	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Increase situational awareness on behalf of citizens and maximize use of social media, Yammer, county employees, CodeRed/R911 to communicate important hazard-related messages.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases, Shoreline Erosion
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management, County Public Information Officer
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

POWHATAN COUNTY MITIGATION ACTION 5	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA, if any arise. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Repetitively flooded areas in the county
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
There are currently no properties on the NFIP list of repetitive flood losses for Powhatan County.	

POWHATAN COUNTY MITIGATION ACTION 6	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas countywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

POWHATAN COUNTY MITIGATION ACTION 7	
Implement measures to reduce wildfire damages, including: 1) mandate Fire Department review for defensible space and wildfire interface in development review process; 2) provide wildfire mitigation training to landowners and other county staff.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Damage from wildfire can be reduced by ensuring new development has protective measures in place. The VDOF has several tools available for training measures, free of charge.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Wildfire
Goal(s) Addressed:	Goal 1; Goal 3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Community Development, VDOF
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	

POWHATAN COUNTY MITIGATION ACTION 8		
Finalize Post-Disaster Redevelopment plan that documents plans and procedures for recovery, including development/designation of a Recovery Operations Center.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	Covering a broad array of hazard events, this plan lays out a plan for recovery that will help align redevelopment efforts with current standards for hazard mitigation, thereby reducing future vulnerability.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		All hazards
Goal(s) Addressed:		Goal 3: Objective 3.2
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		Minimal
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Emergency Management
Implementation Schedule:		Within 1 year of plan adoption
ADDITIONAL COMMENTS		

PRINCE GEORGE COUNTY MITIGATION ACTION 1	
Continue participating in the National Flood Insurance Program, including enforcement of zoning and building codes.	
BACKGROUND INFORMATION	
Site and Location:	Throughout floodprone areas of the county
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Building Department
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 2	
In future updates to the 2018 comprehensive plan, include hazard vulnerability summary and include mitigation actions in the plan.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Repetition of mitigation actions and consistency throughout county plans helps ensure implementation of the plan and subsequent reduction in vulnerability.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Planning Department
Implementation Schedule:	Within 1 year of plan adoption
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 3	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, with particular emphasis on floodprone areas.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Planning and Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 4	
Develop stormwater master plan to study capacity of existing culverts and other structures to determine if sizing is sufficient for current conditions. Identify and replace vulnerable or undersized culvert stream crossings with bridges or larger culverts to reduce flood hazards, where feasible. Implement program for regular inspections and maintenance of roadside ditches and stream channels.	
BACKGROUND INFORMATION	
Site and Location:	Countywide; however, certain areas along Rte 460 and Rte10 (near Deep Bottom)
Benefit Cost:	Benefits of improving the stormwater conveyances accrue to infrastructure and homes in the area flooded by undersized bridges and culverts. Ensuring culverts are sized appropriately for flooding conditions will help address climate change and increased precipitation in the future, as well.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, FMA, BRIC; ARPA
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 5	
Maximize use of VDEM's Crisis Track system to collect and transmit damage assessment information post-disaster.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 6	
Coordinate drought contingency plans with County Extension Office.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Maintaining contingency plans for predicting and addressing drought conditions can help reduce losses, especially in the agricultural sectors.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Droughts and Extreme Heat
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 7	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Target FEMA's repetitive flood loss properties for specialized outreach and mitigation activities to encourage purchase of flood insurance and flood preparedness measures.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
County has active Survivor Day programming, outreach tables at events, and CERT programs, all of which will continue.	

PRINCE GEORGE COUNTY MITIGATION ACTION 8	
Hire appropriately-trained personnel for Emergency Management Office, Building Inspections Office, and Zoning Office to ensure adequate levels of staffing to administer county programs.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Staff who are well-versed in administration of county requirements related to hazard mitigation help make sure that existing standards are enforced and new standards do not increase the impacts of hazards.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	~$150,000/year (salaries) + ~$2000/year (training)
Potential Funding Sources:	DHS; Existing budgets
Lead Agency/Department Responsible:	County Administration and Agency Heads
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 9	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Repetitively flooded areas in the county
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Moderate
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 10	
Build new Fire Department burn building.	
BACKGROUND INFORMATION	
Site and Location:	Benefits accrue regionally; proposed site is off of Wells Station Road close to Route 460
Benefit Cost:	This project is critical for maintaining a competently-trained and coordinated fire and EMS system.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Wildfires
Goal(s) Addressed:	Goal 1: Objective 1.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	$718,306
Potential Funding Sources:	Capitol funds; Virginia Department of Fire Programs; regional partners (tri-cities, Fort Lee)
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 11	
Continue implementation of automatic aid agreement with the City of Hopewell.	
BACKGROUND INFORMATION	
Site and Location:	Countywide, including Hopewell
Benefit Cost:	Mutual aid agreements expand the capabilities of both jurisdictions to respond to and manage hazard events.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal; some costs accrue if agreement is enacted for an event
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

PRINCE GEORGE COUNTY MITIGATION ACTION 12	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Emergency Services, Planning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

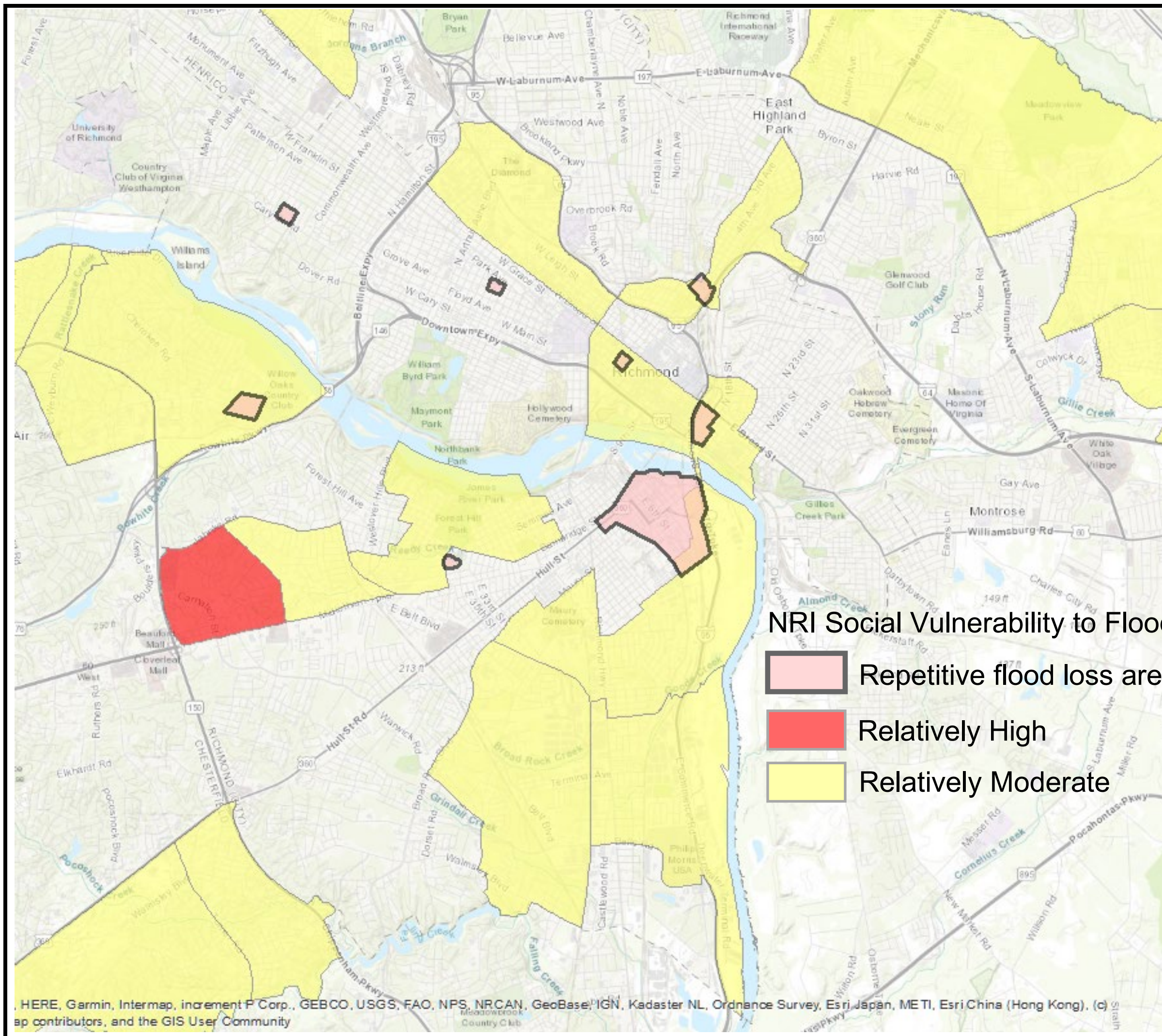
CITY OF RICHMOND MITIGATION ACTION 1	
Re-establish independent Office of Emergency Management.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Make the existing Office of Emergency Management an independent entity within the City of Richmond's governance structure to support and enhance staff's ability to implement citywide priority actions and exercises.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	CIP & General Fund Budget
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	within 2 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 2	
Establish a dedicated, independent EOC to fully support response and recovery efforts, and new technology for Emergency Management.	
BACKGROUND INFORMATION	
Site and Location:	Downtown Richmond
Benefit Cost:	The city's existing EOC is a shared space which inhibits timely coordination and response.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	CIP
Lead Agency/Department Responsible:	City Administration
Implementation Schedule:	Within 4 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 3	
Continue to update emergency response plan and educate the public on hazard resiliency and emergency preparedness. Conduct emergency planning, climate, and resiliency engagement and outreach, particularly in communities with high vulnerability to hazards that have been traditionally underrepresented in city planning processes: Black and African American, Hispanic and Latino, lower-income, and those with limited English proficiency.	
BACKGROUND INFORMATION	
Site and Location:	Citywide, with emphasis on areas with high social vulnerability
Benefit Cost:	By purposefully engaging specific communities, equity in city services is more fully realized.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.3, 1.4; Goal 2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Minimal; estimated <$15,000/year
Potential Funding Sources:	DHS: HMGP; Virginia CFPF; HUD: CDBG
Lead Agency/Department Responsible:	Office of Sustainability, Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Includes conducting annual preparedness days for hazards to include floods, wind, and earthquakes.	

CITY OF RICHMOND MITIGATION ACTION 4	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Repetitively flooded areas in the city
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the city who have to pay for flood insurance.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	Moderate – 5 rep loss areas near downtown Low – 3 rep loss areas near downtown
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Utilities
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 5	
Continue participating in the NFIP and identify additional Community Rating System activities to reduce flood risk.	
BACKGROUND INFORMATION	
Site and Location:	Throughout flood-prone areas of the city
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding; Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	NRI flood risk ranges from Low to Moderate to High. See figure in comments below for additional information.
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Utilities
Implementation Schedule:	Long-term
ADDITIONAL COMMENTS	


NRI Social Vulnerability to Flood
Repetitive flood loss area
Relatively High
Relatively Moderate
, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c)
ap contributors, and the GIS User Community

CITY OF RICHMOND MITIGATION ACTION 6	
Improve existing flood warning system to increase the ability to forecast flood events and flood depths. Acquire additional resources to build components of a local evacuation plan, including: improved IFLOWS gauges, high hazard water crossing elevations for city and state-owned roads, and a flood alert system (using GIS and the City's public warning system).	
BACKGROUND INFORMATION	
Site and Location:	Floodprone areas citywide
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding; Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	NRI flood risk ranges from Low to Moderate to High.
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE; USGS
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Long-term
ADDITIONAL COMMENTS	
Partner with other organizations including the NWS, USGS, local watershed organizations and the Flood Wall Manager.	

CITY OF RICHMOND MITIGATION ACTION 7	
Distribute NOAA weather radios to residents.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	By alerting the public to impending threats, weather radios reduce injuries and damage during disasters.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.2, 1.4; Goal 4: Objectives 4.1, 4.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Radios are $35 to $80 each
Potential Funding Sources:	DHS; Existing budgets
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 8	
Enhance use of GIS for urgent emergency needs.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; Virginia CFPF; General Fund Budget
Lead Agency/Department Responsible:	Emergency Management, DPW, DIT
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 9	
Expand facility assessment inventory of all City-owned facilities, including primary and secondary schools, to evaluate their resistance to all natural hazards. Identify and implement necessary retrofits or relocations to increase facility hardening, including addressing backup power needs through generators or micro-grids. Invest in data management system to allow local GIS/CAD storage archive of building plans for first responders and emergency planners.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Hazard response needs are evolving: an up-to-date inventory of City buildings and capabilities will add needed flexibility to response and recovery. Temporary response and recovery structures operating near a contained disaster site can make response management easier and more cost effective.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	Existing budgets, CIP
Lead Agency/Department Responsible:	Emergency Management and DPW
Implementation Schedule:	Long-term
ADDITIONAL COMMENTS	
City has conducted wind study on many City-owned facilities. An assessment inventory of City-owned facilities is identified in Richmond 300. This HMA would include collection of structural and elevation data, as well.	

CITY OF RICHMOND MITIGATION ACTION 10	
Perform hazard prevention activities to increase the protection of public and private structures from natural hazard damage, such as maintenance of floodwall, acquiring, relocating, retrofitting or elevating flood prone property, upgrading public infrastructure near hazard prone areas or other flood control projects.	
BACKGROUND INFORMATION	
Site and Location:	Citywide, with particular emphasis on flood-prone areas.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	DPU (floodwall) Emergency Management (other)
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 11	
Provide targeted outreach to business owners (particularly those with hazardous materials stored on site) to discuss hazards and mitigation alternatives.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Businesses are a key element in resiliency as they provide services that allow residents to acquire necessary items during recovery. Showing businesses how to plan for recovery and reduce future damages contributes to a shorter recovery period for the whole community.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	<$8000/year
Potential Funding Sources:	DHS: HMGP; EDA: DMTA; ARPA; Virginia CFPF
Lead Agency/Department Responsible:	Richmond Fire and Emergency Services, Economics Portfolio
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 12	
Continue to maintain existing Continuity of Operations Plans with emphasis on redundant power needs for specific critical facilities, and mitigation actions to address the water supply system.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Effective COOPs help identify and reduce vulnerabilities in the city's operational procedures. These plans require continuous refinement and updating, especially post-disaster when memories are fresh regarding how the plan can be improved.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets; DHS
Lead Agency/Department Responsible:	Emergency Management; Citywide
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 13	
Develop plan for community resilience hubs to serve as "one stop shops" for information on hazard and climate resilience and services before, during, and after hazard-related events. Services provided after hazard-related events may include device charging, shower and clothes washing facilities, and cooling/heating refuge.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Multiple hubs for promoting community resilience post disaster are less costly and more efficient than activating full-fledged shelters. These hubs can be spread strategically throughout a disaster area.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3: Objective 3.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS; VDEM
Lead Agency/Department Responsible:	Emergency Management; Office of Sustainability
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 14	
Integrate equity-centered hazard and climate change planning into all city plans, to include special event planning, operational exercises, and disaster management planning.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Mitigation actions require integration with other city functions and planning efforts to be implemented effectively.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Citywide
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 15	
Conduct detailed climate change vulnerability and risk assessments for Richmond's population, natural resources, built assets, and municipal facilities and operations.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	While the hazard mitigation plan has a vulnerability and risk assessment for the entire study area, a more detailed and thorough development of data specifically for Richmond would provide better tools for analyzing the costs and benefits of specific projects.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	~$75,000
Potential Funding Sources:	CIP; Virginia CFPF; DHS
Lead Agency/Department Responsible:	Office of Sustainability
Implementation Schedule:	Within 4 years of adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 16	
Increase staffing levels for hazard mitigation planning and implementation in Emergency Management, Public Utilities, Office of Sustainability, and/or other relevant departments. Establish as part of this a cross-departmental team for coordinating citywide hazard and resilience planning and service delivery.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Establishing mitigation actions, prioritizing and then implementing them requires input from various departments in the city. Staff dedicated to this process are required in more than one department to realize the benefits of mitigation projects in the near term.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	CIP; Virginia CFPF
Lead Agency/Department Responsible:	City Administration
Implementation Schedule:	Within 3 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 17	
Adopt and implement the RVAgreen 2050 equitable climate action and resilience plan. Implement strategies to reduce vulnerability and increase resilience to the impacts of climate change (extreme heat, extreme precipitation, and flooding).	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Since 2017, Richmond has invested significantly in understanding the impacts of climate change and the actions needed to reduce vulnerability. Formally adopting the RVAgreen plan commits city officials to implementing actions to fulfill plan objectives.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Droughts and Extreme Heat, Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1; Goal 3; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Strategy costs vary
Potential Funding Sources:	Funding sources vary by action.
Lead Agency/Department Responsible:	Office of Sustainability
Implementation Schedule:	Adopt and implement in 2022
ADDITIONAL COMMENTS	
RVAgreen 2050 builds on the foundation set by Richmond 300, the city's master planning process that engaged thousands of Richmonders in identifying objectives.	

CITY OF RICHMOND MITIGATION ACTION 18	
Upon completion, implement the RVAH2O Green Infrastructure Master Plan to expand green infrastructure on public lands and rights-of-way to improve stormwater quality and reduce runoff through City projects and community partnerships, including public engagement and education programs.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	The city has invested considerably in identifying opportunities to improve existing stormwater systems with green infrastructure. Implementation of individual projects will provide reduce flood damages into the future.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	NRI flood risk ranges from Low to Moderate to High.
Estimated Cost:	Multiple projects identified; costs vary
Potential Funding Sources:	Funding sources vary; many funded by CIP; Virginia CFPF
Lead Agency/Department Responsible:	Public Utilities
Implementation Schedule:	Plan currently in draft format; due mid/late 2023. Implementation thereafter.
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 19	
Develop, fund, and implement an urban heat island reduction plan and program with a focus on vulnerable populations and ecosystems as part of implementation of the RVAgreen 2050 equity-centered climate action and resilience plan. Include depaving initiatives and other actions to reduce impervious surface.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Urban heat islands contribute to the city's vulnerability for extreme heat. Addressing the types and expanse of impervious surface can provide benefits for reducing flooding and the impacts of extreme heat and drought.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Droughts and Extreme Heat
Goal(s) Addressed:	Goal 1; Goal 3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low to Moderate
Estimated Cost:	TBD
Potential Funding Sources:	DHS; Virginia CFPF; CIP
Lead Agency/Department Responsible:	Office of Sustainability
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 20	
Expand the Community Emergency Response Team (CERT). Hire a full-time coordinator for the CERT program.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	The city's CERT members contribute to response and recovery and could benefit implementation of mitigation actions, as well. Focused coordination of the team is necessary to maximize benefits.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1; Goal 2; Goal 3
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	~$75,000/year
Potential Funding Sources:	General Fund Budget
Lead Agency/Department Responsible:	Emergency Management
Implementation Schedule:	Within 4 years of adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 21	
Increase the proportion of Richmonders within a 10-minute walk of a public green space with amenities such as shade structures and tree canopy, public water fountains, and community garden space.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Public green spaces and their amenities benefit residents during times of extreme heat, and if co-located with floodplains, may provide flood reduction benefits, as well.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1, Goal 3: Objective 3.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	NRI flood risk ranges from Low to Moderate to High.
Estimated Cost:	TBD – studies underway
Potential Funding Sources:	DHS; ARPA; Virginia CFPF; DOI; EPA
Lead Agency/Department Responsible:	Parks, Recreation, and Community Facilities
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
This recommendation is a result of community surveys and is included in several community plans.	

CITY OF RICHMOND MITIGATION ACTION 22	
Increase and enhance the resilience and health of Richmond's urban forest. Increase tree canopy.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Increased tree canopy can achieve co-benefits of improved stormwater management, improved air quality, and reduced urban heat island impacts.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Droughts and Extreme Heat
Goal(s) Addressed:	Goal 1; Goal 3; Goal 4: Objectives 4.1 and 4.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS; ARPA; Virginia CFPF; DOI; EPA
Lead Agency/Department Responsible:	Public Works
Implementation Schedule:	Long-term
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 23	
Adopt an ordinance to require the city to use the Institute for Sustainable Infrastructure Envision framework to assess sustainability, resiliency, and equity in all new infrastructure projects.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Envision is a decision-making guide that provides industry-wide sustainability metrics for all types and sizes of infrastructure to help users assess and measure the extent to which their project contributes to conditions of sustainability across the full range of social, economic, and environmental indicators. Furthermore, the Envision framework recognizes that these sustainability factors are variable across a project's life cycle. Envision helps users optimize project resilience for both short-term and long-term impacts.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Office of Sustainability; Public Works
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 24	
Develop Resilient Design Guidelines and require builders to incorporate design measures to reflect a changing climate, increased precipitation and flooding in concert with a public education campaign to convey the benefits of adaptive and resilient buildings.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	Resilient design guidelines help ensure that future construction is resilient and provides benefits for managing multiple issues, including hazards such as flooding.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Severe Winter Weather, Droughts and Extreme Heat, Earthquakes, Radon Exposure
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.3, 1.4; Goal 3
Priority (High, Moderate, Low):	Low
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	CIP; Virginia CFPF
Lead Agency/Department Responsible:	Office of Sustainability; Planning and Development Review
Implementation Schedule:	Within 4 years of adoption
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 25	
Increase resilience of transit systems as part of implementation of the RVAgreen 2050 equity-centered climate action and resilience plan. Integrate and connect street trees with public transit and biking infrastructure.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	These actions would increase shade to mitigate extreme heat, and improve storm water management to mitigate flooding.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Droughts and Extreme Heat
Goal(s) Addressed:	Goal 1; Goal 3; Goal 4: Objectives 4.1 and 4.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	Virginia CFPF; ARPA
Lead Agency/Department Responsible:	Public Works, Office of Sustainability, GRTC, Office of Equitable Transit and Mobility
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 26	
Continue to manage industrial processes and waste streams to protect the community and natural resources from hazardous and other materials.	
BACKGROUND INFORMATION	
Site and Location:	Citywide industrial areas, particularly those intersecting with the city's floodplains
Benefit Cost:	Ensuring industrial waste is managed appropriately is critical to protecting river components, including floodplains.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Earthquakes, Landslides, Shoreline Erosion
Goal(s) Addressed:	Goal 1, Goal 2; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	EPA; DHS; ARPA; Virginia CFPF
Lead Agency/Department Responsible:	DPW, DPU, Fire and Emergency Services
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

CITY OF RICHMOND MITIGATION ACTION 27	
Establish a community response fund for direct and immediate assistance to community organizations that provide services to residents to enhance resilience to climate change hazards as part of implementation of the RVAgreen 2050 equity-centered climate action and resilience plan.	
BACKGROUND INFORMATION	
Site and Location:	Citywide
Benefit Cost:	This action would benefit residents directly by connecting them with organizations that provide services.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Droughts and Extreme Heat, Landslides, Shoreline Erosion, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	CIP
Lead Agency/Department Responsible:	Office of Sustainability
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

TOWN OF SURRY MITIGATION ACTION 1	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, mapping to determine detailed flood hazards, and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Town
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Services/Safety, Utilities
Implementation Schedule:	Immediately upon adoption
ADDITIONAL COMMENTS	

TOWN OF SURRY MITIGATION ACTION 2	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Town
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Existing budgets
Potential Funding Sources:	DHS: HMGP, BRIC; USACE
Lead Agency/Department Responsible:	Emergency Services/Safety, Utilities
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 1	
Add trained staff to Emergency Management, Building Inspections, and Planning and Zoning, to include a Certified Floodplain Manager in Planning & Zoning.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Staff who are well-versed in administration of county requirements related to hazard mitigation help make sure that existing standards are enforced and new standards do not increase the impacts of hazards.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 3
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	3 annual salaries (~$180,000/year) + training (~$2000/year)
Potential Funding Sources:	DHS
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
While some staff changes have occurred, additional personnel are still required.	

SUSSEX COUNTY MITIGATION ACTION 2		
Continue participating in the National Flood Insurance Program through: 1) enforce of zoning and building codes; 2) pursue memorandum of agreement between towns and the county to provide flood ordinance administration, as necessary; and, 3) review and update 2009 flood ordinance.		
BACKGROUND INFORMATION		
Site and Location:	Throughout floodprone areas of the county	
Benefit Cost:	NFIP regulations reduce flood damage by requiring elevation to the base flood elevation.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Flooding due to Impoundment
Goal(s) Addressed:		Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		High – western part of the county, and Stony Creek Moderate – middle part of the county Low – far eastern part of the county
Estimated Cost:		Staff time
Potential Funding Sources:		Existing resources
Lead Agency/Department Responsible:		Planning and Zoning, Building Inspections, USACE, Va DCR, Wakefield and Waverly Administration
Implementation Schedule:		
ADDITIONAL COMMENTS		
This action is also a comprehensive plan recommended action.		

SUSSEX COUNTY MITIGATION ACTION 3	
Develop stormwater master plan to study capacity of existing culverts and other structures to determine if sizing is sufficient for future conditions. Identify and replace vulnerable or undersized culvert stream crossings with bridges or larger culverts to reduce flood hazards, where feasible. Implement program for regular inspections and maintenance of roadside ditches and stream channels.	
BACKGROUND INFORMATION	
Site and Location:	Countywide; however, areas in and near the towns of Wakefield and Stony Creek are of particular concern.
Benefit Cost:	Benefits of improving the stormwater conveyances accrue to infrastructure and homes in the area flooded by undersized bridges and culverts. Ensuring culverts are sized for future flooding will help address climate change and increased precipitation.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High – western part of the county, and Stony Creek Moderate – middle part of the county Low – far eastern part of the county
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, FMA, BRIC; ARPA
Lead Agency/Department Responsible:	Public Safety, VDOT
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 4	
Advocate for a Federal/state project to elevate I-95 bridge and widen channel at Stony Creek.	
BACKGROUND INFORMATION	
Site and Location:	I-95 bridge over Stony Creek, just north of Rte 40 outside of Stony Creek
Benefit Cost:	Bridge is older and appears to constrict the floodway at the crossing during the base flood. SFHA impacts large portion of Stony Creek.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1, Goal 2, Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	PDC, VDOT, USDOT
Lead Agency/Department Responsible:	Public Safety, County Administration
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 5	
Expand GIS capabilities. Acquisition of detailed floodplain BFEs and roadway crossing elevations are particular areas of interest for evacuation and emergency access planning.	
BACKGROUND INFORMATION	
Site and Location:	Countywide; however, area outside of Stony Creek along the Nottaway River are of particular interest.
Benefit Cost:	Emergency Management and hazard response functionality are improved with high level data integration and geographic/spatial data.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	All hazards
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 2; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Public Safety, VDOT, USACE, VaDCR
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 6	
Increase capacity of stormwater system in conjunction with towns of Wakefield and Waverly.	
BACKGROUND INFORMATION	
Site and Location:	Wakefield and Waverly
Benefit Cost:	Properly sized and maintained culverts and other stormwater structures can help alleviate flooding and minimize damages to nearby infrastructure and buildings.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1: Objective 1.1; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; ARPA; VDOT
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 7	
Increase outreach to citizens regarding preparation and response to hazard events, to include: promote the "Turn Around, Don't Drown" public education campaign; install high water marks at key crossings; social media information ahead of rain/wind/winter storms; temporary digital signage on critical roadways; and other permanent signage to warn of known driving hazards.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Severe Wind Events, Severe Winter Weather
Goal(s) Addressed:	Goal 1
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Staff time; digital signage cost is $15,000 - $30,000 per sign
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Emergency Management, NWS
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

		SUSSEX COUNTY MITIGATION ACTION 8
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, mapping to determine detailed flood hazards, and stormwater management system improvements. Target repetitive flood loss areas identified in Section 5, two of which have high risk and social vulnerability.		
BACKGROUND INFORMATION		
Site and Location:		Repetitive flood loss areas, particularly the two near Stony Creek Stony Creek Wastewater Treatment Plant Generators for county evacuation shelters
Benefit Cost:		Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:		Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):		High
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		TBD
Potential Funding Sources:		DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:		Public Safety
Implementation Schedule:		Ongoing
ADDITIONAL COMMENTS		

SUSSEX COUNTY MITIGATION ACTION 9	
Distribute brochures and use other means to educate the public regarding preparedness and mitigation. Conduct annual preparedness days for hazards to include floods, wind, tornado, and earthquakes.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	FEMA, VDEM and other agencies maintain a large library of free paper and online materials to support this action. Social media is free for communities and has potential to reach large number of citizens in a short period of time, and at little cost.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Tornadoes, Wildfires, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes, Radon Exposure, Infectious Diseases
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 2: Objective 2.2
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	Minimal
Potential Funding Sources:	Existing budgets
Lead Agency/Department Responsible:	Public Safety
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 10	
Conduct regular review of repetitive loss and severe repetitive flood loss properties from FEMA. Review will include verification of the geographic location of each property and determination if mitigated and by what means. Corrections can be made to FEMA by filing form FEMA AW-501.	
BACKGROUND INFORMATION	
Site and Location:	Repetitively flooded areas in the county
Benefit Cost:	Structures designated as repetitive flood losses are treated differently under NFIP rating procedures. Ensuring the list is correct is important for property owners in the county who have to pay for flood insurance.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objectives 1.1, 1.4; Goal 3; Goal 4: Objective 4.1
Priority (High, Moderate, Low):	
Impact on Socially Vulnerable Populations:	High – 2 rep loss areas along I-95 Low – 1 rep loss area in northeast corner of county
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Zoning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 11	
Develop and implement detailed tornado response and recovery plan, to include safe rooms for manufactured home parks, and post-event housing considerations for impacted residents (with HUD).	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	This targeted mitigation action will help reduce impacts to citizens in a post disaster scenario. Safe rooms can save lives, particularly in highly vulnerable manufactured home parks.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Tornado
Goal(s) Addressed:	Goal 1: Objectives 1.2, 1.4; Goal 3: Objective 3.2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP; HUD: CDBG (see 2003 Tornado Shelters Act)
Lead Agency/Department Responsible:	Sussex County/Towns
Implementation Schedule:	

ADDITIONAL COMMENTS
On December 3, 2003, the President signed into law the Tornado Shelters Act (Public Law 108-146), which amends the Housing and Community Development Act of 1974, authorizing communities to use community development block grant funds to construct tornado-safe shelters in manufactured home parks. It allows construction or improvement of tornado-safe shelters for manufactured housing including loans and grants to non-profit or for-profit entities. Shelters built under the auspices of the Act must be located in a neighborhood or park that contains at least 20 units, consists predominately of low- and moderate-income households, and is in a state where a tornado has occurred within the current or last 3 years. Further, each constructed shelter must comply with the Department of Housing and Urban Development's (HUD's) standards for construction and safety, and be large enough to accommodate all members of the park/neighborhood, and be located in a park/neighborhood that has a warning siren.

SUSSEX COUNTY MITIGATION ACTION 12		
Develop/update county capital improvements plan to include timelines and appropriations for projects identified under this hazard mitigation planning effort.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	Several mitigation actions identified in the plan cannot be implemented without grant funding and/or county appropriations.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:	All hazards	
Goal(s) Addressed:	Goal 1, Goal 3	
Priority (High, Moderate, Low):	High	
Impact on Socially Vulnerable Populations:	Low	
Estimated Cost:	Staff time	
Potential Funding Sources:	Existing budgets	
Lead Agency/Department Responsible:	Unknown, no response	
Implementation Schedule:	Within 1 year of plan adoption	
ADDITIONAL COMMENTS		
This action is also a comprehensive plan recommended action.		

SUSSEX COUNTY MITIGATION ACTION 13	
Reduce physical vulnerability of County staff with offices currently in temporary modular units from wind, snow and rain. Provide freestanding building with structural protections that meet or exceed current building code standards.	
BACKGROUND INFORMATION	
Site and Location:	County complex in Sussex
Benefit Cost:	Some county staff currently have offices in manufactured buildings outside of the main building. These structures are temporary in nature and may be more vulnerable to damage during weather extremes.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Severe Wind Events, Tornadoes, Severe Winter Weather, Thunderstorms, Droughts and Extreme Heat, Earthquakes
Goal(s) Addressed:	Goal 1; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	Low
Estimated Cost:	TBD – new building is more expensive than reconfiguring existing space
Potential Funding Sources:	Existing county revenues
Lead Agency/Department Responsible:	County Administration
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

SUSSEX COUNTY MITIGATION ACTION 14	
Establish development criteria and requirements to include density and intensity criteria, cluster subdivision design, stream buffers, impervious surface limits and innovative stormwater management alternatives.	
BACKGROUND INFORMATION	
Site and Location:	Countywide
Benefit Cost:	Existing design and development criteria for subdivisions are minimal. Beneficial design that accounts for existing and future hazards reduces damage from disasters in the future.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High – western part of the county, and Stony Creek Moderate – middle part of the county Low – far eastern part of the county
Estimated Cost:	Staff time
Potential Funding Sources:	Existing resources
Lead Agency/Department Responsible:	Planning and Zoning
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
This action is also a comprehensive plan recommended action.	

SUSSEX COUNTY MITIGATION ACTION 15		
Provide improved healthcare facilities for county residents, to include services before during and after all types of hazard events, to ensure continuity of operations. Options may include coordination and consolidation of existing health facilities and other county functions.		
BACKGROUND INFORMATION		
Site and Location:	Countywide	
Benefit Cost:	Maintaining functionality of county resources during and after the pandemic proved challenging.	
MITIGATION ACTION DETAILS		
Hazard(s) Addressed:		Infectious Diseases, Radon Exposure, Tornadoes, Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Droughts and Extreme Heat, Earthquakes
Goal(s) Addressed:		Goal 1; Goal 2; Goal 3: Objective 3.2
Priority (High, Moderate, Low):		Moderate
Impact on Socially Vulnerable Populations:		Low
Estimated Cost:		TBD
Potential Funding Sources:		DHS: HMGP, other; ARPA
Lead Agency/Department Responsible:		Health Department, Public Safety
Implementation Schedule:		Within 2 years of plan adoption
ADDITIONAL COMMENTS		
This action is also a comprehensive plan recommended action.		

TOWN OF STONY CREEK MITIGATION ACTION 1	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Repetitive loss area along south bank of creek and Halifax Road; floodway area north of the intersection of Rte 301 and Halifax Road (restaurant); structures at the intersection of Main Street and Halifax Road, just south of the Main Street bridge over Stony Creek
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Mayor, with assistance from Crater PDC
Implementation Schedule:	Ongoing

ADDITIONAL COMMENTS
Small flood control structure (*e.g.,* kneewall) may be cost-beneficial along Halifax Road, outside of floodway. Elevation of residential structures, or floodproofing of commercial structures may be feasible options at the east and west ends of town. Request assistance from USACE, Norfolk District. FPMS division could conduct study to determine feasibility of various alternatives in the town to alleviate repetitive flooding.

	TOWN OF STONY CREEK MITIGATION ACTION 2
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Mayor & Town Clerk
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF STONY CREEK MITIGATION ACTION 3	
Advocate for a Federal/state project to elevate I-95 bridge and widen channel at Stony Creek.	
BACKGROUND INFORMATION	
Site and Location:	I-95 bridge over Stony Creek, just north of Rte 40 outside of Stony Creek
Benefit Cost:	Bridge is older and appears to constrict the floodway at the crossing during the base flood. SFHA impacts large portion of the Town of Stony Creek.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1, Goal 2, Goal 4
Priority (High, Moderate, Low):	Moderate
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	PDC, VDOT, USDOT
Lead Agency/Department Responsible:	Mayor
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

TOWN OF STONY CREEK MITIGATION ACTION 4	
Install high water signage to warn drivers and pedestrians of dangerous crossing during flooding. Use Turn Around, Don't Drown campaign materials to further warn drivers of hazards.	
BACKGROUND INFORMATION	
Site and Location:	Main Street bridge over Stony Creek, Halifax Road and Route 301 near I-95.
Benefit Cost:	Signage warning drivers helps prevent water rescues and saves lives.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding
Goal(s) Addressed:	Goal 1, Goal 2
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	~$5000
Potential Funding Sources:	PDC, USACE, ARPA, FEMA: HMGP
Lead Agency/Department Responsible:	Mayor
Implementation Schedule:	Within 2 years of plan adoption
ADDITIONAL COMMENTS	

TOWN OF WAKEFIELD MITIGATION ACTION 1	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities, mapping to determine detailed flood hazards, and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Town, particularly in flood-prone areas that have flooded recently along Route 460 near the Virginia Diner.
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Emergency Services/Safety, Utilities
Implementation Schedule:	Immediately upon adoption
ADDITIONAL COMMENTS	

TOWN OF WAKEFIELD MITIGATION ACTION 2	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the Town, particularly in flood-prone areas that have flooded recently along Route 460 near the Virginia Diner.
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	Existing budgets
Potential Funding Sources:	DHS: HMGP, BRIC; USACE
Lead Agency/Department Responsible:	Emergency Services/Safety, Utilities
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	
Examples include the *Virginia Hurricane Evacuation Guide* and data from VDEM's Crisis Track collected post-disaster.	

TOWN OF WAVERLY MITIGATION ACTION 1	
Protect public and private structures from natural hazard damage, including acquiring, relocating, retrofitting or elevating floodprone property. This action may include minor structural flood control projects, retrofits to address critical infrastructure and facilities and stormwater management system improvements.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	Structures and infrastructure can often be retrofitted to provide additional protection from hazards such as flood, thereby reducing average annual losses.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Severe Wind Events, Wildfires, Severe Winter Weather, Thunderstorms, Earthquakes, Landslides, Radon Exposure
Goal(s) Addressed:	Goal 1: Objective 1.4; Goal 3; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: BRIC, HMGP, FMA, RFC; ARPA; USACE: SFCP, FPMS; HUD: CDBG; Virginia CFPF
Lead Agency/Department Responsible:	Mayor and Town Administration
Implementation Schedule:	
ADDITIONAL COMMENTS	

TOWN OF WAVERLY MITIGATION ACTION 2	
Use available statewide, regional, or county advanced warning systems, weather gauging systems, evacuation planning tools, and public information resources to prepare community officials and residents in case of a hazard event. Acquire additional resources to supplement these systems, as required.	
BACKGROUND INFORMATION	
Site and Location:	Throughout the town
Benefit Cost:	When people have adequate time to prepare for a hazard event and know what actions to take ahead of time, damages are reduced.
MITIGATION ACTION DETAILS	
Hazard(s) Addressed:	Flooding, Flooding due to Impoundment Failure, Tornadoes, Severe Wind Events, Thunderstorms, Earthquakes, Severe Winter Weather
Goal(s) Addressed:	Goal 1; Goal 2; Goal 4
Priority (High, Moderate, Low):	High
Impact on Socially Vulnerable Populations:	High
Estimated Cost:	TBD
Potential Funding Sources:	DHS: HMGP, BRIC; Virginia CFPF; USACE
Lead Agency/Department Responsible:	Mayor and Town Administration
Implementation Schedule:	Ongoing
ADDITIONAL COMMENTS	

8.0 Plan Maintenance Procedures

8.1 Updates for 2022

Section 8 was updated to modify the wording and scope, clarify the planning and updating requirements, and to amend the communities participating in this planning process.

8.2 Introduction

This section discusses how the Mitigation Strategy will be implemented by the communities and how the overall Hazard Mitigation Plan will be evaluated and enhanced over time. This section also discusses how the public and participating stakeholders will continue to be involved in the hazard mitigation planning process in the future.

8.3 Implementation

44 CFR Requirement

Part 201.6(c)(4)(i): The plan will include a plan maintenance process that includes a section describing the method and schedule of monitoring, evaluating and updating the mitigation plan within a five-year cycle.

In addition to the assignment of a lead department or agency, an implementation time period has been established for each mitigation action in order to assess whether actions are being implemented in a timely fashion. Each community will seek funding sources to implement mitigation projects in both the pre-disaster and post-disaster environments. When applicable, potential funding sources have been identified for proposed actions listed in each MAP.

44 CFR Requirement

Part 201.6(c)(4)(ii): The plan maintenance process will include a process by which local governments incorporate the requirements of the mitigation plan into other planning mechanisms such as comprehensive or capital improvement plans, when appropriate.

Emergency Management officials in each community will be responsible for determining additional implementation procedures beyond those listed within the Mitigation Action Plan. This includes further integrating the Hazard Mitigation Plan into other local planning documents such as comprehensive or capital improvement plans, when appropriate. The members of the planning committees for each community remain charged with ensuring that the goals and strategies of new and updated local planning documents (such as Comprehensive Plans and Zoning Ordinances) are consistent with the goals and actions of the Hazard Mitigation Plan, and that those planning documents will not contribute to an increased level of hazard vulnerability in the region.

Opportunities to integrate the requirements of this Plan into other local planning mechanisms will continue to be identified through future meetings of each community's mitigation planning committee and through the five-year review process described in this section.

Each community will integrate the tenets of this mitigation plan into relevant local government decision making processes or mechanisms. The primary means for integrating mitigation strategies into other local planning documents will be accomplished through the revision, update, and implementation of the Mitigation Action Plan that requires specific planning and administrative tasks (i.e., plan amendments, ordinance revisions, capital improvement projects). In addition, each community will incorporate existing planning processes and programs addressing the impacts of climate change, resiliency programs, and flooding mitigation into this document by reference.

8.4 Monitoring, Evaluation and Enhancement

Periodic revisions and updates to the Plan are required to ensure that the goals of the Plan are kept current, taking into account potential changes in hazard vulnerability and mitigation priorities. In addition, revisions may be necessary to ensure that the Plan is in full compliance with changing Federal, state and local regulations. Periodic evaluation of the Plan will also ensure that specific mitigation actions are being reviewed and carried out according to the Mitigation Action Plan.

The Hazard Mitigation Planning Working Group will continue to meet at least annually and following any disaster events warranting a re-examination of the mitigation actions, thus continuously updating the Plan to reflect changing conditions and needs within the communities. An annual report on the Plan will be developed and presented to elected officials through PlanRVA and Crater PDC in order to report progress on the actions identified in the Plan and to provide information on the latest legislative requirements. The report may also highlight proposed additions or improvements to the Plan. The report will be released to the media and made available to the public via appropriate methods, such as the PDCs' web sites.

Each community has designated a lead person and agency responsible for the monitoring, evaluation and enhancements to the plan. Those position titles and agencies are shown in Tables 3.2a and 3.2b as rows marked with an asterisk. These individuals are the primary contacts moving forward with plan implementation.

8.4.1 Annual Progress Reports

Each community's hazard mitigation planning committee will be responsible for producing an annual progress report to evaluate the Plan's overall effectiveness. As part of the contract for preparing this plan, the contractor is providing a mitigation action plan spreadsheet in Appendix G that lists all mitigation actions for each community and the region. Updating this spreadsheet with status information will allow periodic progress checkups that can feed into the annual progress reports.

8.4.2 Five-Year Plan Review

At a minimum, the Plan will be reviewed and must be updated every five years by the hazard mitigation planning committees as required by DMA 2000. The purpose of the review and update is to determine whether there have been any significant changes that may, in turn, necessitate changes in the types of mitigation actions proposed. New development in identified hazard areas, an increased exposure to hazards, the increase or decrease in capability to address hazards, and changes to federal or state legislation are examples of factors that may affect the content of the Plan.

The plan review provides community officials with an opportunity to evaluate those actions that have been successful and to explore the possibility of documenting potential losses avoided due to the implementation of specific mitigation measures. The plan review also provides the opportunity to address mitigation actions that may not have been successfully implemented. Each community will be responsible for reconvening and conducting the five-year review, although it is expected that the PDCs will again lead the effort to update the plan in five years. During the five-year plan review process, the following questions will be considered as criteria for assessing the effectiveness and appropriateness of the Plan:

- Do the goals and actions address current and expected conditions?
- Has the nature or magnitude of hazard risk changed?
- Are current resources adequate to implement the Plan?
- Should additional local resources be committed to address identified hazard threats?
- Are there any issues that have limited the current implementation schedule?
- Has the implementation of identified mitigation actions resulted in expected outcomes?
- Has the committee measured the effectiveness of completed hazard mitigation projects in terms of specific dollar losses avoided?
- Did the community, agencies and other partners participate in the plan implementation process as proposed?

Following the five-year review, any revisions deemed necessary will be summarized and implemented according to the reporting procedures and plan amendment process outlined in this section. Upon completion of the review and update process, the Plan will be submitted to VDEM for review and approval. Upon final approval, VDEM will submit the Plan amendments to FEMA for final review as required by DMA 2000.

8.4.3 Disaster Declaration

Following a state or federal disaster declaration, the hazard mitigation planning committee will reconvene and the Plan will be revised as necessary to reflect lessons learned or to address specific circumstances arising from the event. Community committees may find it necessary to convene following localized emergencies and disasters, or when pursuing funding for a specific mitigation project, in order to determine if administrative changes to the Plan are warranted.

8.4.4. Reporting Procedures

The results of the five-year review will be summarized by the committee in a report that will include an evaluation of the effectiveness of the Plan and any required or recommended changes or amendments. The report will also include a brief progress report for each mitigation action, including the identification of delays or obstacles to their completion along with recommended strategies to overcome them. Any necessary revisions to the Plan must follow the plan amendment process outlined herein.

8.4.5 Plan Amendment Process

Upon initiation of the amendment process, the community(ies) will forward information on the proposed change(s) to interested parties, including affected municipal departments. Information will also be forwarded to the VDEM. This information will be disseminated in order to seek input on the proposed amendment(s) for not less than a 5-day review and comment period.

At the end of the 5-day review and comment period, the proposed amendment(s) and all comments will be forwarded to the PDCs for final consideration. The committee will review the proposed amendments along with the comments received from other parties, and if acceptable, the committee will submit a recommendation for the approval and adoption of changes to the Plan.

Minor revisions to the plan may be approved by each community's Chief Administrative Officer, while substantial amendments and addendums must be approved by the community's elected governing body.

In determining whether to recommend approval or denial of a Plan amendment request, the following factors will be considered by the committee:

- There are errors, inaccuracies or omissions made in the identification of issues/needs in the Plan;
- New issues/needs have been identified which are not adequately addressed in the Plan;
- There has been a change in data or assumptions from those upon which the Plan is based.

Upon receiving the recommendation from the committee and prior to adoption of the Plan, each community's governing body will hold a public hearing. The governing body will review the recommendation from the committee (including the factors listed above) and any oral or written comments received at public hearing(s). Following that review, the governing body will take one of the following actions:

- Adopt the proposed amendments as presented;
- Adopt the proposed amendments with modifications;
- Refer the amendments request back to the committee for further revision; or
- Defer the amendment request back to the committee for further consideration and/or additional hearings.

8.5 Continued Public Involvement

> **44 CFR Requirement**
>
> **Part 201.6(c)(4)(iii):** The plan maintenance process will include a discussion on how the community will continue public participation in the plan maintenance process.

Public participation is an integral component of the mitigation planning process. As described above, significant changes or amendments to the Plan will require a public hearing prior to any adoption procedures.

Other efforts to involve the public in the maintenance, evaluation and revision process will be made. These efforts differ by community based on each community's individual needs, public response and whether the community has been recently affected by a hazard event. Examples of how communities in the Richmond-Crater region already engage the public during the interim planning period, or of how they may choose to approach this task in the future, include:

- Advertise meetings of the committee in local newspapers, public bulletin boards, web sites, social media and community public buildings. Designating a diverse community mitigation committee through official resolution of the governing board, and then scheduling regular meetings of the committee and advertising those meetings aggressively has worked well for some communities.

- Designate willing residents and private sector representatives as official members of the planning committee. While real estate, financial and construction industry leaders are natural partners in mitigation planning, look beyond these to include business leaders, large employers, and representatives of local military installations and transportation hubs, such as the Port of Virginia. Cultural institutions are an important component in the regional economy and their collections may be vulnerable to many of the hazards discussed in the plan. Neighborhood groups, civic leagues and other citizen groups are a valuable source of mitigation ideas for specific areas.

- Engage elected officials and planning commission members in the process, beyond simply providing updates or reports. Elected officials have a responsibility to protect the health, safety and welfare of their constituents and their support is critical to successful implementation of the Mitigation Action Plan in every Richmond-Crater community.

- Use local media to update the public about any maintenance or periodic review activities taking place. The media have moved beyond traditional print and televised formats and their online presence can be valuable in disseminating information about upcoming meetings or activities. Local non-profits can also be invaluable in spreading the word about mitigation planning meetings open to the public.

- Use questionnaires, open houses, fairs and other community events to obtain ongoing public comments on the Plan and its implementation. Many local emergency managers effectively use community events to inform and advise the public on preparedness and evacuation, but the venues can also be valuable for informing the citizenry about the components of effective mitigation, how their community is implementing their Mitigation Action Plan and gathering information from the public to inform the next plan revision.

- Use community web sites, social media and list-servs to advertise any maintenance or periodic review activities taking place. Periodic surveys on social media can be a fun way to raise awareness.

- Hold area-specific meetings on a regular basis to solicit feedback from neighbors. Such meetings, held in public venues, can be used to distribute literature, educate residents on mitigation actions they can implement on their own, and solicit input on how the mitigation process can be more effective for their area or neighborhood.

- Integrate mitigation action plans, goals and objectives, and other plan elements into other community planning objectives. When a community's comprehensive or resiliency planning process includes similar team members and incorporates or references pieces of the hazard mitigation plan, the public gains familiarity with the links between the plans and the ways in which the efforts complement each other.

- Maintain hard copies of the Plan in public libraries, on the web, or other appropriate venues. While many residents are engaged in community affairs through computer technology, keeping hard copies of the plan in public venues with a business card or other contact information for providing feedback or answering questions is an old-fashioned but necessary way of reaching a much larger segment of residents.

Table 8.1 provides summary feedback from individual community's committee leaders indicating how they anticipate their community will include the public in the 5-year period following adoption.

Table 8.1: Including the Public During Plan Implementation Period						
Community	**Advertise committee meetings**	**Designate residents, private sector reps as members of committee**	**Use local media to update public on maintenance activities**	**Use questionnaires, open houses to obtain public comment**	**Use web sites to advertise maintenance activities**	**Maintain copies of the plan in libraries, on the web, or other venues**
Charles City County	✓	✓	✓	✓	✓	✓
Chesterfield County	✓	✓	✓	✓	✓	✓
City of Colonial Heights	✓		✓		✓	✓
Dinwiddie County	✓	✓	✓		✓	✓
Town of McKenney	✓					
City of Emporia	✓		✓		✓	✓
Goochland County	✓	✓	✓		✓	✓
Greensville County	✓		✓		✓	✓
Town of Jarratt	✓					
Hanover County	✓	✓	✓	✓	✓	✓
Town of Ashland	✓	✓	✓	✓	✓	✓
Henrico County	✓	✓	✓	✓	✓	✓
City of Hopewell	✓		✓		✓	✓
New Kent County	✓	✓	✓	✓	✓	✓
City of Petersburg	✓		✓		✓	✓
Powhatan County	✓		✓		✓	✓
Prince George County	✓		✓		✓	✓
City of Richmond	✓	✓	✓	✓	✓	✓
Town of Surry	✓		✓			
Sussex County	✓		✓		✓	✓

Table 8.1: Including the Public During Plan Implementation Period						
Community	Advertise committee meetings	Designate residents, private sector reps as members of committee	Use local media to update public on maintenance activities	Use questionnaires, open houses to obtain public comment	Use web sites to advertise maintenance activities	Maintain copies of the plan in libraries, on the web, or other venues
Town of Stony Creek	✓					✓
Town of Wakefield	✓					✓
Town of Waverly	✓					✓

8.6 Opportunities for Improvement

Several opportunities for improving the plan and planning process are outlined below in **Table 8.2**, primarily as suggestions or strategies that may enhance the planning process effectiveness for either individual communities in the coming 5-year period of implementation, or for future updates of the entire plan.

Table 8.2: Opportunities for Improvement	
Mitigation Planning Step	**Opportunities**
Phase I: Organize Resources **Step 1. Get Organized** **Step 2. Plan for Public Involvement** **Step 3. Coordinate with Other Departments & Agencies**	• Continue to distribute Memorandum of Intent to Participate for all communities in the early stages of the planning process. • Engage public information officers, resiliency officers, equity officers, web site managers and other community communications specialists from each community throughout the process. • The regional planning authority should continue to ask and rely on communities to reach out to large businesses, military installations, educational and medical institutions, neighborhood associations, non-profits, utilities and other groups to spur their involvement in the process, but communities need to provide documentation of these "asks" that is then included in the plan. • Rural town engagement in the planning process was limited. Continue to educate town staff about importance of their input.
Phase II: Assess Risk **Step 4. Identify the Hazards** **Step 5. Assess the Risks**	• Virtual meetings limited the feedback received after presentation of HIRA to the committee. Distributing small elements of the assessment to the committee for review may increase participation and feedback. • Difficulty obtaining repetitive loss data from FEMA and assessor data from some communities delayed completion of the HIRA.
Phase III: Develop Mitigation Plan **Step 6: Review Mitigation Alternatives** **Step 7: Draft an Action Plan** **Step 8: Set Planning Goals**	• Provide a review form for each community to document their review and approval of each plan section. • "Office Hours" with consultant worked well for developing each community MAP but did not include all stakeholders. Reassess this approach once COVID-19 restrictions are lifted.

https://library.municode.com/va/rich

Richmond, Virginia

Richmond, Virginia - Code of Ordinances / Ch

VERSION: AUG 11, 2023 (CURRENT)

Chapter 12 - FINANCE

Chapter 13 - FIRE PREVENTION AND PROTECTION

Chapter 14 - FLOODPLAIN MANAGEMEN
EROSION AND SEDIMENT CONTROL, AN
DRAINAGE

ARTICLE I. - IN GENERAL

ARTICLE II. - FLOODPLAIN MANAGEM

ARTICLE III. - EROSION AND SEDIMEN
CONTROL

ARTICLE IV. - CHESAPEAKE BAY

2017

RVA CLEAN WATER PLAN

Prepared for The City of Richmond's Department of Public Utilities

City of Richmond
Department of Public Utilities

RVA H2O
EVERY DROP COUNTS

LimnoTech
Water Environment | Scientists Engineers

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RVA Clean Water Plan

September 2017

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Appendices

Appendix A – RVA Clean Water Plan Modeling Report

Appendix B – Strategy Fact Sheets

Appendix C – Goals, objectives, and metrics

Appendix D – Excel-based strategy calculator tool

Appendix E – Strategy cost estimation information

Acronyms

CBP – Chesapeake Bay Program

CFU – coliform forming units

CPMI – Coastal Plain macroinvertebrate index

CSO – combined sewer overflow

CSS – combined sewer system

CWA – Clean Water Act

DPU – Department of Public Utilities

EFDC - Environmental Fluid Dynamics Code

EPA – Environmental Protection Agency

GI – green infrastructure

GIS – geographic information system

LA – load allocation

LTCP – long term control plan

MGD – million gallons per day

MS4 – municipal separate storm sewer system

NPDES – national pollution discharge elimination system

PRCF - Parks, Recreation, and Community Facilities

SSO – sanitary sewer overflow

STV – statistical threshold value

SWMM – stormwater management model

TN – total Nitrogen

TP – total Phosphorus

TSS – total suspended solids

TMDL – total maximum daily load

UAA – use attainability analysis

USGS – United States Geological Service

VDCR – Virginia Department of Conservation and Recreation

VDEQ – Virginia Department of Environmental Quality

VSCI – Virginia Stream Condition Index

VPDES – Virginia Pollutant Discharge Elimination System

WWTP – wastewater treatment plant

Executive Summary

The City of Richmond's Department of Public Utilities (DPU) manages five utilities, three of which address water and potentially influence local water resources: wastewater, stormwater, and drinking water. The wastewater utility operates the wastewater treatment plant (WWTP), which discharges treated effluent to the James River, a sanitary sewer and combined sewer collection system, pumping stations, the Hampton-McCloy Tunnel, and the Shockoe Retention Basin. The stormwater utility manages the stormwater that runs off impervious surfaces through underground storm sewer systems and open channels into the James River and its tributaries. Approximately two-thirds of the City of Richmond is served by a municipal separate storm sewer system (MS4). The drinking water utility manages the treatment plant and distribution system of water mains, pumping stations, and storage facilities that provide water to more than 500,000 customers in the city and surrounding area using water from the James River.

Historically, the three utilities were managed independently of one another, primarily driven by the fact the regulatory agencies implemented the regulations and permit requirements independently. This approach forced the City to make decisions related to compliance for each utility without being able to consider the interrelated impacts, especially on local waterways. Integration of all of the separate programs into a coordinated approach would eliminate redundant activities, be more efficient and effective addressing wet weather impacts, and improve water resources overall. USEPA has put a significant amount of effort in recent years into describing and publicizing holistic or integrated processes to protect water quality. Richmond has applied EPA's concepts to form a framework, documented in this Richmond, Virginia (RVA) Clean Water Plan, that allows the City to efficiently evaluate, manage, and implement water quality programs, work toward their goals and objectives, and culminate in a single, integrated VPDES permit that encompasses the City's wastewater, CSO, and stormwater discharges.

The James River and its tributaries drain a watershed of over 10,000 square miles. Within the City of Richmond, the James River flows for 24 miles, providing a substantial amount of waterfront. Major features in the river include Bosher's Dam, which is located just upstream of the City along the James River, and smaller dams, levees, and pipe crossings within the City. Just downstream of the City is the Presquile Wildlife Refuge, home to several species of birds and anadromous fish, including the endangered Atlantic sturgeon.

The focus of the RVA Clean Water Plan is on the portion of the James River watershed within the City's municipal boundary and on restoring and protecting the waterways in this watershed. This watershed-wide, water quality-based strategy allows the City to develop an effective and affordable management plan while also meeting regulatory requirements, and demonstrating to the public that the plan protects and improves the watershed and waterways. Richmond's Clean Water Plan includes six elements[1], which summarized here and discussed in more detail in this document.

[1] (1)Stakeholder Involvement; (2) Watershed Characterization; (3) Strategy Identification, Evaluation and Selection; (4) Program Implementation; (5) Progress Measurement; and (6) Adaptive Management

Stakeholder Involvement

Stakeholders can represent many different groups with an interest in the watershed, including, for example, advocates for wildlife and habitat protection; boaters; residential, commercial and business interests; and environmental justice groups. The City has incorporated stakeholder involvement throughout the entire planning process to help ensure stakeholders understood the process from the outset and were part of decision-making efforts throughout the development of the plan. The City's Watershed Characterization Report includes additional discussion of the various stakeholders that have been invited to participate and/or are participating within this planning process.

The City created and initiated RVAH2O (RVAH2O.org), the name representing a citywide effort to arrive at "Cleaner Water Faster", to disseminate outreach information and facilitate communication with stakeholders. Beginning with an initial meeting in November 2014, the City has held technical meetings every 2-3 months. The City also initiated a public outreach effort, including several open houses, to lay a foundation of understanding before laddering up to the more technical conversation around watershed integration. The City's Public Outreach Plan, which includes online and offline communication strategies, has a goal of reaching 20% of the City's population in the MS4 area by 2018. Progress towards this and other goals are being measured by tracking RVAH2O Facebook and Twitter traffic, email campaign, and flier distributions.

Watershed Characterization

Understanding existing water quality, along with the sources of pollutants or stressors that impact the City's waterbodies, are key elements for developing priority actions to address existing or potential problems and developing an effective integrated plan. Collection of data and characterization of the City's watersheds were the City's first steps towards development of the Clean Water Plan. Another key step towards was the development of a water quantity and quality modeling framework, that incorporates models for the CSO areas, the non-CSO areas (including Richmond's MS4 area), and for the James River itself. The purpose of the modeling framework was to quantify present day bacteria (*E. coli*) concentrations in the James River and to predict future bacteria concentrations under the Clean Water Plan strategies.

Watershed Data and Features

The western and very northern portions of the City have experienced the least amount of hydrologic modification and possess the lowest intensely developed land use and most forested land cover. These more western areas also correspond with areas with higher soil infiltrative capacity. Alternatively, the eastern portion of the City corresponds with a higher intensity of developed land and industrial land use corridor as well as the City's urban core. Consequently, this area also corresponds to soils that are considered urban and tend to have less infiltration capacity and possesses a topography that includes some considerably steep slopes.

The James River and several of its tributaries [(Almond Creek, Falling Creek, Goode Creek, Powhite Creek, Reedy Creek, Bernards Creek, and Gillies Creek and Upham Brook (which is a tributary to the Chickahominy River and ultimately the James River)] have all been listed as impaired due to *E. coli* levels. The sources of bacteria in these streams within the City limits include CSOs, the MS4, the WWTP, direct discharge of urban runoff, and wildlife. Upstream sources also impact water quality in the City. Upstream sources include livestock, land application of manure, malfunctioning septic systems, illicit discharge of residential waste, other permitted waste treatment facilities. Reducing bacteria levels in these streams is consistent with the City's goal to provide safe recreational opportunities in the river.

The number of available water quality samples are biased heavily towards the James River, with little-to-no data available in tributary streams. Additionally, there is a lack of hydraulic data within the City, with the only local USGS gauges located outside the City limits. Biological samples and habitat assessments are also limited.

Water Quality Modeling

Water quantity and quality modeling was conducted to allow for longer and continuous periods to be evaluated relative to the water quality monitoring program. The purpose of the modeling framework is to quantify present day bacteria (E. coli) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the Clean Water Plan strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events.

Three models were used to achieve the modeling objectives and include:

- A watershed model, created using EPA's Stormwater Management Model (SWMM), to simulate flow and bacteria loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system.
- A collection system model, created using EPA's SWMM framework, to simulate flow and bacteria loads from the combined sewer system (CSS).
- A receiving water quality model, created using EPA's Environmental Fluid Dynamics Code (EFDC) model, which computes bacteria concentrations in the James River resulting from the various sources of bacteria to the river. The outputs of the watershed and CSS models are used as inputs to the receiving water quality model.

After the water quality modeling tools were developed and calibrated, they were jointly applied to assess water quality benefits associated with the selected strategies (described further below). Under current conditions, the model results illustrate that the James River is in violation of both the geometric mean and the statistical threshold value water quality standard criteria for some months out of the three year model simulation period, and the primary cause of a water quality criteria violation can sometimes be linked to Richmond's combined sewer overflows, while at other times it is due to upstream sources coming in from outside of the City. Background (mainly wildlife) and stormwater sources play a smaller overall role in the bacteria water quality violations. The WWTP does not contribute significantly to bacteria water quality violations.

Strategy Identification, Evaluation & Selection

Goals and Objectives Selection

The City implemented a multi-step process with stakeholders to form consolidated lists of overarching goals, refined goals, and objectives. Although a number of opinions and viewpoints were represented through the stakeholder process, ultimately, stakeholders achieved consensus on the overarching goal, refined goals, and objectives.

Weighting was incorporated into this process to reflect the priorities of the City and its stakeholders. This weighting process not only allowed for an understanding of how one goal or objective ranked in relation to another, it also provided information on the extent of the importance of these priorities to one other. The result of this process was a prioritization of refined goals as well as a prioritization of objectives associated with each of these goals.

The goals, objectives, and respective weights are summarized in Table ES.1.

Table ES.1 Clean Water Plan goals and objectives with associated weights

Goals (with weights)	Objectives	Weights
19%: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.	Develop one stormwater management plan to cover the City's four watershed groupings based on the City's watershed characterization report.	19%
	Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).	18%
	Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).	18%
	Reduce toxics (e.g., mercury, PAHs, PCBs), trash and other pollutants and address TMDLs for these pollutants.	17%
	Develop green infrastructure, including riparian buffers, and removal of impervious surfaces on development, existing development, and redevelopment.	27%
15%: Protect and restore aquatic and terrestrial habitats to support balanced indigenous[2] communities	Restore streams to improve, restore, and enhance native ecological communities.	25%
	Identify, protect, and restore critical habitats.	36%
	Enhance aquatic and terrestrial habitat connectivity.	23%
	Investigate, and where feasible, promote actions that might surpass regulatory requirements.	16%
14%: Engage and educate the public to share responsibility and take action on achieving healthy watersheds.	Engage and efficiently educate the public about standards, processes, and actions associated with watershed health and public health.	25%
	Assist in the education of citizens about overall water quality issues, benefits of improved water quality.	30%
	Support and encourage local action to improve water quality.	24%
	Provide quicker public notifications of spills or pollution from regulators or other "river watchers"	21%
12%: Implement land	Protect, restore, and increase riparian buffers	21%

[2] The language included here was crafted based on Technical Stakeholder discussion and a resulting consensus process. For clarification, however, this refers to balanced indigenous ecological communities.

conservation and restoration and incorporate these into planning practices to improve water quality.	Reduce impervious surfaces	19%
	Increase natural land cover with a focus on preserving, maintaining, and increasing tree canopy.	24%
	Incorporate green infrastructure in new development and redevelopment	18%
	Conserve lands where possible and consistent with Richmond's Comprehensive Plan	18%
11%: Create partnerships across the watersheds internal and external to the City of Richmond to maximize benefits and minimize impacts to all stakeholders	Develop and implement a source water prevention plan/strategy	33%
	Establish public-private partnerships to secure funding, implement strategies and projects, and to achieve plan goals.	40%
	Maintain and expand the RVAH20 group.	27%
10%: Maximize water availability through efficient management of potable, storm, and wastewater.	Reduce use of potable water for industry and irrigation.	39%
	Achieve water conservation by improving the existing water conveyance system.	30%
	Achieve water conservation by incentivizing upgrades to end-user water fixtures where appropriate.	31%
9%: Provide safe, accessible, and ecologically sustainable water-related recreational opportunities for all.	Improve water quality to promote safe recreation consistent with the City's Riverfront Plan.	36%
	Promote ecologically sustainable management of riverfront and riparian areas.	40%
	Improve river and waterfront access for recreation.	24%
9%: Work collaboratively to gather consistent high-quality data to characterize the status and trends of water resources and to gauge the effectiveness of restoration efforts.	Conduct water quality and biological monitoring	28%
	Provide timely water quality information.	19%
	Collaborate with citizens and local/state agencies for coordinated monitoring.	23%
	Utilize results to target restoration efforts and convey progress.	30%

Strategy Identification

The next step in this process was the identification of strategies that can be expected to achieve the previously identified goals and objectives. Strategies were defined as activities, actions, or items that will help meet goals and objectives.

The first step in brainstorming potential strategies included a workshop for DPU staff involved in stormwater, wastewater, and CSO-related projects. Because the Clean Water Plan would be implemented during the next VPDES permit cycle (2018 - 2023), staff compiled a list of projects that had been identified or proposed to meet various programmatic needs and could be implemented over that period. Because many of these projects impact small-scale areas, these City projects were "rolled up" to a strategy scale where necessary.

In addition to these DPU projects, stakeholders were also asked to submit suggestions for strategies that they felt would achieve the agreed upon goals and objectives. The Clean Water Plan development team created a synthesized set of draft strategies that consolidated ideas put forth by both stakeholders and DPU staff.

Once the draft set of strategies was identified, it was important to determine if these strategies were feasible. Because DPU is ultimately responsible for implementation of this program, the feasibility of strategies was defined as efforts that DPU has the authority to implement.

Final draft strategies and supporting actions were presented to stakeholders who were given the opportunity to edit them further. Supporting actions include efforts that may broaden the main strategy, add specificity on how a strategy could be implemented, or identify additional resources and data needs to fully implement the main strategy. Each of the strategies referenced in the remainder of the Clean Water Plan are considered to be "feasible" and agreed upon by the Technical Stakeholder group (Table ES.2).

Table ES.2. Strategies and associated details

Strategy	Strategy Details
Riparian Areas	Replace or restore 10 acres of riparian buffers according to state guidance. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Green Infrastructure in MS4	Install or retrofit GI draining 104 acres of impervious surfaces, including efforts such as: • 30 acres on DPU property • 18 acres on City-owned vacant properties • 20 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 100 trees in tree boxes (e.g., Filtera-type practices); 30 acres total drained to this practice • Retrofit 4 DPU stormwater BMPs (e.g., dry ponds to more efficient BMPs), draining at least 6 acres of impervious surface
Green Infrastructure in CSS	Install or retrofit GI draining 18 acres of impervious surfaces, including efforts such as: • 6 acres on DPU property • 2 acres on City-owned vacant properties • 2 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 24 trees in tree boxes (e.g., Filtera-type practices); 8 acres total drained to this practice
Stream Restoration	Restore 2,500 linear feet of stream: • Through removal of concrete channels, repair of incised banks, etc. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Natives/Invasives	Use 80% native plants in new landscaping at public facilities by 2023.
Trees	• Increase tree canopy on City property by 5% (80 acres added) • Protect existing tree canopy by following maintenance addressed in the Tree Planting Master Plan
Land Conservation	Place an additional 10 acres under conservation easement, prioritizing conservation of land that creates connected green corridors. • Evaluate opportunities for inclusion of access points to waterbody for recreational

	activities
Water Conservation	Reduce water consumption by 10% through implementation of new water conservation technologies and promotion of water conservation efforts, including: • Installing water-efficient fixtures as a policy by 2023 in all new public facility construction • Implementing incentive programs • Encouraging water conservation on City properties
Pollution Identification and Reduction	Reduce contribution of pollutants to the MS4 through: • Conducting at least one special study per year in hot spot areas to identify illicit discharges/connections. (Studies will meet the criteria necessary to achieve Bay TMDL pollutant reduction requirements. Assume that, over five years, three of these studies will result in pollutant reductions that meet Bay TMDL requirements.) • Collecting data associated with non-structural BMPs to facilitate quantification of pollutant reduction (e.g., storm drain clean-outs, pet waste stations, street sweeping)
CSS Infrastructure	LTCP projects, including: • Installing wet weather interceptor to convey more flow to the WWTP • Increasing WWT to 300 MGD at the treatment plant • Expanding secondary treatment at the WWTP to 85 MGD • Expanding Shockoe retention basin by 15 MG to capture more overflow • Disinfecting overflow at Shockoe retention basin (wet weather disinfection facility) *Note that that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost.*

Strategy Evaluation

Once strategies were drafted, an analysis was needed to determine which ones would be best for implementation. There are multiple factors at play that influence the selection of strategies. A strategy may do well with one factor, such as permit-related pollutant reductions, but not so well with others, like cost. As a result, the analysis of the various factors did not result in a clear and decisive outcome of one strategy that performed the best across all factors. What the strategy evaluation did determine was that all of the "pieces of the puzzle" needed to be evaluated collectively to achieve a complete picture of how well strategies achieve specific goals (Figure ES.1).

Figure ES.1. Puzzle piece conceptual model demonstrating how various factors fit together to inform the decision making process

An Excel-based strategy scoring calculator was developed to compare the various strategies proposed through this stakeholder process. This tool helped in the decision-making process by allowing the City and stakeholders to evaluate various alternatives by assigning scores to the alternative strategies.

The methodology used for this scoring calculator is a multi-objective decision analysis (MODA). A set of metrics was developed that includes a method of measurement. At least one metric was identified for each objective.

Multiple "puzzle pieces", or factors, were taken into consideration in the analysis of strategies (Figure ES.1). The **Permit** puzzle piece represents the VPDES permit-related requirements that establish pollutant reduction targets by which the strategies were compared.

The **Strategy Score** "puzzle piece" involved using the calculator tool to evaluate strategy scores in several different ways. These analyses included evaluating:

- Permit-related metrics – metrics that related to total Nitrogen (TN), total Phosphorus (TP), total suspended solids (TSS) and bacteria were isolated in the calculator and scores associated with just these metrics were used to evaluate the effectiveness of strategies in reducing these pollutants of concern
- "Standardization" of strategies addressing permit-related metrics – strategies, which varied in size, were all standardized to 10 acres to compare these permit-related metrics in an "apples to apples" manner
- All metrics – including the full set of metrics associated with all of the objectives in addition to the pollutant-related metrics
- "Standardization" of all metrics – comparing how the same sized strategies (all 10 acres) address all metrics

The calculator tool was also tied to the **Strategy Cost** information. Metrics specific to pollutant reductions (e.g., pounds of pollutant removed by a strategy) were used to calculate **Cost Effectiveness**. Overall, strategy costs were then evaluated in association with **Affordability**.

Another puzzle piece, **Modeling Results,** provided the bacteria reductions associated with several strategies that were used as raw score inputs into the calculator. Modeling results also provided information pertaining to the relative nature of bacteria sources to the James River and tributaries.

After taking the evaluation process through the "Standardization of all metrics", the following top-ranked strategies resulted:

1. Riparian Area Restoration
2. Stream Restoration
3. Green Infrastructure in the CSS area
4. Green Infrastructure in the MS4

The various "pieces of the puzzle" were used to understand how to best prioritize activities for implementation. What these analyses have shown is that no one strategy consistently scores the highest or performed the best across the analyses, however, several strategies consistently performed well (a summary of the analyses are included in Table ES.3; green highlighted information depicts those that consistently score highest).

Table ES.3. Summary of Strategy Analysis and Strategy Prioritization

Rank	Pollutants of Concern Metrics	Pollutants of Concern Metrics: Standardized*	All Metrics	All Metrics: Standardized*	Cost Effectiveness (TN)	Cost Effectiveness (TP)	Cost Effectiveness (TSS)	Cost Effectiveness (bacteria)
1	**CSO Infrastructure**	**Stream restoration**	**GI in MS4**	**Riparian**	**Stream restoration**	**Stream restoration**	**Stream restoration**	**CSO Infrastructure**
2	**Stream restoration**	**GI in CSS**	**Riparian**	**Stream restoration**	Water conservation	Pollution ID and reduction	**Pollution ID & reduction**	**GI in CSS**
3	**Pollution ID & reduction**	**GI in MS4**	**Stream restoration**	**GI in the CSS**	**GI in MS4**	**GI in MS4**	**GI in MS4**	**GI in MS4**
4	**GI in MS4**	**Riparian**	**CSO Infrastructure**	**GI in MS4**	**GI in CSS**	**GI in CSS**	**GI in CSS**	**Riparian**
5	**GI in CSS**	Water conservation	Water Conservation	Water Conservation	Pollution Identification	Water conservation	Water conservation	
6	**Riparian**	Trees	Trees	Land Conservation	**CSO Infrastructure**	**Riparian areas**	**Riparian areas**	
7	Trees	Pollution ID & reduction	Natives/ invasives	Natives/ invasives	**Riparian**	**CSO Infrastructure**	**CSO Infrastructure**	
8	Water Conservation	Natives / invasives	Land Conservation	Trees	Trees	Trees	Trees	
9	Natives/ invasives	Land Conservation	**GI in the CSS**	Pollution Identification				
10	Land Conservation		Pollution ID and reduction					

*WWTP/CSO strategy cannot be evaluated on a 10-acre basis so it is not included herein

To allow for the consideration of multiple factors in determining priorities, it was determined that rather than ranking 10 strategies individually, that strategies would be grouped into one of three tiers based on effectiveness (Figure ES.2). Tier 1 includes those strategies that best address metrics associated with the pollutants of concern (total Nitrogen, TN; total Phosphorus, TP; total suspended solids, TSS; bacteria) as well as the non-pollutant related metrics. These strategies were also the most cost effective. Tier 2 also addressed pollutant and non-pollutant related metrics, but not as efficiently or cost effectively as those in the Tier 1 grouping. Tier 3 are those strategies that do not address the pollutants of concern.

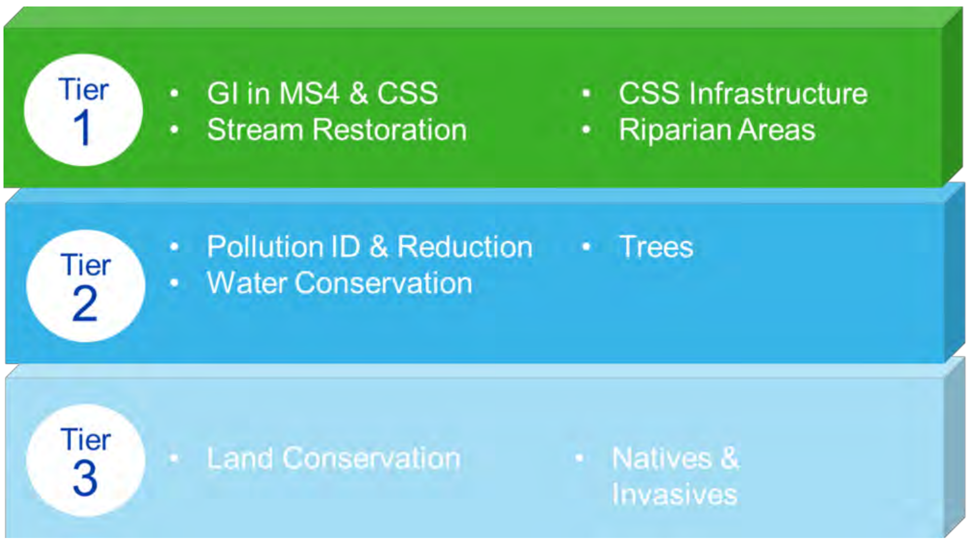


Figure ES.2. Organization of strategies into tiers for prioritization

It is important to note that while select strategies may be *prioritized,* it does not mean that the remaining strategies will be disregarded. Implementation of these strategies will be assessed based on additional resources available to DPU or priorities and resources available from other City departments or other partners.

It is also important to note that this analysis was done at a high level. As DPU moves toward implementation and conducts a more refined evaluation of strategies, there may be modifications to this prioritization.

Program Implementation

An important part of this RVA Clean Water Plan is developing an approach that can help the City implement these strategies in the most efficient and cost effective manner possible. DPU will use a "Framework Planning" approach. The Framework Planning approach provides a methodology that ties together different strategies (and, subsequently, site-specific projects) and, where possible, aligns these strategies with other City or stakeholder-driven initiatives. The goal of the Framework Planning Approach is to identify and sequence a blend of activities that yield the greatest environmental benefit (as measured by identified metrics) in the most cost-effective (and affordable) manner. The Framework Planning approach includes the following elements:

1) Data and information gathering
2) Identification of potential opportunities

3) Prioritization
4) Plan development
5) Implementation

There are several important concepts that will be taken into account through implementation. For instance, it is envisioned that implementation will occur incrementally over the course of the permit cycle (e.g., 10 acres of riparian buffers will not necessarily be restored all at once or within only one project, but may be addressed through the implementation of several projects/project clusters). Flexibility is incorporated into implementation through adaptive management. If it is found that one strategy cannot be implemented in whole or in part, DPU will work to identify an alternative approach to achieving the same or similar pollutant reductions and other identified goals and objectives.

Implementation of projects, particularly those that involve stakeholders or other City departments, will require significant coordination. In addition to regular Technical Stakeholder meetings to provide updates on progress, DPU will convene a workgroup of those organizations involved in these implementation efforts. As projects are implemented, associated benefits (pollutant reductions, area treated, other metrics addressed) will be tracked as well.

Progress Measurement

As the City's implementation moves forward, measuring progress will include determining if goals have been met, if progress has been deemed sufficient, or if changes should be made within the program to try to improve the level of progress made. Measuring progress; however, can be complex. Targets may be established at various scales (i.e., site scale, sub-watershed, watershed, city scale). Implementation actions can also include a wide range of options including structural and non-structural practices as well as practices that address various source sectors (i.e., stormwater, wastewater, non-point sources). As a result, the approach used for measuring progress under the City's program must be flexible enough to account for these variations in scale and options that will be employed to mitigate pollutants and meet the City's goals.

Measuring progress will be done in a holistic manner based on data from the City's monitoring programs, modeling efforts, and other programmatic information (e.g., implementation targets, such as miles of stream buffers restored per year or number of residents reached by outreach efforts). Each element of this process to evaluate Clean Water Plan progress will occur on a regular/annual basis over the course of the permit. Each of these elements is outlined in Table ES.4.

Table ES.4. Monitoring activities and associated outcomes implemented under the Clean Water Plan

	Activities	Outcomes
Water Quality Monitoring	Instream water quality, biological (e.g., macroinvertebrates), CSO and WWTP discharge monitoring	Progress made toward pollutant reduction targets in permit
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
		Identify sources, stressors, or pollutants of concern
		Identify trends over time
	BMP monitoring	Effectiveness of specific BMPs or source reduction efforts
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
Programmatic Monitoring	Tracking strategy implementation	Progress made toward strategy implementation goals (e.g., acres of green infrastructure implemented)
		Progress made in pollutant reduction through strategy implementation (e.g., pounds of TN reduced through green infrastructure implemented)
		Progress made toward pollutant reduction targets identified in permit
Modeling	Receiving water, CSS, and watershed modeling and analysis	Progress made in bacteria WQS compliance
		Progress made in bacteria load reduction
		Progress made in reduction of CSO events or volume discharged

Next Steps

The RVA Clean Water Plan has resulted in a comprehensive understanding of the City's watersheds and associated water resources. The next step is to use the Clean Water Plan to develop a watershed-based VPDES permit. Watershed-based permitting has been long supported by EPA and allows multiple pollutant sources to be managed under one permit. For Richmond, these pollutant sources are CSO, wastewater, and stormwater via the MS4 and direct drainage. The Clean Water Plan provides the planning framework and strategies to manage these sources and prioritize control projects based on their improvements to local waterways. Therefore, the Clean Water Plan will be included in the VPDES permit as a source of data and provide information to be included in the "Special Condition" section related to best management practices (BMPs) to be implemented and additional monitoring to be done to track progress. The Clean Water Plan will also be included in the Permit Fact Sheet as an information source.

Once the watershed-based VPDES permit is issued to the City, next steps include implementing the projects and programs in the Clean Water Plan and conducting monitoring and modeling to measure progress towards the goals of the plan. The City will also continue to engage stakeholders to inform them of activities and associated progress towards the goals of the Plan, and solicit their input on Plan updates.

The Modeling Framework will continue to be used as needed to evaluate the water quality improvements related to the implementation of projects and strategies. Additionally, it is anticipated that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the Long Term Control Plan (LTCP) projects, but at a reduced cost.

1. Background and Introduction

The City of Richmond's Department of Public Utilities (DPU) manages five utilities, three of which address water: wastewater, stormwater, and drinking water. As all three of these utilities can influence local water resources, such as the James River, each operates under regulations and permit requirements established to ensure protection of the environment and public health.

The Wastewater Utility was implemented to operate and maintain the wastewater treatment plant (WWTP), which discharges treated effluent to the James River (45 MGD dry weather flow and 75 MGD wet weather flow). The Utility also operates and maintains a sanitary sewer and combined sewer collection system, pumping stations, and the Hampton-McCloy Tunnel, storage capacity of 7.2 million gallons, and the Shockoe Retention Basin, a 50-million gallon reservoir used during heavy rains.

The Stormwater Utility is relatively new compared to the other utilities. It was implemented in July 2009 to manage the stormwater that runs off impervious surfaces. The Stormwater Utility also enhances public safety and health and protects property by improving the quality and decreasing the quantity of polluted stormwater runoff. Approximately two-thirds of the City of Richmond is served by a municipal separate storm sewer system (MS4). This mixture of underground storm sewer systems and open channels are separate from the sanitary sewer system.

The City of Richmond is one of the largest water producers in Virginia, with a modern plant that can treat up to 132 million gallons of water a day from the James River at the western edge of the City. The Drinking Water Utility manages the treatment plant and distribution system of water mains, pumping stations, and storage facilities that provide water to more than 200,000 customers in the city. The facility also provides water to the surrounding area through wholesale contracts with Henrico, Chesterfield, and Hanover counties. All total, this results in a facility that provides water for approximately 500,000 people.

Historically, the three utilities were managed independently of one another, primarily driven by the fact the regulations and permit requirements established by the regulatory agencies were also implemented independently. This approach forced the City to make decisions related to compliance for each utility without being able to consider the interrelated impacts. There is often overlap in these requirements and sometimes an action occurring under one regulatory program has a direct impact on another. For instance, separating a combined section of sewer leads to impacts on the separate sanitary sewer system and the storm sewer system. Integration of all of the separate programs into a coordinated approach is necessary to eliminate redundant activities and be more efficient and effective addressing wet weather impacts and improving water resources overall.

USEPA Integrated Planning Frameworks

USEPA has put a significant amount of effort in recent years into describing and publicizing its vision of management of these separate programs through the concepts of Integrated Planning (EPA 2011, EPA 2012a), Integrated Watershed Management (EPA 1996, EPA 2008), and Watershed-based Permitting

(EPA 2007, EPA 2003). An emphasis within each of these concepts involves providing an opportunity to examine different possible ways to look at protecting water quality given very limited resources at both the City and the state level. Often these limited resources must be used to manage and implement multiple and costly regulatory requirements, such as:

- Replacing/repairing aging infrastructure;
- Developing and implementing long-term control plans (LTCPs) for combined sewer overflows (CSOs);
- Developing and implementing capacity, management, operation and maintenance programs for sanitary sewer overflows (SSOs);
- Improving peak flow management at WWTPs;
- Addressing requirements to control nutrients and emerging contaminants at the WWTP;
- Managing stormwater to mitigate flooding;
- Developing and implementing MS4 pollution prevention plans;
- Investing in treatment technologies to comply with effluent limits based on total maximum daily loads (TMDLs); and,
- Complying with Safe Drinking Water Act and/or National Pollutant Elimination Discharge System (NPDES) requirements.

All of these issues are currently of importance to the City of Richmond, or will be over time. All of these activities or requirements are rarely coordinated or considered in a holistic manner. Without coordination among these competing demands, the City's constrained resources aren't likely to achieve the maximum benefit to the utility, the public, and the environment. Too often, the need for investment (especially for wet weather controls) greatly exceeds the City's financial capacity, even over a 20-year period. As a result, there is uncertainty in prioritizing investments, and with how to create a plan that progressively moves toward meeting clean water goals.

To address these issues, Richmond is using EPA's Integrated Watershed Management and Integrated Planning frameworks for planning purposes. Because both of these have a number of consistencies between them, these approaches have been combined and organized to form a framework that allows the City to efficiently evaluate, manage, and implement water quality programs and work toward their goals and objectives (see Figure 1.1). The endpoint of this overall effort is a single, integrated VPDES permit that encompasses DPU's wastewater, CSO, and stormwater discharges.

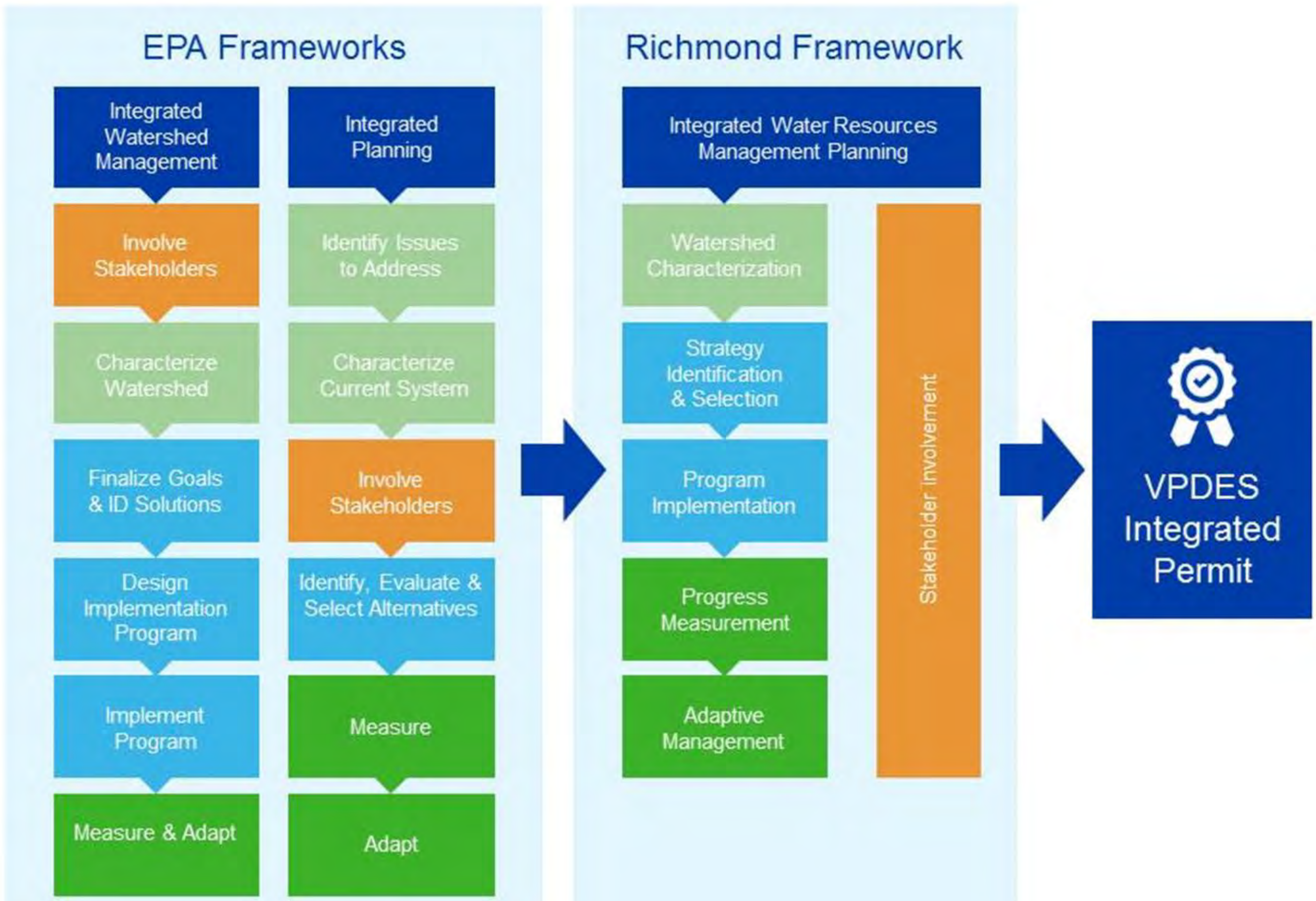


Figure 1.1 – Demonstration of the overlap in elements between EPA's Integrated Watershed Management and Integrated Planning Approaches and how these elements have been merged to develop the framework for the Integrated Water Resources Management Plan where stakeholder involvement is a part of each step of the process.

Richmond's Clean Water Plan Framework

Efforts to prioritize a community's investments have traditionally tended to focus on meeting infrastructure-related goals, such as reduction in the number of CSOs. The focus of the RVA Clean Water Plan, however, is on the watershed and restoring and protecting the waterways in these watersheds. Given this focus, the Clean Water Plan is framed by water quality standards (WQS) and watershed goals rather than solely by municipal infrastructure project considerations. This watershed-wide, water quality-based strategy allows the City to develop an effective and affordable management plan while also meeting regulatory requirements and demonstrating to the public that the plan protects and improves the watershed and waterways. The integration includes the WWTP, CSO, and stormwater programs, and maintaining minimum in-stream flows. Richmond is also taking drinking water and source water protection into consideration to ensure a more comprehensive focus on overall watershed health.

The City's Department of Public Utilities began the Clean Water Planning process in March of 2014 (see Figure 1.2), with the establishment of a Technical Stakeholder Group and related outreach plan. The effort continued in January, 2015 with a watershed characterization effort that culminated in the development of a Watershed Characterization Report (Richmond DPU 2015). Work on the Clean Water Plan began in 2016, which will ultimately be used to inform the development of an integrated Virginia Pollutant Discharge Elimination System (VPDES) permit that collectively addresses DPU's discharge permit requirements. The permit application is due to VDEQ in January, 2018, with the Integrated VPDES permit expected to be reissued in June of 2018.

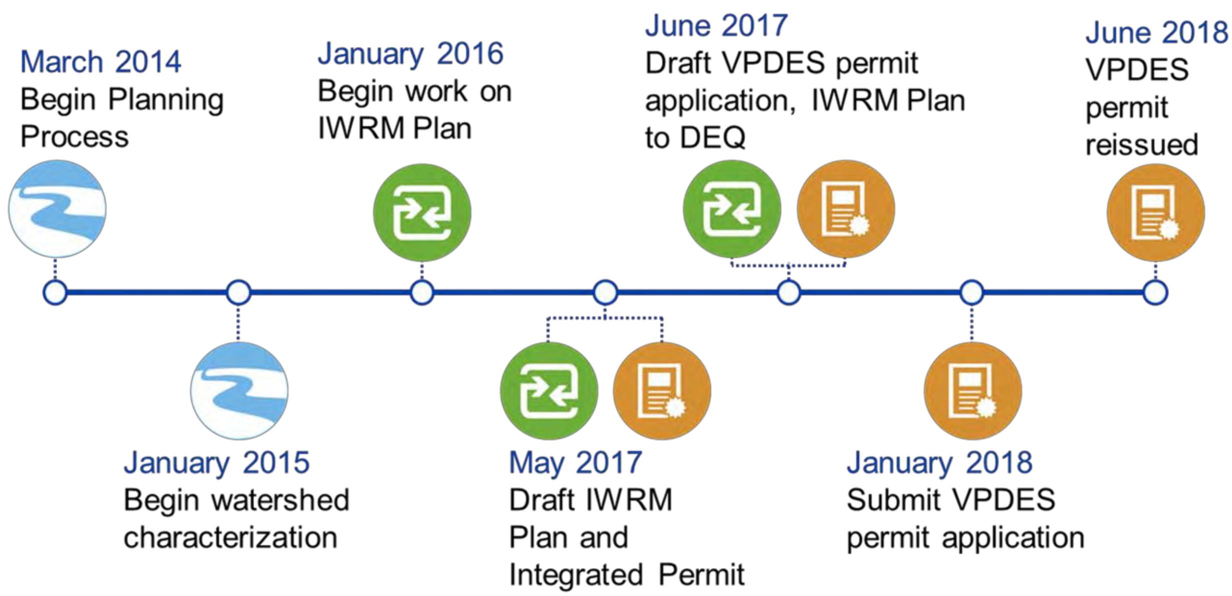


Figure 1 .2– Richmond's schedule for the development of a Watershed Management Plan (WMP), Integrated Plan and Watershed-based Permit (WBP)

Richmond's Clean Water Plan includes six elements, which are summarized below and discussed in more detail in the subsequent sections of this document.

Stakeholder Involvement

DPU determined early on that community input and support would be key to the success of its Clean Water Plan as this support would facilitate development of an integrated VPDES permit as well as future implementation efforts. It was felt that this input and support could be gained by implementing a thoughtful, well-informed approach that demonstrates the Utility's commitment to improving the environment while continuing their good stewardship of their infrastructure assets and local water resources. Community support was especially important in considering priorities and options for improving and protecting the City's waters.

Watershed Characterization

The watershed characterization process within the Clean Water Plan provides the data needed to support this process. This includes data such as monitoring related to meeting receiving water standards and goals, and characterizing receiving water conditions and sources of pollutants throughout the watershed. Existing data are compiled and, if necessary, new data are collected to provide the data needed to complete the watershed characterization. Evaluating data from a watershed perspective helps to facilitate a watershed-based approach to planning and, subsequently, implementation. Ongoing data collection will ensure the Clean Water Plan is up-to-date and accurate, and will facilitate future updates using an adaptive management approach. A beneficial outcome will be that data collected through watershed characterization efforts will serve multiple purposes. For instance the activities associated with the TMDL development and implementation will help determine appropriate targets for the Clean Water Plan.

Strategy Identification, Evaluation, and Selection

The data collected through the watershed characterization effort serves as the basis for helping to identify and quantify problems or issues of concern within the watersheds. This helped guide the selection of goals and objectives the City and its stakeholders identified for this process. As high-level strategies to meet these goals were identified, they were incorporated into an Excel-based strategy scoring calculator that included the weighting of these goals, associated objectives, and metrics by which these strategies were measured. Other factors, such as strategy costs, cost effectiveness, and watershed and water quality modeling results, were also used to prioritize strategies.

Program Implementation

After selection and prioritization of high-level strategies is completed, these high-level strategies (e.g., Green Infrastructure implementation in the MS4 area) will be translated into localized projects (e.g., two acres of bioretention and one acre of pervious pavement in a particular subwatershed). A "Framework Planning" approach is being used to strategically direct implementation in a way that aligns activities that yield the greatest environmental benefit in the most cost-effective manner.

Progress Measurement

Once projects and programs have been implemented, measuring progress will be accomplished through a three-pronged approach. This will include programmatic tracking, which will involve evaluating the progress made toward strategy implementation (e.g., acres or feet of implementation, etc.) as well as the pollutant reduction calculated through this implementation. The City will also conduct water quality monitoring to evaluate progress made toward pollutant reduction targets in the permit, progress made toward achieving WQS, and trends over time. Modeling will also be used to evaluate progress made toward bacteria-related WQS, bacteria load reductions, and reduction of CSO events or volume discharged. Progress will be reported annually through VPDES permit-related reporting.

Adaptive Management

Because the City, its waterbodies, regulatory drivers, and community needs are not static, City and stakeholder priorities may also change over time. The Clean Water Planning process incorporates flexibility to address these changing needs. This flexibility, or adaptive management, is an iterative, ongoing, learning process used to continually improve understanding of the City's programs and practices by learning from their outcomes over time.

Adaptive management will be critical for the success of Richmond's Clean Water Plan as new data collected through the course of this effort will be used to refine and modify the Plan so it is up-to-date and accurate.

2. Stakeholder Involvement

From the very beginning, the City knew stakeholder involvement would be a key component of developing and implementing an effective and successful integrated approach to the City's water resources management. While building partnerships is identified as one "Step" in both EPA's Integrated Watershed Management and Integrated Planning processes, the City has actually incorporated stakeholder involvement throughout the entire planning process to help ensure stakeholders understood the process from the very beginning and were part of decision-making efforts along the way. It also helped ensure that stakeholders had a voice to convey any concerns they may have or encourage sharing of data and information that could be helpful with planning, and subsequently, implementation efforts.

To aid in this communication effort as well as in the dissemination of outreach information, DPU created and initiated RVAH2O (RVAH2O.org). The name was formed from "RVA," which is popular shorthand for Richmond, Virginia, and "H2O," which is the chemical formula for water. Together, the name represents a citywide effort to arrive at "Cleaner Water Faster."

The RVAH2O.org website educates the community about ways to keep the City's waterways pollution-free and the importance of integrating drinking water, wastewater, and stormwater under one watershed management program. It is all water. The website is also used to share information conveyed during Technical Stakeholder and public meetings discussing the Clean Water Planning process. RVAH2O has also been expanded into a Facebook page and Twitter feed to reach a larger public audience. The logo and its clean water messages appear on billboards, bumper stickers, community meeting handouts, school bulletin boards, and on DPU booths and water stations at community events and water-related festivals.

A detailed discussion of each of the elements of the stakeholder involvement process is included below, as well as further detail surrounding public outreach.

Stakeholder Identification

Stakeholders can represent many different groups with an interest in the watershed, including, for example, advocates for wildlife and habitat protection; boaters; residential, commercial and business interests; and environmental justice groups. As discussed in the City's Watershed Characterization Report, an initial step in this process was the identification of groups or individuals that would be interested in being more involved in the City's water future and/or would potentially bring data, information, and insight to the table that could assist the City with reviewing the problems and looking at the relative contribution of all sources and stressors on the watershed.

The City reached out to a variety of stakeholders in and surrounding the City, including environmental advocates, recreational users of the James River, property owners, businesses, and state and local governmental agencies and representatives.

The initial stages of the stakeholder involvement process resulted in categorizing these participants into several groups based on expected technical knowledge and perceived level of interest and involvement. As a result, a Technical Workgroup was formed to provide technical insight and feedback on the Clean Water Planning process. This group included representatives of groups such as:

- Chesapeake Bay Foundation
- James River Association & Riverkeepers
- The Nature Conservancy
- Middle James Round Table
- Alliance for the Chesapeake Bay
- Virginia Department of Environmental Quality (VDEQ)
- Virginia Department of Health (VDH)
- City Department of Public Works (DPW)
- The Reedy Creek Coalition
- Fall of the James Scenic River Group
- James River Park System
- Virginia Commonwealth University (VCU)
- Richmond Regional Planning District Commission
- James River Outdoor Coalition
- Capital Region Land Conservancy
- Marine Resources Commission
- University of Richmond
- American Water
- Tree Stewards of Richmond
- The Counties of Hanover, Chesterfield & Henrico (reached through the Planning District Commission)

Additionally, a special interest and public stakeholder group was identified with participants anticipated to have a high level of involvement. This group included representatives of organizations such as:

- Friends of James River Park
- Sierra Club – Falls of the James Group
- Home Builders Association of Virginia
- Hispanic Chamber of Commerce
- Richmond City Council Districts
- Richmond Paddle Sports and other sports organizations

Participants in this special interest and public stakeholder group with an anticipated lower level of involvement included representatives from organizations such as:

- Richmond Audubon Society
- James River Advisory Committee
- Retail Merchants Associations
- Tenant, Civic and Neighborhood Associations

The City's Watershed Characterization Report includes additional discussion of the various stakeholders that have been invited to participate and/or are participating within this planning process.

Once stakeholders were identified, kick-off meetings were held in November 2014 to speak with the technical stakeholders and the special interest/non-technical stakeholder group. A meeting schedule was developed early on to ensure consistent communication with the technical stakeholders on a quarterly basis and with the special interest/public stakeholder group approximately every six months.

Technical Stakeholder Meetings

Since the initial meetings in November 2014, technical stakeholder meetings have been held regularly every two to three months and have accomplished several specific objectives including: identifying issues of concern, setting goals, developing indicators to track progress, and conducting public outreach. Information on the Technical Stakeholder meetings (including when and what information was discussed at each meeting) can be found on the RVAH2O.org website under meetings.

The activities of the Technical Stakeholder workgroup have included:

- Determining the overarching goal for the City of Richmond's watershed plan
- Identifying and weighting goals and multiple objectives and strategies
- Meeting bi-monthly to shape the plan's contents and discuss outstanding issues
- Forming partnership agreements that will aid in achieving cleaner water faster

The majority of technical stakeholders have found the meetings to be important opportunities to learn about and discuss watershed issues, and have expressed interest in continuing to meet regularly once the Plan and Permit are in place.

Public Meetings

At the outset of this initiative, a survey of the Richmond public was conducted to establish a baseline of knowledge about Richmond's water systems. It was determined that Richmond residents had limited knowledge about water sources, water quality and their role in helping to keep waterways clean and litter-free. Using RVAH2O as a platform, 2015 was the start of a public outreach effort to lay a foundation of understanding before laddering up to the more technical conversation around watershed integration.

First, a flier was created to illustrate how a household contributes to stormwater pollution. This was widely distributed at libraries, schools, neighborhood meetings, and public events.

Then, a series of posters were created to be put up around the City, each with a theme related to its location: 1) Pet waste poster mounted at dog parks and veterinary offices; 2) Automotive oil poster mounted at service stations and oil-changing stations; 3) Cigarette butt poster mounted at workplaces where people take smoking breaks, etc. In all, six themed posters were created.

An initial public meeting was held in October of 2014. This provided an opportunity for a high-level introduction to the City's regulatory requirements, what has been done to date to address water quality in the City, and the City's goals moving forward. On June 9, 2015, an open house was held at the Science Museum of Virginia to provide opportunity for the general public to be introduced to the City's Integrated Planning process (Figure 2.1). Five different stations were set up, each at which a different topic area was discussed. There were over 50 attendees recorded from the general public. Each station was staffed with members of the RVAH2O team or other DPU staff. This provided a one on one opportunity for the public to ask questions about each station including:

- The watersheds

- The stormwater, sanitary, and wastewater collection systems
- Stormwater issues
- The James River and associated creeks and streams
- Outreach and educational information

A station was also set up at which the public could sit down and anonymously submit questions and comments for the RVAH2O team.

In general, it was observed that attendees expressed knowing little about the river's needs coming in, but by the end, their post-it note comments and comment cards seemed to demonstrate that they had obtained a real grasp of the needs and concerns for water quality in Richmond.

This public open house was deemed a success and in the following year, August 2016 and September 2016, two more open houses were held in local parks (Figure 2.2). Attendance at the first 2016 event was 52; at the second, due to a storm, attendance was less than 10. However, this format for sharing information as the watershed program evolves will continue.

Figure 2.1. Flier advertising the June 9, 2015 community open house

Conducting Public Outreach

While technical stakeholders have been involved during each step of the Clean Water Planning process, the City also recognized the need to conduct a wider public outreach effort related to the City's water resources. The RVAH2O initiative also aims to further educate and identify ways in which the community can be involved in clean water management. The benefits of the effort are two-fold: to help ensure a wider dissemination of information associated with the RVAH2O initiative (integrated water resources planning) as well as to conduct outreach and education related to the City's various water related programs.

Outreach and involvement in association with the Clean Water Planning process are also closely coordinated and consistent with other DPU and City communication programs. For instance, a plan for public outreach and communication will be incorporated as part of the monitoring plan, to achieve the objective of making the monitoring data (historical and current) available to the public. This plan includes a web-based component as well as other print media.

Both online and offline communication strategies make up a Public Outreach Plan that builds awareness and encourages support for the goals of RVAH2O. This effort has also been designed to meet the requirement of the City's VPDES MS4 permit, which is to reach 20% of the City's population in the MS4 area by 2018.

DPU, using RVAH2O as the communications platform, has invited the public to numerous events and shared its water quality message widely through email, social media, the RVAH2O website, billboards, fliers, school education and community meetings. For example:

- Thousands of Richmonders and others were able to fuel themselves with public water at the September 2015 Union Cycliste Internationale (UCI) bike competitions, where eight drinking stations were hooked up to fire hydrants and draped with RVAH2O logo and information.
- At the 2016 Earth Day and Riverrock festivals, DPU employees at an RVAH2O booth greeted nearly 1,100 people personally, passed out literature, and held drawings for rain barrels.
- The first annual Storm Drain Art Contest attracted several dozen entries and drove hundreds of visitors to RVAH2O social media pages; over 450 people voted for their favorite Storm Drain. Each drain selected flows directly into the James River; one of the requirements was that each drain feature a stormwater/pollution message.
    - This contest's art submissions were showcased at Richmond City Hall for one month.
    - The contest received numerous online and print articles, with front page news in the Richmond Times Dispatch on two occasions when the City's mayor toured the drains in July 2016.
    - The project won a national award by the National Association of Clean Water Agencies and Richmond local ad club award, furthering the news coverage.

Figure 2.2. Flier for Watershed Open House public meeting held at a local park

  - A "How-To" flier was created to assist other U.S. municipalities in setting up their own storm drain projects. So far, approximately two dozen communities have requested guidance.
  - The 2017 RVAH2O Storm Drain Art Project has already launched, and storm drains for this annual promotional effort are earmarked through 2020.
- RVAH2O took its message to neighborhood associations and universities, engaging students at VCU and the University of Richmond, some of whom have joined outreach causes.
- RVAH2O representatives have met with the James River Association to help them further their outreach efforts with a storm drain stencil art project. It's anticipated that more collaboration with special interest groups will take place in the future.
- A billboard campaign took place throughout the summer of 2016 in both English and Spanish and will be repeated in 2017 and include bus wraps on routes passing through under-served neighborhoods.
- 100 sets of "James River Pollution and Water Conservation" messages have been printed for bulletin boards in elementary school classes, libraries and community centers.

The Future of Public Outreach

The goals associated with stakeholder involvement and transparency to the public are critical and have been incorporated into this process to ameliorate concerns regarding:

- If progress is being made;
- If limited resources are being expended wisely;
- If benefits are being realized; and,
- If adjustments are being made based on what has been learned.

With a foundation of knowledge about the importance of keeping Richmond's waterways litter-free, Richmond's water sources and systems, and the public's role and responsibility in assuring a cleaner water future, DPU will turn its attention to bringing Richmonders up to speed on the Clean Water Planning process. In late 2017, it will focus more attention on business and civic leaders as well as on partnerships with the technical stakeholders to deliver a unified message to the public.

Tracking process of outreach efforts included (depicted in Figure 2.3):

- Email campaign to "public" attendees
- Flier distributed at Riverrock 2015
- Social media campaign drove up on-line engagement

On Facebook:

- RVAH2O Facebook page likes increased by 8%
- RVAH2O received at least 25 direct event responses and reached 4,967 people through Facebook Ads –on less than a $70 budget

- 45 people joined the event through Facebook (organic and paid)

On Twitter:

- Tweet mentions were up 28.6%.
- RVAH2O followers increased by 14.85%.

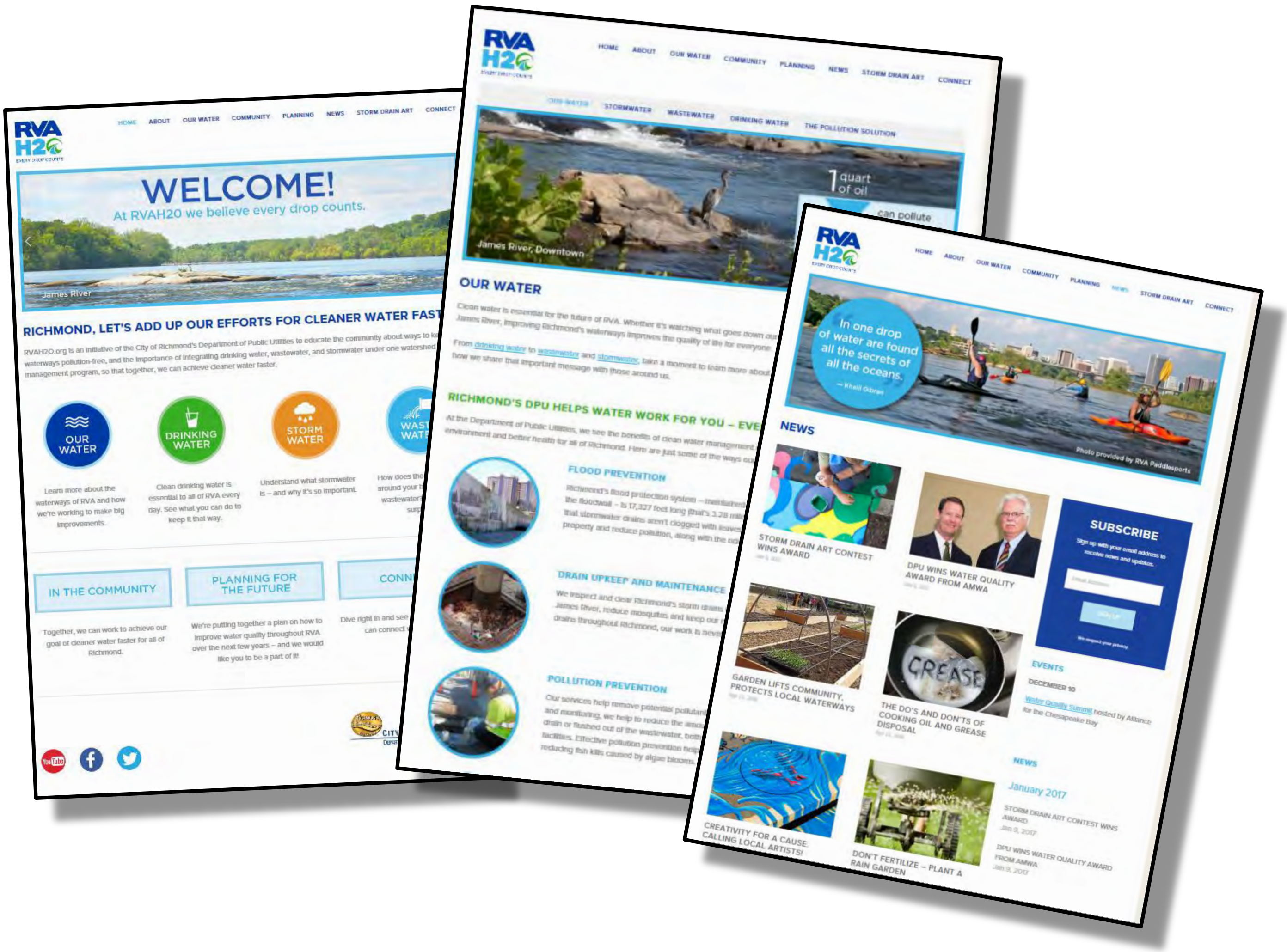


Figure 2.3. Examples of RVAH2O website and Facebook pages.

Stakeholder Partnerships

As discussed further in Chapter 5 (Strategy Identification), DPU is limited in terms of the land and other resources available for strategy implementation. Opportunities to expand strategies will require tapping into the resources from other entities, including other City departments and stakeholder organizations within the City. One way to address this challenge was to create partnerships among the RVAH2O technical stakeholders who have an interest in helping the City implement the goals and objectives that form the basis for the RVA Clean Water Plan.

DPU presented on partnerships at several Technical Stakeholder meetings and discussed ways organizations may wish to partner by making commitments at varying levels of involvement. Examples include participating in the ongoing RVAH2O technical advisory committee, providing volunteer assistance for different types of work (e.g., water quality monitoring, habitat monitoring, tree planting and maintenance), or partnering on larger projects involving land conservation, green infrastructure or stream restoration.

Partnership Opportunities for Implementation
A "Declaration of Cooperation" Approach

Oregon Solutions Partnership Model

RVAH2O Partnership Survey

1. DPU welcomes the opportunity to create partnerships among the RVAH2O technical stakeholders who have an interest in helping the City implement the Goals, Objectives and Strategies that will form the basis for an **Integrated Resources Management Plan**. Organizations may wish to partner by making commitments at varying levels of involvement – such as participating in the ongoing RVAH2O technical advisory committee, providing volunteer assistance for different types of work (e.g., water quality monitoring, habitat monitoring, tree planting and maintenance), or partnering on larger projects involving land conservation, green infrastructure or stream restoration.

For the March 21 RVAH2O Technical Stakeholder Meeting, we would like to discuss different ways that your organizations might envision partnering in the years ahead. Whatever level of detail you're able to provide would be most helpful.

First, please indicate whether you give permission to RVAH2O to share your answers with other stakeholders at the March 21 meeting.

- Yes, I give permission on behalf of my organization to share this information with other RVAH2O stakeholders.
- No, I do not give permission.

Figure 2.4 Partnership survey circulated to technical stakeholders

A partnership survey was circulated to stakeholders (Figure 2.4) and additional detail on partnership efforts will be documented as these conversations continue over 2017.

3. Watershed and System Characterization

Effective integrated planning and watershed management rely upon identification of the conditions and issues that characterize the watershed. Understanding existing water quality, along with the sources of pollutants or stressors that impact the City's waterbodies, are key elements for developing priority actions to address any existing or potential problems. Characterization of existing collection systems and drainage areas within the City also helps assist in meeting regulatory requirements and implementing other watershed improvements.

Collection of data and characterization of the City's watersheds were the City's first steps towards development of the Clean Water Plan. The City's Watershed Characterization Report (Richmond DPU 2015) includes a detailed discussion of this information. This chapter summarizes this information and highlights how the information and data collected through the effort served as the foundation for subsequent steps of the watershed planning process.

Another key step towards the development of the Plan was the development of a water quantity and quality modeling framework, that incorporates models for the CSO areas, the non-CSO areas (including Richmond's MS4 area), and for the James River itself. The purpose of the modeling framework was to quantify present day bacteria (*E. coli*) concentrations in the James River and to predict future bacteria concentrations under the Clean Water Plan strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. The City's Clean Water Plan Modeling Report (Appendix A) includes a detailed discussion of the model development, calibration, and application.

Regulatory Drivers

To understand how the characterization of the collection systems and the City's watersheds can help assist in meeting regulatory requirements, it is important to first understand the regulatory drivers associated with the design and management of these systems and associated programs. Each of these drivers is discussed further below.

Water Quality Standards (WQS)

The Clean Water Act (CWA) establishes the requirement for states to develop and set WQS (see CWA § 303(c)). Once approved by EPA, the WQS are then to be used for CWA purposes, such as in establishing VPDES permit requirements.

The WQS have three distinct parts:

- A designated use;
- Criteria to protect the designated use (generally referred to as ambient water quality criteria and often expressed as chemical-specific concentration values); and

- An antidegradation policy and implementation method.

The designated uses are established based upon data available and are expected to be consistent with the goals established in § 101 of the CWA.

Virginia's regulations set at a minimum that all waters have these designated uses:

- recreational uses (e.g., swimming and boating);
- propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them;
- wildlife; and
- production of edible and marketable natural resources (e.g., fish and shellfish).

The regulations provide authority to establish more specific subcategories of designated uses, such as for the Chesapeake Bay – "Subcategories of the propagation and growth of a balanced indigenous population of aquatic life, including game fish designated use for waters in the Chesapeake Bay and its tidal tributaries are listed in this subsection."

As noted, water quality criteria are required as part of the WQS and must be established at a level to protect the designated use. Criteria protecting recreational uses rely primarily on fecal indicator bacteria levels to prevent an unacceptable level of illnesses when recreating on or in the water. Criteria for aquatic life uses, such as cold water fishery or areas designated as habitat for specific sensitive species can include temperature, dissolved oxygen, and toxic pollutant limitations designed to ensure healthy populations of organisms that are expected to be present in those areas. Criteria for aquatic life uses may also be based on biological indices. States may designate water bodies for agricultural water supply to ensure that water quality is appropriate for irrigation of crops.

> *The applicable WQS can be found at:*
>
> *9VAC25-260*
>
> *http://leg1.state.va.us/000/lst/h2568263.HTM*

The third part of the WQS is the antidegradation policy and its purpose is to protect existing uses and the level of water quality necessary to support these uses, to protect high quality waters, and to provide a transparent analytic process for states and tribes to use to determine whether limited degradation of high quality waters is appropriate and necessary. It is important to note that antidegradation focuses on "existing uses" not "designated uses."

Assessing Water Quality Standard Attainment and Total Maximum Daily Loads (TMDLs)

In addition to addressing state requirements to develop WQS, § 303 of the CWA requires states to periodically assess whether waters are attaining WQS and provide a list to EPA detailing the locations of nonattainment and the suspected reasons for impairments. States submit this list for EPA approval every two years and it is referred to as the "impaired waters list" or 303(d) list. For waters placed on the 303 (d) list, states are also required to develop a TMDL. A TMDL calculates the maximum pollutant load that the water body can receive and still attain WQS. The CWA requires that the "load shall be established at a level necessary to implement the applicable WQS with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality[3]."

The CWA categorizes pollutant sources as either point sources or non-point sources. A point source is defined as any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel, conduit, or container. Control of point sources is handled primarily through the NPDES permit program, in Virginia it is the state VPDES permit program. In the CWA, point sources are clearly the focal point to be controlled, as the legal prohibition against pollutant discharge without a permit or other specific allowance applies only to point source discharges.

A nonpoint source is not specifically defined in the CWA, but is any source that is not a point source. Typical nonpoint sources include runoff from rural areas, including farming, animal grazing, and timber harvesting. The CWA does not establish a control program for nonpoint sources, as it did for point sources. Nonpoint sources are primarily addressed through voluntary programs that include grant funding as incentive for reducing pollutant loads. Significant differences between the two approaches to source control are problematic, especially in situations involving TMDLs for waterbodies with both point sources and nonpoint sources. In many cases, the focus to achieve pollutant reductions will be on point sources regardless of the load delivered by point sources versus nonpoint sources.

The TMDL establishes a ceiling for the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, natural background sources, seasonal variations, and a margin of safety. EPA has issued numerous guidance documents and policy memos to assist states (and stakeholders) in developing TMDLs, as well as in developing permits and assessing WQS attainment[4].

VPDES WWTP Permit

The City has a VPDES permit for discharges into the James River from the wastewater treatment plant. The permit, issued by the Virginia Department of Environmental Quality, regulates discharges from the WWTP and the CSOs, which serve as relief points in the combined sewer system (CSS). The permit includes effluent limits and monitoring requirements, as well as nine minimum control measures required for the combined sewer system under EPA's 1994 Combined Sewer Overflow Policy. Development of a Long Term Control Plan (LTCP) for the CSS is also required under this permit.

Richmond's CSO LTCP involves construction of conveyance systems and retention facilities to help control discharges from the combined sewer system (Richmond DPU 2002). The goals of the LTCP are to correct or minimize the public health, water quality, and aesthetic impact on the James River caused by CSOs.

State Consent Order

Implementation of Richmond's CSO LTCP is required under a consent order from the State Water Control Board. The consent order was issued in 2005 and includes an implementation schedule and a

[3] See CWA Section 303(d)(1)(C)

[4] Guidance and information on impaired waters and TMDLs can be found at: https://www.epa.gov/tmdl/impaired-waters-and-tmdls-tmdl-information-and-support-documents

description of LTCP projects that will be implemented. These projects were used as the basis for the CSO Infrastructure strategy that is discussed further in Chapter 5.

VPDES General Nutrient Watershed Permit

The General VPDES Watershed Permit Regulation for Total Nitrogen and Total Phosphorus Discharges and Nutrient Trading in the Chesapeake Bay Watershed is also applicable to the City. The City's WWTP has nutrient discharge limits that are established by this permit. These limits were used in the evaluation of the Clean Water Plan strategies (see Chapter 5 for additional discussion).

VPDES MS4 General Permit

The City's MS4 system is authorized to discharge into the James River and its tributaries under a general VPDES permit. The permit requires compliance with TMDL waste load allocations and implementation of minimum control measures, including public education/involvement, illicit discharge detection and elimination, runoff control at construction sites and new developments, and pollution prevention/good housekeeping to the maximum extent practicable.

Watershed Data

As discussed above, the previously developed Watershed Characterization Report compiled a significant amount of information on the following elements that was used to inform the Clean Water Planning process:

- Evaluation of existing geospatial (GIS) data including watershed features
    - Physical and natural features (including topography, soils, hydrology, geology, and land cover)
    - Land use and population characteristics
    - Infrastructure features
    - Wastewater collection system
    - Wastewater treatment system
    - Stormwater system
    - Sensitive areas

- Water quality data
    - Designated uses
    - 303(d) status / TMDLs (water quality issues - identification and characterization of water quality impairments and threats - and WLAs of approved TMDLs)
    - Monitoring programs
    - Water quality data
    - Flow data
    - Biological conditions
    - Pollutant sources
    - Stressors

A summary of some of this key information is discussed below in addition to how it has helped direct the Clean Water Planning process.

Watershed Features

The James River and its tributaries drain a watershed of over 10,000 square miles. Within the City of Richmond, the James River flows for 24 miles, providing a substantial amount of waterfront. Because of its location and access to the waterfront, Richmond was established as a shipping and industrial center. While shipping is still an important function of the river, it also provides passive and active recreation through its waterfront and rapids, and serves as the drinking water source for the City and most of the metropolitan area. Major features in the river include Bosher's Dam, which is located just upstream of the City along the James River, and smaller dams, levees, and pipe crossings within the City. There are multiple locations along the river for swimming, kayaking, and canoeing. These include:

- Huguenot Flatwater – near the crossing of N. Huguenot Road and the James River, this site provides canoes, kayaks, and inner tubes. This is also a popular fishing spot.
- Pony Pasture – a popular swimming and sunbathing area, the site provides access for Class II whitewater boating and fishing.
- Texas Beach – at the end of Texas Avenue, a trail leads to a sandy beach and sunbathing rocks and connects to the Belle Isle Pedestrian Bridge to the east.
- Ancarrow's Landing/Manchester Slave Docks – this is a popular fishing spot and includes boat ramp.
- James River Park – near the crossing of Riverside Road and Hillcrest Road, this location provides the opportunity for Class IV whitewater boating

Just downstream of the City is the Presquile Wildlife Refuge, home to several species of birds and anadromous fish, including the endangered Atlantic sturgeon.

Physical and Natural Features and Land Use Characteristics

There are a number of observations that can be made about the City's watersheds. The western and very northern portions of the City have experienced the least amount of hydrologic modification and possess the lowest intensely developed land use and most forested land cover. These more western areas also correspond with areas with higher soil infiltrative capacity. Alternatively, the eastern portion of the City corresponds with a higher intensity of developed land and industrial land use corridor as well as the City's urban core. Consequently, this area also corresponds to soils that are considered urban and tend to have less infiltration capacity and possesses a topography that includes some considerably steep slopes.

While any project slated for implementation will require a more detailed, site-specific assessment, the watershed-scale analysis in the Watershed Characterization Report provided information that helped guide the selection of high-level strategies. These strategies were created at this larger scale, rather than at a localized or neighborhood scale at which a project would be identified, to allow flexibility in the subsequent stages of integrated planning. For instance, in the assessment of green infrastructure as a strategy, GIS data were evaluated. Given the presence of steep slopes and soils in certain areas of the City that are not conducive to the infiltration necessary for green infrastructure, the total available land for this strategy was reduced by half. This conservative approach to identifying land availability incorporates an inherent flexibility that can allow for inclusion of additional acres into the strategy as more site specific data are collected. Chapter 5 includes additional discussion on strategies identification, Chapter 6 discusses the evaluation and prioritization of these strategies and Chapter 7 discusses implementation.

Infrastructure and Collection Systems

Similar to other older cities, especially in the eastern United States, the City of Richmond is served by both a CSS and a MS4. The distribution of area covered by these systems is shown in Table 3.1 and depicted in Figure 3.1.

Table 3.1. Area located within sewered sections of the City

Sewered Area	Area Served by (acres)
Combined Sewer System	12,000
Separate Sewer System	26,000 (24,500 in MS4; 1,500 in direct drainage)
Total	**38,000**

In dry weather conditions, both sanitary discharges and flows from the CSS are treated by the Richmond WWTP. The capacity of the City's WWTP, which serves approximately 215,000 people, is 45 million gallons per day during dry weather and up to 75 million gallons per day during wet weather. Combined sewer flows during wet weather events which would exceed the plant's capacity can be stored at the Shockoe Retention basin with a capacity of 44 million gallons[5] as well as the Hampton / McCloy CSS retention tunnel with a capacity of seven million gallons. Any remaining wet weather flow volumes are discharged through the City's 26 active CSOs.

The MS4 system, in the remaining portion of the City, includes over 220 miles of pipe, 280 miles of open channel and 50 miles of culverts that discharge stormwater flows at over 1,200 outfalls into receiving waters. Additional discussion of the MS4 area as well as the sanitary and combined sewer systems is included in the City's Watershed Characterization Report (2015).

[5] The basin holds 35 MGD, while in-line storage holds an additional 9 MGD

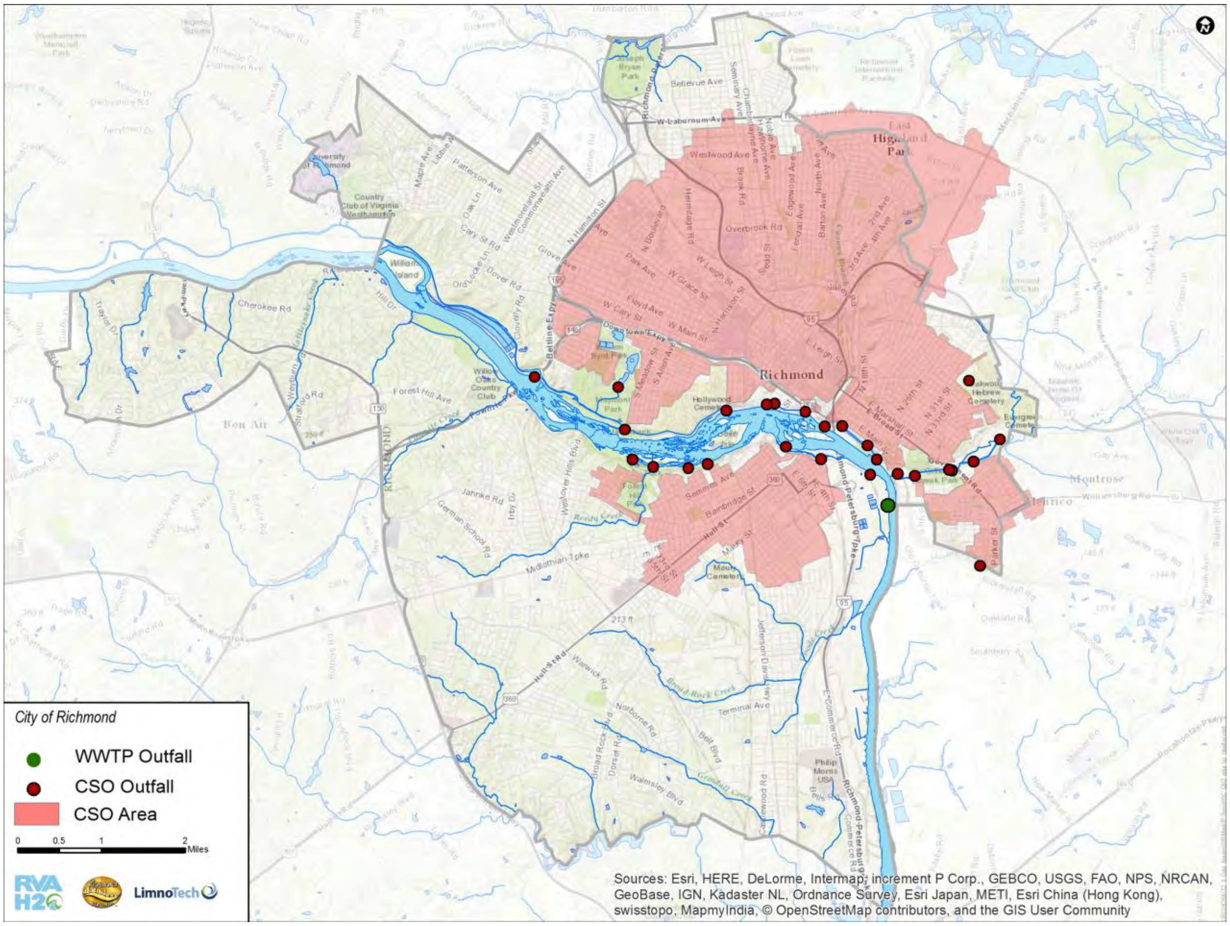


Figure 3.1. Combined sewer overflow area within the City of Richmond and location of CSOs

Understanding these areas within the City, and their associated sources and stressors, were essential to determining the extent to which they were contributing to impairments and the strategies that would be necessary to help the City mitigate these impacts.

Sensitive Areas

EPA's CSO Control Policy (Federal Register 59 [April 19, 1994]: 18688-18698) provides a framework for the control of CSO discharges through the NPDES permitting process. This policy establishes the expectation that CSO communities will give the highest priority to the control of CSO discharges within "sensitive areas". The Policy and EPA Combined Sewer Overflows Guidance for Long-Term Control Plans (EPA 832-B-95-002) define sensitive areas as:

- Outstanding National Resource Waters ("Exceptional State Waters" or "Tier III" waters in Virginia)
- National Marine Sanctuaries
- Waters with threatened or endangered species or their designated critical habitat
- Primary contract recreation waters, such as bathing beaches
- Public drinking water intakes or their designated protection areas

- Shellfish beds

While this sensitive area analysis is applicable only to Richmond's CSO area, the data and information provided do help better characterize the City and potential concerns that should be taken into consideration in the development of goals, objectives, and high-level strategies for future implementation.

The City's LTCP discusses how the six criteria for sensitive areas identified in the CSO policy were evaluated for the James River and its tributaries in the vicinity of Richmond's CSO outfalls. No Outstanding National Resource Waters have been designated in the vicinity of Richmond (State of Virginia, 9 VAC 25-260). No National Marine Sanctuaries have been designated within the state of Virginia. Additionally, no commercial shellfish harvesters operate within the area.

The Virginia Department of Conservation & Recreation (DCR) Natural Heritage Program's Database was used to assess the presence of threatened or endangered species in the CSO area of Richmond. The database did not include or indicate the presence of any species on the Federal- or State-listed threatened or endangered species or critical habitat of any species in the CSO area.

Richmond's drinking water intake is on the James River over three miles upstream of the CSO area.

The original LTCP study identified the sensitive areas associated with the City's CSS as the south and north James River Park areas. These two areas are primarily in the vicinity of public contact recreation waters, especially the south side James River Park, which receives a large number of visitors each year, particularly during the summer months. CSOs in these areas discharge into canals and pools which can be slow moving and therefore have limited capability for flushing and diluting pollutants as they progress toward the main channel of the river. For this reason, CSO discharges to these areas exerted significant public health, aesthetic and water quality impacts, although the pollutant loads of these areas are relatively small compared to the total pollutant load for all CSOs in the City.

These issues are all of particular concern with regard to localized bacteria issues, especially in areas where in-stream recreation is common or where the community would like to expand on such in-stream recreational activities in the future.

Water Quality Data

In addition to geographical data, the Watershed Characterization Report included an extensive amount of water quality-related data on the following topics:

- Pollutant sources
- Stressors
- Designated uses
- 303(d) status / TMDLs (water quality issues - identification and characterization of water quality impairments and threats - and WLAs of approved TMDLs)
- Monitoring programs
- Water quality data

- Flow data
- Biological conditions

A summary of some of this key information is also discussed below in addition to how it has helped direct the Clean Water Planning process.

Sources and Stressors of Watershed Impacts

The 2012 Integrated Report GIS data included suspected pollutant sources for each impaired waterbody segment. Common impacts include:

- MS4 discharges
- Combined sewer overflows
- Non-point sources
- Wastewater discharges
- Industrial point source discharges
- Atmospheric deposition (nitrogen, toxics)
- Clean sediments
- Internal nutrient cycling
- Loss of riparian habitat

Waterbody stressors are described as actions or impacts that may adversely affect (apply some form of stress) the ecosystem in some way. Stressors are categorized by whether or not they have an accompanying water quality standard or screening value. Virginia DEQ has identified the following stressors as being most prevalent:

- Biomonitoring Indices (VSCI/CPMI)
- Streambed Sedimentation
- pH below 6
- Habitat Disturbance
- Nickel in Sediment
- Total Phosphorus
- Dissolved Nickel
- Total Nitrogen
- Dissolved Cadmium
- CCU Metals Index
- Mercury in Sediment
- Ionic Strength
- Dissolved Oxygen

Based on the watershed characterization analysis, key regulatory drivers, and additional modeling [discussed further in Appendix A], it was determined that the sources of particular concern include CSOs and MS4 discharges. Other sources, such as clean sediment (from in-stream erosion and scouring) and loss of riparian habitat, were taken into consideration in the development of strategies (see Chapter 5 on Strategy Identification for further discussion).

Again, key regulatory drivers, watershed analysis and modeling also focused the prioritization of stressors on total nitrogen, total phosphorus, total suspended solids, and bacteria. These key pollutants were used as a priority metric for evaluating the effectiveness of strategies in achieving goals and objectives related to water quality improvements.

Existing Water Quality Data

Obtaining sufficient water quality data to assess the status of the City's waterbodies and impacts to these waterbodies is essential to developing an effective Clean Water Plan. As part of the City's

Watershed Characterization process, monitoring data from all available sources were compiled from entities such as Virginia DEQ, local universities, and watershed groups. These data supported the watershed characterization as well as the City's watershed and water quality monitoring (discussed further in Chapter 3). Moving forward, this data assessment can help the City determine how its existing monitoring program may need to be modified or how to better coordinate with local partners to integrate monitoring efforts.

The existing water quality data analysis showed that the number of available samples across data types (water quality sampling, biological sampling, and habitat assessments) are biased heavily towards the James River, with little-to-no data available in tributary streams. Additionally, there is a lack of hydraulic data within the City, with the only local USGS gauges located outside the City limits. Table 3.2 summarizes samples by data type and receiving water category. This table also highlights the dearth of biological samples and habitat assessments.

Dividing the data on a regional basis (watershed groupings discussed in the Watershed Characterization Report) reveals that the majority of available water quality samples were collected in the Lower James CSO and Lower James MS4 watershed groupings, while the majority of biological and habitat samples were collected in the Lower James CSO and the Middle James MS4. Table 3.3 summarizes samples by data type and watershed group.

Table 3.2: Overall Sample/Assessment Counts by Data Type and Receiving Water Category

Data Type	James River	Tributaries
Water Quality	4,759	368
Biological	44	5
Habitat	44	5

Table3.3: Overall Sample/Assessment Counts by Data Type and Watershed Group

Data Type	Lower James CSO	Lower James MS4	Lower James-Chickahominy MS4	Middle James MS4
Water Quality	2,012	2,341	85	689
Biological	30	1	3	15
Habitat	30	1	3	15

Other types of data, such as hydraulic and meteorological samples, are more limited. There are no hydraulic data available within the City limits. While there are two USGS stations within the City limits (James River at Boulevard Bridge [USGS #02037618] and James River at City Locks [USGS #02037705]), neither station has flow data. The two closest USGS gaging stations with daily flow data are James River and Kanawha Canal Near Richmond (USGS #02037000) and James River Near Richmond (USGS #02037500), both of which are located upstream of the city. There is meteorological data available, but there are only two stations within the City (one in the Lower James CSO and another in the Lower James-Chickahominy MS4), both of which provide daily rainfall totals.

The lack of data in certain portions of the City and in the various tributaries emphasized the need for not only the collection of additional monitoring data, but the collection of monitoring data in a more coordinated manner between the City and various partners. Various supporting actions related to monitoring were recommended in association with the development of strategies. Part of supporting actions includes the establishment of a workgroup made up of the City and technical stakeholders to plan and implement an integrated monitoring strategy to identify efficiencies across partner monitoring efforts, coordinate efforts, and facilitate the sharing of data.

Surface Water Quality Issues

As discussed above, all Virginia waters are designated for the following uses:

- Recreation (e.g., swimming and boating);
- Propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them;
- Wildlife; and
- Production of edible and marketable natural resources (e.g., fish and shellfish)[6].

Waterways may also be considered for primary shellfish harvesting status (Richmond DPU 2016).

> **Waterbody Impairments**
>
> *If a water body contains more contamination than allowed by water quality standards, it will not support one or more of its designated uses. Such waters have "impaired" water quality. In most cases, a cleanup plan (called a "total maximum daily load") must be developed and implemented to restore impaired waters.*
>
> *- Virginia DEQ*

The City's Watershed Characterization Report (2015) discusses the water quality criteria for the waterways in the Richmond area (Class II Estuarine waters for the tidal James River; Class III Non-tidal waters for the falls of the James and other tributaries).

Impairments to Richmond's waters are discussed further in the 2014 Integrated Report (VDEQ 2016) and are summarized in Table 3.4. Impairments include Chlorophyll-a, *E. coli,* Estuarine Bioassessments, benthic macroinvertebrate bioassessments, dissolved oxygen, PCB in fish tissue, PCB in water column, aquatic plants (macrophytes), pH, chlordane, DDE, DDT, and mercury in fish tissue.

The TMDLs applicable to the City include the James River bacteria TMDL and the Chesapeake Bay TMDL, which addresses total nitrogen, total phosphorus, and sediments. These TMDLs were identified as the main drivers behind this planning process. When other TMDLs, such as that for PCBs in the James River,

[6] See http://www.deq.virginia.gov/Programs/Water/WaterQualityInformationTMDLs/WaterQualityStandards/DesignatedUses.aspx

are developed, the City will evaluate the need to adjust the Clean Water Plan as part of the adaptive management approach.

Human, Aquatic Life, and Wildlife Health Issues

Several of the City's impaired waters pose health hazards for humans, aquatic life, and wildlife. The issues specifically addressed by this Clean Water Plan are those caused by bacteria, nutrients, and sediments. These are the same pollutants addressed by the TMDLs which will be included in the City's VPDES permit.

The James River (lower and tidal reaches) and several of its tributaries (Almond Creek, Falling Creek, Goode Creek, Powhite Creek, Reedy Creek, Bernards Creek, and Gillies Creek) and Upham Brook (which is a tributary to the Chickahominy River and ultimately the James River) have all been listed as impaired due to *E. coli* levels. These stream segments do not support the primary contact recreation use. The sources of bacteria in these streams within the City limits include CSOs, the MS4, the WWTP, direct discharge of urban runoff, and wildlife. Upstream sources also impact water quality in the City. Upstream sources include livestock, land application of manure, malfunctioning septic systems, illicit discharge of residential waste, other permitted waste treatment facilities. Presence of these bacteria is strongly linked with gastrointestinal illness in recreational users of the waterways. Reducing bacteria levels in these streams is consistent with the City's goal to provide safe recreational opportunities in the river.

While the James River bacteria TMDL addresses near-field water quality issues that must be addressed with localized strategies, the Chesapeake Bay TMDL, which applies to the James River and all its tributaries, sets targets for nutrient and sediment reductions downstream in the Chesapeake Bay. An excess of nutrients (nitrogen and phosphorus) in water can lead to an overgrowth of algae in water, or harmful algal blooms. Algal blooms can produce toxins harmful to humans and animals, create dead zones, and increase drinking water treatment costs for downstream communities. Sediments and algae in the water lead to murky conditions that block sunlight from underwater grasses and create low levels of oxygen for aquatic life. Safe nutrient and sediment levels are needed to maintain safe recreational opportunities and protect aquatic life in the river.

Again, while Richmond's waterbodies have impairments for a number of different pollutants (Table 3.4), the key focus for this Clean Water Plan are bacteria, nutrients, and sediment. Additional discussion of specific targets for these pollutants is included in Chapter 6.

Table 3.4 Impairments of waterbodies within the City of Richmond

River Segment	Segment	HUC Code(s)	Length (miles)	Benthic	Chlorophyll *a*	DO	E. coli	Estuarine Bioassessments	Macrophytes	Mercury	Chlordane	DDE	DDT	PCB	pH
North of the River															
Upham Brook	Flippen Creek to confluence with Chickahominy River	JL18	1.2			X									
Upham Brook	Headwaters to confluence with Chickahominy River	JL18	55.72				X								
Stony Run Creek	Headwaters to mouth of Gillie's Creek	JL01	3.23				X								
Gillie's Creek	Headwaters to mouth of James River	JL01	6.02				X							X	X
South of the River															
Powhite Creek	Headwaters to mouth of James River	JM86	8.05	X			X								
Rattlesnake Creek	Headwaters to mouth of James River	JM86	2.32				X								
Reedy Creek	Headwaters to trib above Roanoke St.	JM86	2.34			X	X								
Reedy Creek	Trib above Roanoke St to Forest Hill Ave.	JM86	0.6												X
Manchester Canal	Manchester Canal	JM86	0.75				X								
Pocoshock Creek	Headwaters to mouth of Falling Creek Reservoir	JL02	8.7				X								
Falling Creek Reservoir	Falling Creek Reservoir	JL02	88.37 (acres)			X	X								
Broad Rock Creek	Headwaters to mouth of Goode's Creek	JL01	3.15				X								
Goode's Creek	Mouth of Broad Rock Creek to confluence with James River	JL01	1.25				X							X	
James River															
James River	Blvd bridge to fall line at Mayo's Bridge	JM86	2.91			X	X			X	X	X	X		
James River	Mayo Bridge to mouth of Appomattox River	JM86, JL01	1.47		X	X	X	X	X						
James River	Big Island Dam to I-95 bridge		13.28											X	

Water Quality Modeling

Water quantity and quality modeling was conducted to allow for longer and continuous periods to be evaluated relative to the water quality monitoring program. Therefore, a key step towards the development of the Clean Water Plan was the development of a water quantity and quality modeling framework. The purpose of the modeling framework is to quantify present day bacteria (E. coli) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the Clean Water Plan strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. The City's Clean Water Plan Modeling Report (Appendix A) includes a detailed discussion of the model development, calibration, and application. A summary of each step is provided here.

Model Development

Three models were used to achieve the modeling objectives, and together they comprise the modeling framework. These three models include:

- A watershed model to simulate flow and bacteria loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system. This model was developed using the EPA SWMM software.
- A collection system model to simulate flow and bacteria loads from the combined sewer system (CSS). The CSS model is an existing model that is used to by the City of Richmond for Wastewater Master Planning, to support implementation of the CSO Long Term Control Plan, and to prepare the Annual CSS Reports. This model was developed using the EPA SWMM software, and was adapted for use in this study.
- A receiving water quality model that computes bacteria concentrations in the James River resulting from the various sources of bacteria to the river. The outputs of the watershed and CSS models are used as inputs to the receiving water quality model. The receiving water quality model was developed using the EPA-supported EFDC software.

Model Calibration

Model calibration is the process of adjusting model parameters and assumptions within defensible ranges to achieve reasonable agreement between modeled and observed environmental conditions. The calibration process demonstrated that the modeling framework is sufficiently well calibrated to support the following modeling objectives:

- Design the modeling framework to provide a reliable and reasonably complete accounting of bacteria sources to the James River;
- Develop the modeling framework using sufficiently complete and accurate site specific data;
- Calibrate the models using reasonable assumptions consistent with the site data, literature, and professional judgment;
- Achieve a level of model accuracy that is adequate to support decision making;

- Apply the models for a period including a wide range of common environmental conditions (i.e. river flow and precipitation conditions); and,
- Evaluate and synthesize model output to interpret major sources of current water quality impairment and to forecast future water quality conditions.

Model Application

After the water quality modeling tools were developed and calibrated, they were jointly applied to assess water quality benefits associated with the selected strategies. For this purpose, the model was applied for a 3-year simulation period that includes a dry year (less than normal precipitation), and average rain year, and a wet year (more than normal precipitation). To date, the model has been applied to evaluate the following conditions or strategies:

- Current conditions: Best representation of current conditions, and includes all the Phase I and Phase II CSO improvements from the CSO Long Term Control Plan (LTCP).
- Baseline Conditions: represents the current conditions, plus all the currently funded Phase III collection system improvement projects from the LTCP.
- Green Infrastructure in the MS4 area Strategy: represents the baseline conditions, plus the implementation of 104 acres of green infrastructure on city-owned area in the MS4.
- Green Infrastructure in CSS area Strategy: represents the baseline conditions, plus the implementation of 18 acres of green infrastructure on city-owned area in the CSS area.
- CSS Infrastructure Strategy: Implementation of CSS projects included in the LTCP: represents the baseline conditions, plus all the remaining unfunded Phase III collection system improvement projects from the LTCP.

These strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges, expressed as billion CFU per year
- Percent increase in monthly geomean water quality standard compliance in the James River at the downstream city limit
- Reduction in number of CSO events per year
- Reduction in CSO volume, expressed as million gallons per year

These water quality benefits were then entered into a calculator tool that integrates the benefits of strategies across a wide range of Goals and Objectives, as further explained in the next chapter. Water quality benefits were also assessed relative to the two existing water quality standards: a monthly geometric mean standard and a statistical threshold value (STV) standard.

Assessing Current Conditions

The Clean Water Plan Modeling Framework was applied to better understand the sources and impacts of bacteria in the James River. The main metrics evaluated by the model include average bacteria loads entering the river from the main sources, *E.coli* concentration in the James River and comparison to the water quality standards, number of CSO discharge events, and CSO discharge volume.

An evaluation of current conditions helped assess the impact of the five major sources of bacteria in Richmond (upstream, CSO, stormwater, background, and WWTP sources), and how each contributes to water quality standard exceedances relative to the other sources. Figure 3.2 graphically shows these results for both the monthly geomean and statistical threshold value (STV) standard. The model results illustrate that the James River is in violation of both the geometric mean and the statistical threshold value water quality criteria for some months out of the three year model simulation period, and the primary cause of a water quality criteria violation can sometimes be linked to Richmond's combined sewer overflows, while at other times it is due to upstream sources coming in from outside of the City. Background (mainly wildlife) and stormwater sources play a smaller overall role in the bacteria water quality violations. The WWTP does not contribute significantly to bacteria water quality violations.

Because the model shows that Richmond's CSOs contribute in large part to the bacteria water quality criteria exceedances, this information was used to support the prioritization of strategies, such as CSO infrastructure, to address this source. Figure 3.3 shows the relative volume of CSO discharges at the CSO outfalls (based on data from 2004 to 2016), and may present potential opportunities for targeting specific CSO discharge points.

Other important metrics evaluated by the model are shown below in Table 3.5.

Table 3.5 Model Output for Current Conditions

Model Output	Model Value
Average yearly E.coli load (billion cfu)	9.65E6
Average annual number of CSO events	53
Average yearly CSO volume discharged (million gallons)	1,670

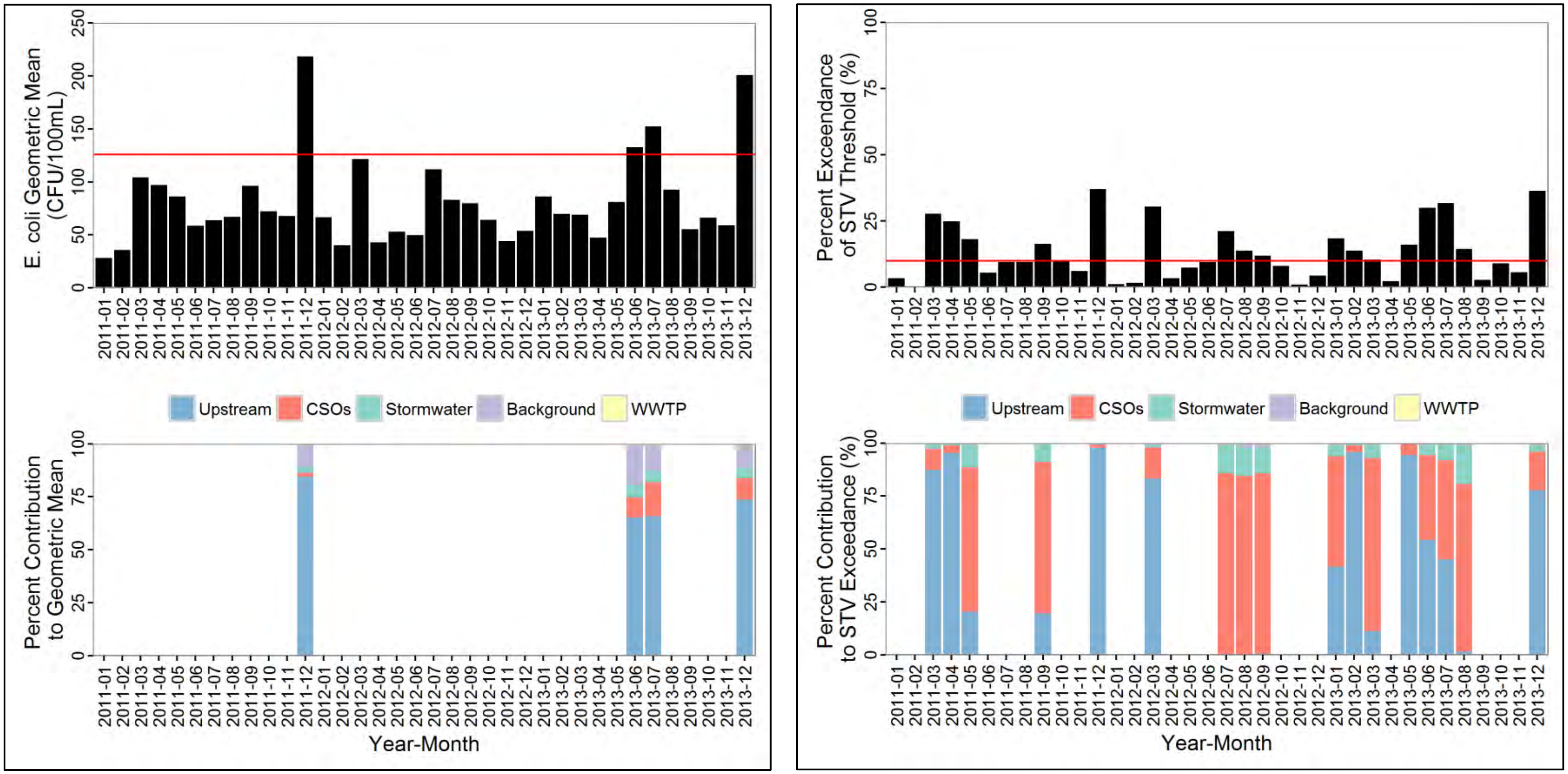


Figure 3.2. E.coli Monthly Geometric Mean and STV Standard Model Results for Current Conditions

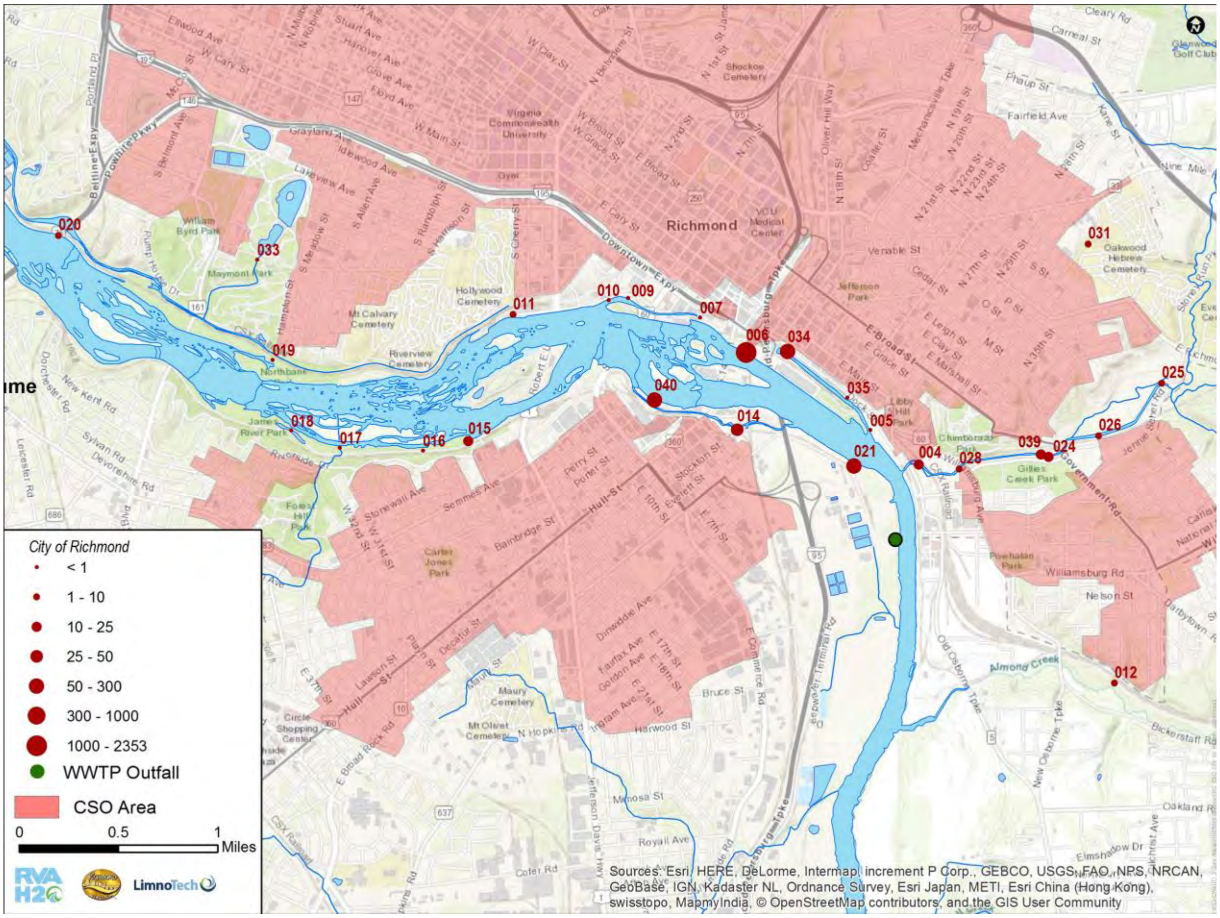


Figure 3.3. CSO Overflow volume by CSO outfall (million gallons/year)

Additional information on the modeling results can be found in Appendix A.

4. Goals & Objectives Selection

Traditional integrated planning efforts tend to focus on meeting infrastructure goals, such as reduction in the number of CSOs. The City's Clean Water Plan, however, is built around a watershed framework that accounts for the City's collective water needs and requirements (including, but not limited, to infrastructure) while considering watershed characteristics. While DPU's understanding of these needs and requirements provide a starting point for establishing the goals and objectives of the Clean Water Plan, DPU recognized that stakeholder input would also be critical to fully capturing the desired direction and outcome of the Plan. This process included not only extensive stakeholder feedback to develop the goals/objectives, but included a weighting process to assign a degree of relative importance of these goals/objectives to one another. The goals, objectives, and respective weights are summarized in Table 4.1 and the approach used to develop this is described below.

Table 4.1 Clean Water Plan goals and objectives with associated weights

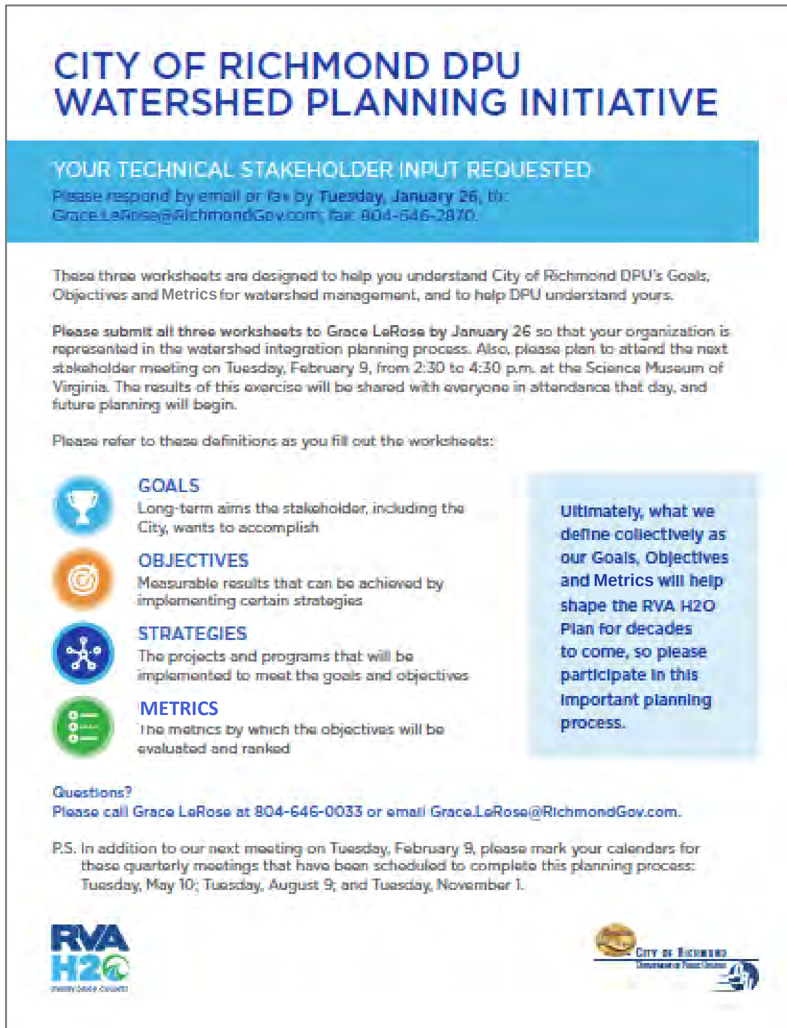
Goals (with weights)	Objectives	Weights
19%: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.	Develop one stormwater management plan to cover the City's four watershed groupings based on the City's watershed characterization report	19%
	Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL)	18%
	Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards)	18%
	Reduce toxics (e.g., mercury, PAHs, PCBs), trash and other pollutants and address TMDLs for these pollutants	17%
	Develop green infrastructure, including riparian buffers, and removal of impervious surfaces on development, existing development, and redevelopment	27%
15%: Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities	Restore streams to improve, restore, and enhance native ecological communities	25%
	Identify, protect, and restore critical habitats	36%
	Enhance aquatic and terrestrial habitat connectivity	23%
	Investigate, and where feasible, promote actions that might surpass regulatory requirements	16%
14%: Engage and educate the public to share responsibility and take action on achieving healthy watersheds.	Engage and efficiently educate the public about standards, processes, and actions associated with watershed health and public health	25%
	Assist in the education of citizens about overall water quality issues, benefits of improved water quality	30%
	Support and encourage local action to improve water quality	24%
	Provide quicker public notifications of spills or pollution from regulators or other "river watchers"	21%
12%: Implement land conservation and restoration and incorporate these into	Protect, restore, and increase riparian buffers	21%
	Reduce impervious surfaces	19%
	Increase natural land cover with a focus on preserving, maintaining, and increasing tree canopy	24%

planning practices to improve water quality.	Incorporate green infrastructure in new development and redevelopment	18%
	Conserve lands where possible and consistent with Richmond's Comprehensive Plan	18%
11%: Create partnerships across the watersheds internal and external to the City of Richmond to maximize benefits and minimize impacts to all stakeholders	Develop and implement a source water prevention plan/strategy	33%
	Establish public-private partnerships to secure funding, implement strategies and projects, and to achieve plan goals	40%
	Maintain and expand the RVAH20 group	27%
10%: Maximize water availability through efficient management of potable, storm, and wastewater.	Reduce use of potable water for industry and irrigation	39%
	Achieve water conservation by improving the existing water conveyance system	30%
	Achieve water conservation by incentivizing upgrades to end-user water fixtures where appropriate	31%
9%: Provide safe, accessible, and ecologically sustainable water-related recreational opportunities for all.	Improve water quality to promote safe recreation consistent with the City's Riverfront Plan	36%
	Promote ecologically sustainable management of riverfront and riparian areas	40%
	Improve river and waterfront access for recreation	24%
9%: Work collaboratively to gather consistent high-quality data to characterize the status and trends of water resources and to gauge the effectiveness of restoration efforts.	Conduct water quality and biological monitoring	28%
	Provide timely water quality information	19%
	Collaborate with citizens and local/state agencies for coordinated monitoring	23%
	Utilize results to target restoration efforts and convey progress	30%

Establishing Goals & Objectives

The first step of the Clean Water Planning process was determining the direction in which the City and its stakeholders wished to take this effort. To accomplish this, goals and objectives were selected through an extensive stakeholder communications process. The watershed characterization efforts, described in Chapter 3, were used as a basis for understanding the City's watershed features, water quality, and any issues of concern within the watersheds. While this helped inform the City and stakeholders, the selection of overarching goals, refined goals, and objectives was also influenced by the mission of stakeholder organizations or City department as well as stakeholder's additional first-hand knowledge of local issues.

To account for the multiple opinions and perspectives that were anticipated, the City implemented a multi-step process to form consolidated lists of overarching goals, refined goals, and objectives. The first step in this process was to survey stakeholders (Figure 4.1). The City requested that stakeholders submit what they felt were appropriate overarching goals, refined goals, objectives, and metrics (discussed further in Chapter 6) based on definitions and guidance on what these terms included.


CITY OF RICHMOND DPU
WATERSHED PLANNING INITIATIVE

YOUR TECHNICAL STAKEHOLDER INPUT REQUESTED

Please respond by email or fax by **Tuesday, January 26**, to: Grace.LeRose@RichmondGov.com; fax: 804-646-2870.

These three worksheets are designed to help you understand City of Richmond DPU's Goals, Objectives and Metrics for watershed management, and to help DPU understand yours.

Please submit all three worksheets to Grace LeRose by January 26 so that your organization is represented in the watershed integration planning process. Also, please plan to attend the next stakeholder meeting on Tuesday, February 9, from 2:30 to 4:30 p.m. at the Science Museum of Virginia. The results of this exercise will be shared with everyone in attendance that day, and future planning will begin.

Please refer to these definitions as you fill out the worksheets:

GOALS
Long-term aims the stakeholder, including the City, wants to accomplish

OBJECTIVES
Measurable results that can be achieved by implementing certain strategies

STRATEGIES
The projects and programs that will be implemented to meet the goals and objectives

METRICS
The metrics by which the objectives will be evaluated and ranked

Ultimately, what we define collectively as our Goals, Objectives and Metrics will help shape the RVA H2O Plan for decades to come, so please participate in this important planning process.

Questions?
Please call Grace LeRose at 804-646-0033 or email Grace.LeRose@RichmondGov.com.

P.S. In addition to our next meeting on Tuesday, February 9, please mark your calendars for these quarterly meetings that have been scheduled to complete this planning process: Tuesday, May 10; Tuesday, August 9; and Tuesday, November 1.

RVA H2O

Figure 4.1. Guidance provided to technical stakeholder to support the gathering of input on goals, objectives, and metrics.

Fifteen stakeholders provided input through responding to the request. Given the large amount of feedback to discuss, the City addressed the discussion of overarching goals and refined goals during the February, 2015 meeting and objectives during the May, 2015 meeting.

Prior to the February meeting, the City evaluated all of these submissions and identified a number of themes. It was important to the City that no feedback was lost in this process, so all input was incorporated verbatim into one of these themes:

Overarching Goal Themes:

- Collaboration
- Water consumption
- Preservation and restoration
- Water quality

Refined Goal Themes:

- Recreation
- Aquatic and riparian habitat
- Stormwater peak flows
- Pollution
- Land conservation and management
- Partnerships
- Monitoring
- Public engagement & action
- Water conservation

At the stakeholder meetings, attendees were broken into small groups with each group being provided one of these themes and its associated goals. Each small group was then asked to combine and synthesize the items within that theme. Goals could be combined, reworded, or moved to another goal topic area. Goals could also be re-categorized as an objective or a strategy if deemed more appropriate. Ultimately, one goal was developed for each topic area.

A similar approach was taken in developing a refined list of objectives. Stakeholders provided objectives associated with each of the proposed goals. Stakeholders then refined these objectives so there were between one and six objectives associated with each of the refined goals.

Striving for Consensus

A number of opinions and viewpoints were represented through the stakeholder process. While the City felt it was important for the Clean Water Planning process to reflect these views, it was also important for the process to move forward in a timely manner. To accomplish this, the City strived to reach consensus on each of the steps of this process and the associated decisions made.

The goal behind *striving* for consensus is that everyone will be able to live with and support the idea or issue, or, at least, no one opposes it. If the group was not able to support an element of the issue/item up for discussion, additional discussion was deemed necessary.

While stakeholders were a key part of the process for identifying goals and objectives, they did represent many different groups with interests in the City. To ensure stakeholders all shared the same amount of influence during this process, each interest group was allowed one member at the table who could participate (i.e., vote) in the consensus process.

As shown in Figure 4.2, each voting stakeholder could select either “1”, “2”, or “3” to represent their level of agreement with a particular goal or objective being discussed. If any stakeholder selected “1”, then the topic was discussed further until the stakeholder agreed, the item for discussion was modified so that all stakeholders could at least live with the decision, or the item/topic was removed from the options moving forward.

Ultimately, stakeholders achieved consensus on the overarching goal, refined goals, and objectives.

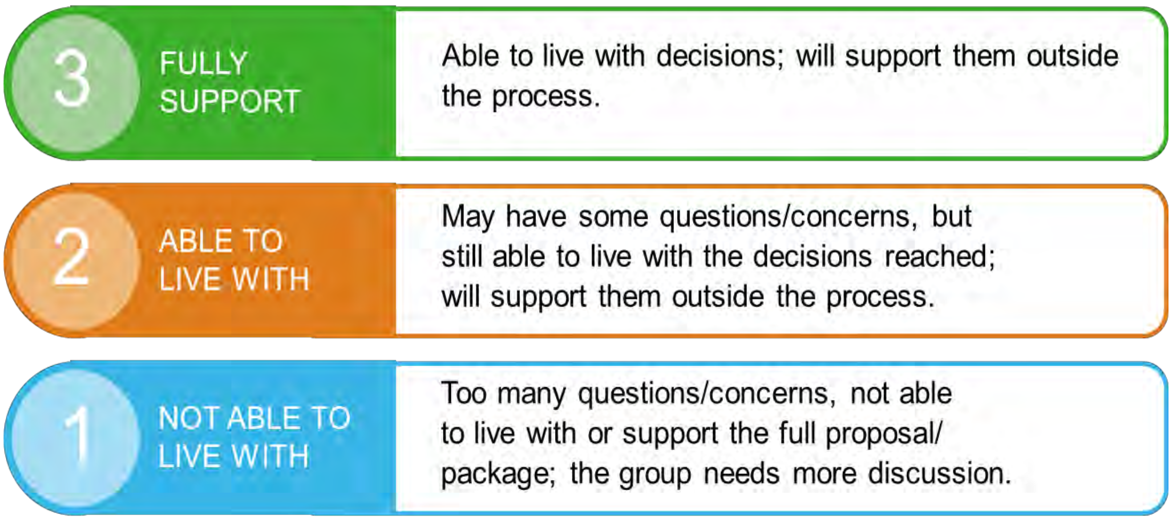


Figure 4.2 Consensus voting process for the Clean Water Plan

Prioritizing through Weighting

Weighting was incorporated into this process to reflect the priorities of the City and its stakeholders. This weighting process not only allowed for an understanding of how one goal or objective ranked in relation to another, it also provided information on the extent of the importance of these priorities to one other.

Weighting included the process of assigning a portion of 100 points to each of the items in a grouping. As shown in the example in Table 4.2, 100 points are apportioned across a grouping of refined goals. In this example, refined goal #2 was given the highest priority, with 50 points. One or more objectives were assigned to each refined goal. Each grouping of objectives

Table 4.2 Example weighting process

Refined Goals	Weight	Objectives	Weight	
Refined goal #1	15	Objective #1	50	Total: 100
		Objective #2	30	
		Objective #3	10	
		Objective #4	10	
Refined goal #2	50	Objective #1	10	Total: 100
		Objective #2	60	
		Objective #3	30	
Refined goal #3	30	Objective #1	40	Total: 100
		Objective #2	60	
Refined goal #4	5	Objective #1	20	Total: 100
		Objective #2	40	
		Objective #3	10	
		Objective #4	30	
Total:	**100**			

was also given a proportion of 100 total points.

The result of this process was a prioritization of refined goals as well as a prioritization of objectives associated with each of these goals.

Once the goals and objectives were finalized by the City and its stakeholders, Surveymonkey.com was used to circulate a questionnaire to each stakeholder organization to obtain their opinion on the weights of each goal and objective. The weights provided by each stakeholder organization were then averaged to produce a weight for each refined goal and for each objective. These averaged weights were presented and discussed at a technical stakeholder meeting. Stakeholders were allowed to suggest modifications to the weights of the goals or objectives as long as the overall ranking of these weights remained the same. Using the example in Table 4.1, while the order of the refined goals must remain #2, #3, #1, and #4, stakeholders might collectively decide that refined goal #3 should be 38 points, while refined goal #2 should be changed to 42 points.

5. Strategy Identification

The next step in this process was the identification of strategies that can be expected to achieve the previously identified goals and objectives. Strategies were defined as activities, actions, or items that will help meet goals and objectives. The process that was used to develop the strategies is discussed below.

Brainstorming Potential Strategies

Implementation of projects and programs that may benefit the City's water resources are undertaken by numerous departments within the City as well as other entities, such as local universities, watershed organizations, or private developers. While the City can coordinate or partner with these entities to implement such efforts (as was discussed in Chapter 2), DPU recognized that the starting point in determining a list of strategies for the Clean Water Plan was determining what projects and programs the Department could implement and maintain itself.

Strategies vs. Projects

The Clean Water Plan-related planning is occurring at the sub-watershed to the City-scale. As such, projects or programs at a finer scale needed to be "rolled up", or grouped, to produce a higher level strategy.

The first step in brainstorming potential strategies included a workshop for DPU staff involved in stormwater, wastewater, and CSO-related projects. Staff compiled a list of projects that had been identified or proposed to meet various programmatic needs. Because the Clean Water Plan would be implemented during the next VPDES permit cycle (beginning in June of 2018), any project that would be funded, initiated, or implemented prior to this date was removed from the list. The resulting list included the remaining potential projects that could be implemented over the next VPDES permit cycle (2018 through 2023). City staff also brainstormed other ideas, such as opportunities for expanding existing efforts like the residential stormwater credit process, to help increase implementation.

It is important to note, however, that the initial stages of the Clean Water Planning process is being developed at a high-level scale (sub-watershed, watershed, to City-scale). Because many of these projects impact small-scale areas, these City projects were "rolled up" to a strategy scale where necessary. For example, several bioretention or permeable paving projects were rolled up, or grouped, into a Green Infrastructure strategy.

In addition to these DPU projects, stakeholders were also asked to submit suggestions for strategies that they felt would achieve the agreed upon goals and objectives. Numerous ideas were gathered with varying levels of detail. Because there were a number of distinct themes to these suggested strategies, the Clean Water Plan development team created a synthesized set of draft strategies that consolidated ideas put forth by both stakeholders and DPU staff.

It was determined that a number of the ideas put forth, while important, were not strategies in and of themselves. A number of these ideas could also be tied to more than one strategy. These ideas were defined as "supporting actions". Supporting actions include efforts that may broaden the main strategy, add specificity on how a strategy could be implemented, or identify additional resources and data needs to fully implement the main strategy. These supporting actions are not necessarily quantifiable in and of themselves and may be components of multiple main strategies. Actions, such as those related to partnerships, may also involve activities on non-City property and rely on resources that are outside the DPU's authority.

Supporting actions include:

- Partnerships – establishing partners to facilitate a greater level of future implementation of projects and programs (partners include those within the City, such as the Department of Public Works (DPW), as well as with non-City agencies, such as watershed groups)
- Maintenance – including resources and funding to ensure a strategy will continue to meet its intended objectives
- Monitoring, Assessment & Planning – gathering data and information and using these results to help guide and implement future implementation
- Incentives/Credits – evaluating and implementing mechanisms to incentivize new initiatives or higher levels of future implementation
- Regulations/Ordinances/Codes – analyzing and modifying, if necessary, the framework within which implementation will occur
- Outreach – including ways to potentially expand upon future implementation by conveying information on resources available or ways for partners and the public support a strategy

Some of these Supporting Actions are specific to a particular strategy, but others, such as some related to monitoring or public outreach, cut across various strategies.

Strategy Feasibility

Once the draft set of strategies was identified, it was important to determine if these strategies were feasible. Because DPU is ultimately responsible for implementation of the Clean Water Planning program, the feasibility of strategies was defined as efforts that DPU has the authority to implement. For instance, a strategy could be identified as infeasible if it requires implementation on land not owned by the City, and where it is not possible for the City to purchase or obtain the land in some way.

Because the City's Parks, Recreation, and Community Facilities (PRCF) Department works so closely with DPU and shares similar departmental objectives for project implementation and maintenance, PRCF land was also considered to be available for the feasible implementation of a strategy.

Feasibility also takes into account the potential limitations on strategy implementation due to physical constraints such as steep slopes or soils with poor infiltration that are unsuitable for some strategies such as green infrastructure. Therefore, the acreage included in the strategies reflects a portion of DPU/PRCF in the City that is appropriate for that particular strategy. For example, based on an evaluation of slopes and soils GIS data and best professional judgement, a decision was made to conservatively include 50% of the total DPU and PRCF lands within the Green Infrastructure Strategy in both the MS4 and CSS areas. Details on assumptions made for each of the strategies is included in Appendix B.

Final Strategies

Once feasibility was evaluated, final draft strategies and supporting actions were presented to stakeholders who were given the opportunity to edit them further. Once all feedback was incorporated, a final set of strategies and supporting actions was presented to the stakeholders for a consensus vote.

Each of the strategies referenced in the remainder of the Clean Water Plan are considered to be "feasible" and agreed upon by the Technical Stakeholder group (Table 5.1).

Table 5.1. Strategies and associated details

Strategy	Strategy Details
Riparian Areas	Replace or restore 10 acres of riparian buffers according to state guidance. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Green Infrastructure in MS4	Install or retrofit GI draining 104 acres of impervious surfaces, including efforts such as: • 30 acres on DPU property • 18 acres on City-owned vacant properties • 20 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 100 trees in tree boxes (e.g., Filtera-type practices); 30 acres total drained to this practice • Retrofit 4 DPU stormwater BMPs (e.g., dry ponds to more efficient BMPs), draining at least 6 acres of impervious surface
Green Infrastructure in CSS	Install or retrofit GI draining 18 acres of impervious surfaces, including efforts such as: • 6 acres on DPU property • 2 acres on City-owned vacant properties • 2 acres on Parks department property (one playground/park per year, cemetery roadways, impervious to pervious area in park properties, vacant properties) • Install 24 trees in tree boxes (e.g., Filtera-type practices); 8 acres total drained to this practice
Stream Restoration	Restore 2,500 linear feet of stream: • Through removal of concrete channels, repair of incised banks, etc. • In MS4 and/or CSS area • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Natives/Invasives	Use 80% native plants in new landscaping at public facilities by 2023.
Trees	• Increase tree canopy on City property by 5% (80 acres added) • Protect existing tree canopy by following maintenance addressed in the Tree Planting Master Plan
Land Conservation	Place an additional 10 acres under conservation easement, prioritizing conservation of land that creates connected green corridors. • Evaluate opportunities for inclusion of access points to waterbody for recreational activities
Water Conservation	Reduce water consumption by 10% through implementation of new water conservation technologies and promotion of water conservation efforts, including: • Installing water-efficient fixtures as a policy by 2023 in all new public facility construction • Implementing incentive programs

	• Encouraging water conservation on City properties
Pollution Identification and Reduction	Reduce contribution of pollutants to the MS4 through: • Conducting at least 1 special study per year in hot spot areas to identify illicit discharges/connections. (Studies will meet the criteria necessary to achieve Bay TMDL pollutant reduction requirements. Assume that, over 5 years, 3 of these studies will result in pollutant reductions that meet Bay TMDL requirements.) • Collecting data associated with non-structural BMPs to facilitate quantification of pollutant reduction (e.g., storm drain clean-outs, pet waste stations, street sweeping)
CSS Infrastructure	LTCP projects, including: • Installing wet weather interceptor to convey more flow to the WWTP • Increasing WWT to 300 MGD at the treatment plant • Expanding secondary treatment at the WWTP to 85 MGD • Expanding Shockoe retention basin by 15 MG to capture more overflow • Disinfecting overflow at Shockoe retention basin (wet weather disinfection facility) *Note that that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost.*

Table 5.2 includes the final, agreed upon supporting actions for the strategies.

Table 5.2. Supporting Actions associated with the various strategies

Supporting Actions	Details
Partnerships	Restore 20 acres of riparian buffers on private properties through efforts such as: • Purchases of land • Partnerships with residents: Promote program for buffers on private properties (include tiers of level of involvement – (1) maintenance agreement with City, (2) conservation agreement/ easement.) • Partnerships with Master Naturalists to enlist their support for assistance with riparian restoration.
	Implement 10 acres of GI on private property
	Implement 5 acres of GI on DPW property (rights of way, roadways, green alleys) through efforts such as: • Adopt a rain garden program – coordinate with residents, non-profits, commercial entities • Partnering with the City's community garden program to identify 0.5 acres of area for additional GI implementation • Partnering with Public Works to ensure City greenways include GI
	Develop a program to encourage the use of native plants in private landscaping – sign up 20 private landscapers.
	Initiate an Adopt a Lot program (10 lots with invasive species removed, replanted and maintained)
	Partner with organizations such as the James River Park System Invasive Plant Task Force to better determine areas with significant invasive species issues and identify resources to deal with the problem.
	Partner with the public and other stakeholders, such as the Richmond Tree Stewards, to plant and maintain trees on public properties.

	Promote requests for stream restoration by private landowners and streamline the process by which these requests are addressed.
	Hire DPU staff member or assign 1 FTE to coordinate volunteers from corporate entities, watershed/environmental groups and public with partnership opportunities associated with the IP effort. Staff to enlist/maintain 6 partnerships per year.
	Hold 3 stakeholder meetings per year to continue communication with partners/stakeholders and add purpose to the IP effort.
	Evaluate partnership network in 5 years (at the end of the permit cycle) to assess gaps and identify new public/private partners.
	Partner with the public and other stakeholders to identify land to put in conservation easements.
	Partner with the Richmond Redevelopment and Housing Authority to identify homes/properties that are eligible for upgrades to water-efficient fixtures.
	Partner with upstream localities and Virginia Department of Health to update/maintain Source Water Protection Plan.
Maintenance	Include funding to support maintenance of newly replanted/restored riparian buffers (to ensure success of plantings, prevention of establishment of invasive species, etc.).
	Include funding to support maintenance of newly planted native plants and maintain newly established plantings where invasives have been removed from the landscape.
	Provide funding to support maintenance of trees on City property to ensure their survival and health.
Monitoring, Assessments & Planning	Inventory and map riparian areas to better understand loss or growth of riparian buffers.
	Inventory and map locations of trees and tree boxes to better understand loss or growth of tree coverage.
	Continue monitoring of 8 locations across the City for macroinvertebrate, habitat and in-stream water quality. Continue monitoring at 2 locations for flow. Evaluate opportunities to expand the flow monitoring network across the City.
	Evaluate the development of a monitoring data portal to facilitate sharing of data collected within the City with stakeholders and the public.
	Initiate monitoring work group in year one made up of technical stakeholders and other key groups/individuals to evaluate current monitoring efforts and identify potential efficiencies and additional monitoring needs moving forward.
	Evaluate potential for conducting pre- and post-construction monitoring of key stormwater BMPs.
	Conduct assessments of 4 stream segments across the 4 watershed groupings to support the development of watershed restoration plans to address pollutant sources and watershed stressors.
	Monitor growth/expansion of invasive species.
	Implement IDDE-related monitoring to support this effort – supported by a desktop analysis of high-risk dischargers.
Incentives/ credits	Reevaluate the stormwater credit program to determine potential to include practices such as replacing or restoring riparian buffers.
	Evaluate incentives/credits for purchasing/planting native species (such as Montgomery County, MD).
	Reevaluate the stormwater credit program to determine potential to include practices such as

	planting trees on private property. Provide 500 trees for planting on private property or equivalent incentives to purchase native trees.
	Offer grants to replace 20% of inefficient fixtures in moderate- to low-income units Evaluate expansion of incentive program to cover washing machines and dishwashers
Regulations/ ordinances/ codes	Evaluate expanding the regulatory buffer from 100 ft. to 200 ft.
	Evaluate inclusion of language in City zoning and planning-related ordinances to protect existing trees and add new trees on developed property.
	Adopt permitting standards for water-efficient appliances/fixtures in City code.
Outreach	Conduct outreach to educate the general public about the goals and objectives of RVAH2O, and the resources and services available through the City.
	Conduct outreach to advertise the resources, requirements and services available through the City related to green infrastructure for private property owners.
	Conduct outreach to advertise the resources, requirements and services available through City related to tree planting and maintenance.
	Promote ability to use grey water for toilet flushing as a way to achieve higher LEED standards
	Encourage and incentivize water capture and reuse for landscaping
	Promote water conservation for commercial, industrial and residential customers through efforts such as "Fix a Leak Week" and the City's Every Drop Counts initiative.
	Conduct targeted outreach to high-risk industries, particularly in areas of the City identified as hot spots.

6. Strategy Evaluation

Once strategies were drafted, an analysis was needed to determine which ones would be best for implementation. Figure 6.1 provides an overview of the multi-step strategy evaluation process that was used to make this determination. This process constrains proposed strategies by feasibility, relative achievement of goals/objectives, compliance with permit and regulatory drivers, and cost-related factors.

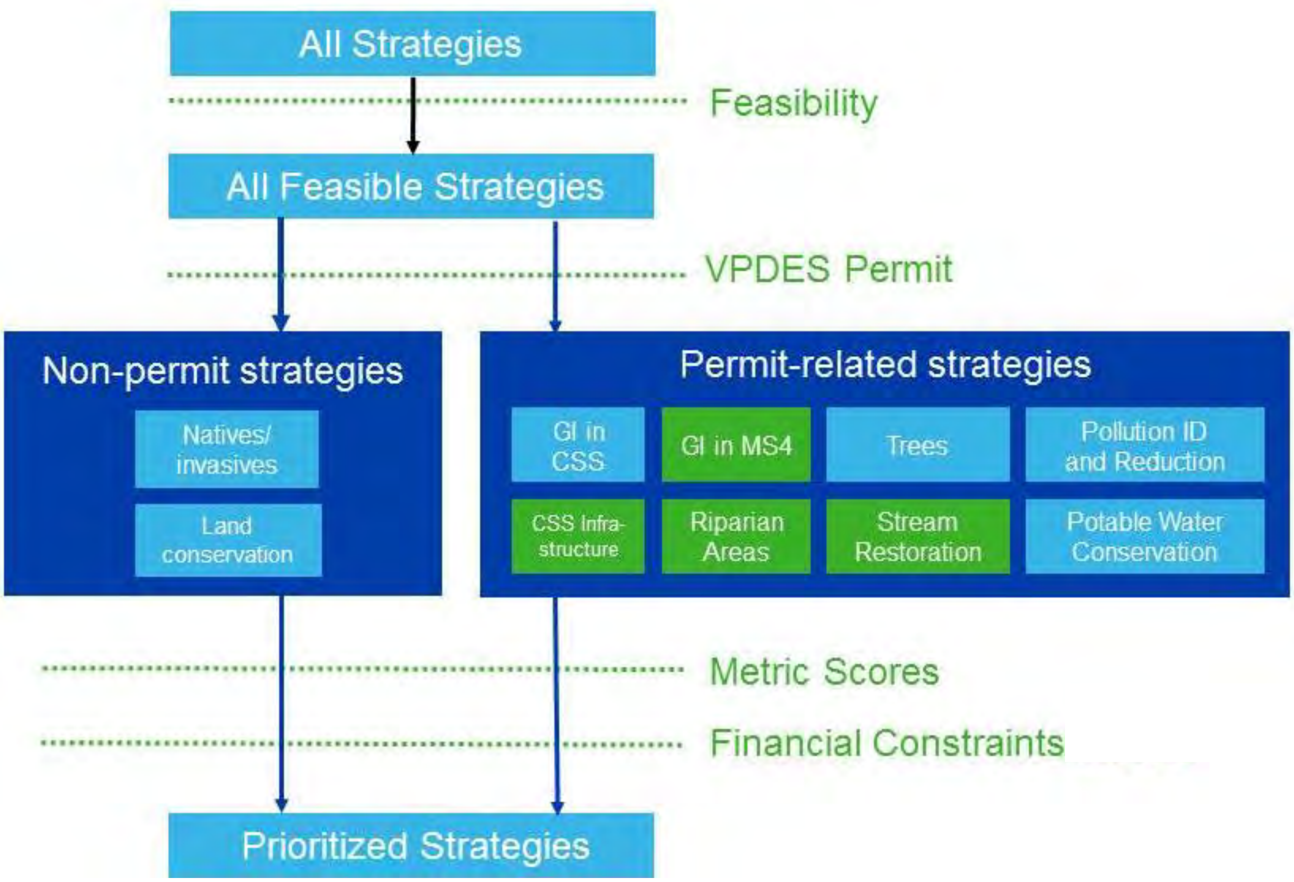


Figure 6.1. The process used for strategy evaluation

There are multiple factors at play that influence the selection of strategies. A strategy may do well with one factor, such as permit-related pollutant reductions, but not so well with others, like cost. As a result, the analysis of the various factors did not result in a clear and decisive outcome of one strategy that performed the best across all factors. What the strategy evaluation did determine was that all of the "pieces of the puzzle" needed to be evaluated collectively to achieve a complete picture of how well strategies achieve specific goals (Figure 6.2).

Figure 6.2. Puzzle piece conceptual model demonstrating how various factors fit together to inform the decision making process

Each of the "puzzle pieces" (other than Feasibility, which was discussed in Chapter 5) is discussed further below.

Strategy Scores

A comparison of the various strategies proposed through this stakeholder process was needed. To accomplish this, an Excel-based strategy scoring calculator was developed. This tool helped in the decision-making process by allowing the City and stakeholders to evaluate various alternatives by assigning scores to the alternative strategies.

The methodology used for this scoring calculator is a multi-objective decision analysis (MODA). Decision-making based on consideration of multiple goals/objectives and metrics is a widely documented research discipline. While referred to by a variety of terms in the literature, this decision-making approach is used to evaluate how well each of the alternative strategies (e.g., management practices, policy options) achieves a desired outcome (a decision-making problem, goal, etc.) through the use of metrics[7]. This approach also helps facilitate the involvement of diverse stakeholders by accounting for competing priorities and preferences in the decision-making process through inclusion of the weighting process (Saairkoski et. al. 2015).

Development of calculator-based strategy scores to support strategy evaluation includes the development of metrics that are tied to the goals/objectives. The development of these metrics is discussed below. Also discussed is how the analysis of individual metrics helped to answer specific questions related to strategy effectiveness. These metric-based strategy scores were then used in conjunction with other factors, like cost, to comprehensively evaluate strategies.

[7] There are a number of names for this approach in the literature, which share similar methodologies. These include: Multi-Criteria Decision Analysis, Multi Criteria Evaluation, Multi-Criteria Preference Analysis, Multi Objective Evaluation, Multi-attribute Decision Analysis, Multi-attribute Utility Analysis, etc.

Developing Metrics

An important component of strategy scoring is the development of metrics. While stakeholders and City staff dedicated significant time to the establishment of Integrated Planning goals and objectives, a standard of measurement was needed to evaluate how well the strategies achieved these goals and objectives and how well the strategies compared to one another.

Metrics:
Measurable properties by which efficiency, performance, or progress can be assessed

To accomplish this, a set of metrics was developed that includes a method of measurement. Table 4.2 provides examples of several metrics that were identified and how these are measured. Because metrics must be measureable, they are often quantitative. They may also be qualitative as long as there is a translation into a quantitative format. For instance, the "Stormwater Management Plan produced" in Table 6.1, is qualitative, but it is translated to a quantitative metric by incorporating a measuring scheme of a scale of 0 or 1.

Table 6.1 Example metrics and associated methods of measurement

Metric	Method of Measurement
Average yearly pollutant load reduction	Pounds of TN, TP, and TSS reduced Billion CFU of E.coli reduced
Percent increase towards meeting monthly geomean WQS compliance	Comparison of modeled E.coli concentration in the James River with the WQS standard
Riparian buffer restored/increased	Acres of riparian buffer
Partnerships implemented for Integrated Planning	Number of partnerships
Stormwater Management Plan produced	1=yes, 0=no
Amount of water conserved	Gallons

At least one metric was identified for each objective. An example is included in Table 6.2, which shows one of the Clean Water Planning goals. This goal includes several objectives (three of which are included here). Each objective is evaluated by at least one metric.

Table 6.2 Example of goal, objectives, metrics, and how metric is measured

Goal	Objectives	Metric	Measure of Metric
Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities	Restore streams to improve, restore, and enhance native ecological communities.	Streams restored	Feet (of stream restored)
		Reduce stormwater volume discharging to streams	Millions of gallons
		Riparian buffers restored and/or increased	Acres (of buffer restored)
	Identify, protect, and restore critical habitats.	Habitat protected or restored	Acres (protected or restored)
	Enhance aquatic and terrestrial habitat connectivity.	Habitat connected by green corridor	Acres (included in "green corridor")

Appendix C includes the complete list of the goals, objectives, metrics, and Appendix D (the Excel-based Strategy calculator tool, discussed below) also includes the raw scores that were identified for each strategy.

Raw Scores for Metrics

Each strategy was then given a raw score for each metric. Table 6.3 takes the example from Table 6.2 a step further and shows how a raw score is assigned to a metric. These scores can come from sources, such as the Integrated Plan model (e.g., number of extra days of bacteria compliance), from the literature (e.g., nitrogen reduced by an infiltration-based stormwater BMP), or from stakeholder input (e.g., number of acres of conservation easements that can be added).

Table 6.3. Example of how raw scores are assigned to each metric

	Riparian Areas Strategy	MS4 Green Infrastructure Strategy	Stream Restoration Strategy
Goal: Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities			
Objective: Restore streams to improve, restore, and enhance native ecological communities			
Metric: Streams restored (in feet)	0	0	2,500
Metric: Reduce stormwater volume discharging to streams (in millions of gallons)	3	30	0
Metric: Riparian buffers restored and/or increased (in acres)	10	0	6

Once the raw scores were input into the calculator tool they were normalized and weighted. Normalization was performed to account for the various units represented (acres, pounds, feet, etc.). The normalized, weighted scores for each of strategies were summed to produce one score for each strategy. These final scores allowed strategies to be compared to one another. The calculator tool (in

Appendix D) includes all of the formulas necessary for one to understand how these final scores are developed. Additionally, a call-out box on page 53, explains the concept of normalization further.

Strategy Analysis

As discussed above, there are multiple "puzzle pieces", or factors, that were taken into consideration in the analysis of strategies (Figure 6.2). The **Permit** puzzle piece represents the VPDES permit-related requirements that establish pollutant reduction targets by which the strategies were compared.

The Strategy Score "puzzle piece" involved using the calculator tool to evaluate **strategy scores** in several different ways. These analyses included evaluating:

- Permit-related metrics – metrics that related to total Nitrogen (TN), total Phosphorus (TP), total suspended solids (TSS) and bacteria were isolated in the calculator and scores associated with just these metrics were used to evaluate the effectiveness of strategies in reducing these pollutants of concern
- Standardization of strategies addressing permit-related metrics – strategies, which varied in size, were all standardized to 10 acres to compare these permit-related metrics in an "apples to apples" manner
- All metrics – including the full set of metrics associated with all of the objectives in addition to the pollutant-related metrics
- Standardization of all metrics – comparing how the same sized strategies (all 10 acres) address all metrics

The calculator tool was also tied to the **Strategy Cost** information. Metrics specific to pollutant reductions (e.g., pounds of pollutant removed by a strategy) were used to calculate Cost Effectiveness. Overall, strategy costs were then evaluated in association with Affordability.

Another puzzle piece, **Modeling Results**, provided the bacteria reductions associated with several strategies that were used as raw score inputs into the calculator. Modeling results also provided information pertaining to the relative nature of bacteria sources to the James River and tributaries.

Each of these specific analyses is discussed in more detail below.

The Permit

Establishing Targets

Stakeholders and City staff have dedicated significant time to the establishment of Integrated Planning goals and objectives as well as strategies to help ensure these are achieved. While stakeholder concerns ranging from pollutant reduction to habitat restoration and invasive species removal are all considered in the Clean Water Plan, it is essential to remember that there are VPDES permit-related requirements that must be addressed and therefore, these requirements are key drivers behind the Plan. Therefore, it is important to understand that these VPDES permit requirements are water quality-focused and this permit-driven approach inherently prioritizes efforts that help improve water quality in Richmond's waters. Determining the extent to which water quality needs to be improved and the targets that help guide these improvements is a key step in the strategy analysis. Once these targets are determined, the next step is to evaluate how the strategies themselves help the City best (efficiently and effectively) achieve these targets.

One pollutant the City must work toward reducing is bacteria. Table 6.4 includes the existing bacteria (*E.coli*) loads and the allowable pollutant loading (the Waste Load Allocation, or WLA) for the City's MS4 (as documented in the Bacteria TMDL Action Plan based upon the James River Bacteria TMDL) and for the CSO/WWTP discharges (as documented in the James River Bacteria TMDL). These loads and the WLAs are summed in this table to provide an overall bacteria reduction by watershed addressed by the TMDL.

Table 6.4. E.coli Bacteria reduction requirements for Richmond's WWTP/CSS and MS4 systems

	MS4			WWTP			CSO		
	Existing Load	WLA	Load Reduction Target	Existing Load	WLA	Load Reduction Target	Existing Load	WLA	Load Reduction Target
Bacteria (BCFU)	606,312	221,842	384,470	6,792	444,000	(437,208)	16,511,684	3,025,710	13,485,974

What Table 6.4 shows is that the MS4 and CSOs in particular are still the biggest sources of bacteria and will drive additional reductions. The WWTP is reducing bacteria efficiently. The existing bacteria load from the plant, therefore, is far below the WLA, which produces a "credit" for bacteria (this negative number is denoted by parenthesis around the load reduction target).

The City also has total Nitrogen (TN), total Phosphorus (TP), and total suspended solids (TSS) pollutant loading reduction targets driven by the Chesapeake Bay TMDL. TN and TP reductions are also reflected in the VPDES Watershed General Permit for Nutrient Discharges to the Chesapeake Bay. Table 6.5 identifies the WLA and reduction goals associated with the City's WWTP and its CSOs as well as with its MS4 program.

Table 6.5. TN, TP, and TSS reduction requirements for Richmond's WWTP/CSS and MS4 systems

	MS4			WWTP			CSO		
	Existing Load	Waste Load Allocation	Load Reduction Target	Existing Load	Waste Load Allocation	Load Reduction Target	Existing Load	Waste Load Allocation	Load Reduction Target
TN (lbs)	166,955	154,901	12,054	338,328	1,093,652	(755,324)	141,759	409,557	(267,798)
TP (lbs)	19,813	17,262	2,550	29,411	55,754	(26,343)	17,720	31,642	(13,922)
TSS (lbs)	6,327,579	5,223,204	1,104,375	361,031	847,754	(486,723)	2,303,581	3,396,550	(1,092,969)

Table 6.5 shows that the WWTP is very efficient in reducing these pollutants and resulting load reduction targets for Nitrogen, Phosphorus, and sediment are not only met, but exceeded.

As will be discussed in further in Chapter 9, the intent of the watershed-based integrated VPDES permit is to look at the City's source sectors collectively to determine greatest impacts. In an effort to do this, bacteria, nutrient and sediment targets for the MS4, WWTP, and CSOs are aggregated (Table 6.6).

Table 6.6. Aggregated annual load reduction targets

	Waste Load Allocation	Existing Load	Load Reduction Target
TN (lbs)	1,658,110	647,042	(1,011,068)
TP (lbs)	104,658	66,943	(37,715)
TSS (lbs)	9,467,508	8,992,191	(475,317)
Bacteria (BCFU)	3,691,552	17,124,789	13,433,236

These aggregated annual load reduction targets reflect the effectiveness of the WWTP in reducing nutrients and sediment in general. While this Clean Water Plan will still continue to emphasize additional reductions of these pollutants in the MS4 and its impacts to tributaries in particular, this information helps inform DPU as to where its most significant pollutant reductions are needed. This information will be taken into consideration in the following analyses and how this influences strategy prioritization.

Strategy Scores

Permit-Related Metrics

Permit-related metrics are defined as those that address TN, TP, TSS, or bacteria (the pollutants of concern). Through the population of the Excel-based strategy scoring calculator, each strategy was evaluated to determine what amount of, if any, pollutant reduction was achieved. Table 6.7 includes the strategies that are expected to result in reductions in permit-targeted pollutants associated with the Chesapeake Bay TMDL (TN, TP, and TSS) and bacteria TMDL (for compliance with recreational water quality standards). The values in Table 6.7 are excerpted from the strategy scoring calculator. How well each of these strategies addresses these pollutants is also conveyed in this table by color coding the cells based on the strategies that best address these pollutants of concern:

- **Green** – address all pollutants of concern (light green addresses fewer metrics)
- **Orange** – Address nutrients and sediments, but not bacteria
- **Red** – don't address any pollutants of concern, but can be used as supplemental strategies that can be incorporated as appropriate and as resources and opportunities allow

*Table 6.7. How strategies address pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID	CSOs / WWTP Infrastructure
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).										
Average yearly TN load reduction (lbs)	19	414	74	188	0	30	0	11	448	7,066
Average yearly TP load reduction (lbs)	4	90	16	170	0	4	0	1	162	903
Average yearly TSS load reduction (lbs)	1,081	42,397	7,393	75,013	0	447	0	422	57,893	116,843
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).										
Percent increase in monthly geomean WQS compliance	0	0	0	0	0	0	0	0	0	11
Average yearly E.coli load reduction (billion cfu)	83	3,531	40,642	0	0	0	0	0	0	3,551,112
Average yearly reduction in CSO events (number)	0	0	0	0	0	0	0	0	0	1
Average yearly reduction in CSO volume discharged (million gallons)	0	0	5	0	0	0	0	0	0	962

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)

The results of this comparison show the following:

- Strategies that address all pollutants including TN, TP, TSS and bacteria
    - CSO/WWTP Infrastructure
    - Green Infrastructure (in the MS4/CSS areas)
    - Riparian Areas
- Strategies that address TN, TP, TSS, but not bacteria
    - Stream restoration
    - Trees
    - Water conservation
    - Pollution identification

Additionally, strategies that can be implemented, but do not help achieve permit requirements include:

- Native/invasives
- Land conservation

The "raw" scores in Table 6.7 were then normalized and weighted (additional information on these processes is included on the call-out box on the following page). These values are included in Table 6.8.

*Table 6.8. Normalized and weighted scores of strategies in addressing pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID	CSOs / WWTP Infrastructure
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).										
Average yearly TN load reduction (lbs)	0.3**	6.8	1.2	3.1	0.0	0.5	0.0	0.2	7.4	116.0
Average yearly TP load reduction (lbs)	0.5	11.6	2.0	21.8	0.0	0.5	0.0	0.2	20.9	116.0
Average yearly TSS load reduction (lbs)	1.1	42.1	7.3	74.5	0.0	0.4	0.0	0.4	57.5	116.0
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).										
Percent increase in monthly geomean WQS compliance	0.0	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Ave. yearly E.coli load reduction (billion cfu)	0.0	0.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Average yearly reduction in CSO events (number)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Average yearly reduction in CSO volume discharged (million gallons)	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	87.0
Score	1.9	61.4	12.9	99.4	0.0	1.5	0.0	0.8	85.7	696.2
Rank	**6**	**4**	**5**	**2**	**9**	**7**	**9**	**8**	**3**	**1**

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)

** All scores multiplied by 100 for clarification purposes. Total score may be off due to rounding.

Normalizing & Weighting Scores

The intent of the strategy scoring process is to produce a value that demonstrates how well each strategy addresses the metrics of interest. The metrics used to evaluate the strategies; however, can vary in the way they are measured (e.g., pounds of total Nitrogen reduced, acres of impervious surface treated, etc.). Because of the varying units represented, raw scores cannot simply be added together to obtain a score for each strategy. A normalization process is required to adjust these raw scores to a common scale.

To accomplish the normalization process, the raw score is divided by the maximum of the raw scores associated with that particular metric. In the example below, each of the numbers in the red box would be divided by 7,066 to produce the associated normalized scores for this metric.

Additionally, because the metrics may not all be of equal importance, various weights were also applied to them. In the example below TN reduction was considered most important and given a higher weight (50%) than the other metrics. Normalized scores are multiplied by the associated weight to produce a final weighted, normalized score. In the example below, each of the normalized scores in the orange box is multiplied by 50% to produce the associated values in the green box. A strategy's weighted, normalized scores are added together to produce a final score for that strategy. In the example below, Strategy B, with a score of 30, best achieves these four metrics.

Example scoring process

		Raw Scores			Normalized Scores			Weighted, Normalized Scores		
	Weight	Strategy A	Strategy B	Strategy C	Strategy A	Strategy B	Strategy C	Strategy A	Strategy B	Strategy C
Average yearly TN load reduction (lbs)	50%	19	11	7,066	0.003	0.002	1.0	0	0	1.2
Average yearly E. coli load reduction (BCFU)	20%	83	0	3,551,112	0	0	1	0	0	0.9
Impervious Surface reduced or treated (acres)	15%	2	5	0	0.4	1	0	6	15	0
Potable water consumption reduced (gallons)	15%	0	0	250	0	1.0	0	0	15	0
Total	100%							6	30	2.1

The normalized, weighted scores for each strategy are summed, which results in a final score for the strategy. The top ranked strategies for achieving key pollutant reduction include:

1. CSO/WWTP Infrastructure
2. Stream Restoration
3. Pollution Identification
4. GI in MS4

“Standardization” of Permit-Driven Metrics

As previously stated, the numeric targets of the strategies were based on the amount of DPU/PRCF land/resources available for that particular strategy. As a result, each strategy addresses a different amount of area (e.g., 10 acres of land for riparian area restoration vs. 104 acres of land in the MS4 for implementation of green infrastructure, etc.). To evaluate strategies in a “standardized” manner (all strategies being comparable in size to one another in an “apples to apples” manner), strategies were evaluated as if they would be implemented on 10 acres of land (Table 6.9).

It is important to note that the CSO/WWTP strategy is based on reducing the combined sewer overflow volume and frequency, which is not based on acreage of implementation. As such, this strategy cannot be standardized in this way and is not included in the analysis reflected in Table 6.9.

*Table 6.9. How "standardized" strategies address pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).									
Average yearly TN load reduction (lbs)	19	40	41	327	0	4	0	22	1
Average yearly TP load reduction (lbs)	4	9	9	296	0	4	0	1	0
Average yearly TSS load reduction (lbs)	1,081	4,077	4,107	130,702	0	56	0	845	341
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).									
Percent increase in monthly geomean WQS compliance	0	0	0	0	0	0	0	0	0
Average yearly E.coli load reduction (billion cfu)	83	340	22,579	0	0	0	0	0	0
Average yearly reduction in CSO events (number)	0	0	0	0	0	0	0	0	0
Average yearly reduction in CSO volume discharged (million gallons)	0	0	3	0	0	0	0	0	0

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)

Table 6.10 shows the normalized, weighted scores for these strategies standardized across 10 acres. Again, note that the CSO/WWTP strategy is not included in Table 6.10 as it cannot be standardized across 10 acres of land.

*Table 6.10. Standardized strategies that have been normalized and weighted for pollutants of concern**

	Riparian areas	GI in MS4	GI in CSS	Stream restoration	Natives/ invasives	Trees	Land conservation	Water conservation	Pollution ID
Objective: Reduce nitrogen, phosphorus, and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).									
Average yearly TN load reduction (lbs)	6.6	14.1	14.7	116.0	0.0	1.4	0.0	8.0	0.5
Average yearly TP load reduction (lbs)	1.5	2.8	3.0	116.0	0.0	0.2	0.0	1.1	0.0
Average yearly TSS load reduction (lbs)	1.0	2.4	2.5	116.0	0.0	0.0	0.0	0.8	0.3
Objective: Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).									
Percent increase in monthly geomean WQS compliance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ave. yearly E.coli load reduction (billion cfu)	0.3	1.3	87	0.0	0.0	0.0	0.0	0.0	0.0
Average yearly reduction in CSO events (number)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Average yearly reduction in CSO volume discharged (million gallons)	0.0	0.0	87.0	0.0	0.0	0.0	0.0	0.0	0.0
Score	9.4	22.5	195.8	348	0	1.6	0	9.9	0.8
Rank	**5**	**3**	**2**	**1**	**8**	**6**	**8**	**4**	**7**

*(Associated with the goal: Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.)

** All scores multiplied by 100 for clarification purposes

All Metrics

While evaluating key permit related pollutants is important, numerous other metrics were also identified for other goals and objectives (Appendix C). Table 6.11 shows the score (obtained from the strategy scoring calculator) for each strategy that takes all of the metrics collectively into consideration.

Table 6.11 – Scores and ranks of all feasible strategies – total acres/resources available

	Riparian	GI in MS4	GI in CSS	Stream Restoration	Natives/ Invasives	Trees	Land Conservation	Water Conservation	Pollution ID	CSO/ WWTP
Scores	54.90	57.53	39.88	47.82	43.10	44.80	42.02	45.00	35.29	46.22
Rank	2	1	9	3	7	6	8	5	10	4

The results of the scoring process (including all metrics and strategies) results in the following ranking of strategies:

1. Green Infrastructure in the MS4
2. Riparian Area Restoration
3. Stream Restoration
4. CSO/WWTP Infrastructure

"Standardization" of All Metrics

While these available acreages are very important for future implementation purposes, a "standardized" comparison of the strategies with regard to all other metrics was also performed. Again, this analysis assumed 10 acres of implementation for each of the strategies and, as discussed above, the CSO/WWTP strategy was not included in this standardized analysis as it cannot be evaluated on a 10-acre basis. The CSO/WWTP strategy is therefore evaluated separately below. Table 6.12 shows the scoring of the strategies if all were implemented on the same amount of acreage.

Table 6.12 – Scores and ranks of feasible strategies – 10 acres for each strategy

	Riparian	GI in MS4	GI in CSS	Stream Restoration	Natives/ Invasives	Trees	Land Conservation	Water Conservation	Pollution ID
Scores	66.87	55.46	57.67	67.74	44.44	43.83	46.49	56.33	36.27
Rank	2	5	3	1	7	8	6	4	9

The results of these scores produce in the following top-ranked strategies:

1. Stream Restoration
2. Riparian Area Restoration
3. Green Infrastructure in the CSS area
4. Water Conservation

Evaluation of CSS Infrastructure Projects

The CSS Infrastructure strategy was evaluated in previous sections as a whole, but this strategy consist of several different projects outlined in the LTCP, including:

- Installing wet weather interceptor in Lower Gillies to convey more flow to the WWTP
- Increasing WWT (wet weather treatment) at the WWTP to 300 MGD and expanding secondary treatment at the WWTP to 85 MGD
- Replacement of CSO 021 regulator and additional 2MG storage at CSO 021
- Expanding Shockoe retention basin by 15 MG to capture more overflow
- Disinfecting overflow at Shockoe retention basin (wet weather disinfection facility)

Each project was evaluated in isolation to determine individual impact on bacteria load reduction. These CSS "scenarios" are summarized in Table 6.13, below.

Table 6.13. Description of CSS Projects Evaluated by the Water Quality Model

CSS Scenario	CSS Project Name	CSS Project Description
Existing	Existing Conditions	Existing sewer conditions, including all LTCP Phase I and Phase II projects.
14-3	Baseline Conditions	Includes the currently funded projects: --CSO 028A & 028E disconnection --WWTP wet weather treatment up to 140 MGD
14-2	Gillies Conveyance	Lower Gillies Wet Weather Conveyance Interceptor to convey more flow to the WWTP
15-4	300 MGD Wet Weather Treatment	WWTP wet weather treatment up to 300 MGD
15-5	CSO 21 Replacement	Replacement of the CSO 21 regulator and additional 2MG storage
18-4	SRB Expansion	Shockoe retention basin (SRB) expansion to 15MG
18-5	SRB Expansion and Disinfection	SRB Expansion to 15MG and chlorine disinfection of the SRB discharge at CSO 06
19-3A	Full LTCP	All 10 Phase III projects, Full LTCP achieved.

Bacteria load reductions from each CSS scenario is shown in Figure 6.4, below.

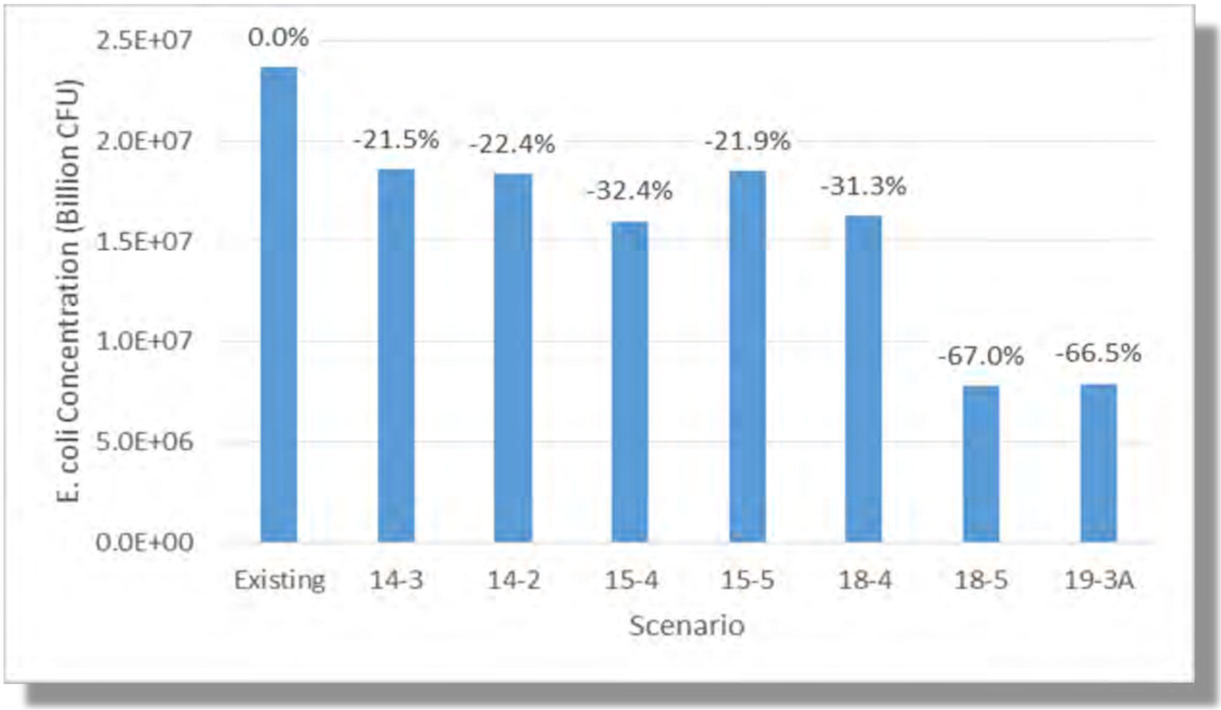


Figure 6.4 Bacteria load reductions from each CSS Infrastructure Project

Additional new projects, or variations to the existing projects, are currently being evaluated to determine if these alternative projects could accomplish similar or greater bacteria load reductions compared to the existing projects, and if this could be done in a more cost efficient way. Those alternative evaluations are currently ongoing, and include projects such as controlling discharge from CSO-040 and other combined sewer outfalls, and different types of disinfection for wet weather treatment at the wastewater treatment plant and at Shockoe retention basin.

Comparison of Targets with Load Reductions

The aim of the Integrated VPDES permit is to more efficiently control the discharge of pollutants from all DPU sources. In order to do this, it is necessary to look at the ultimate targets and all the sources together and assess where it is possible to get the greatest gains. It is also important to recognize not all pollutants will be assessed in the same way, different pollutants have different impacts. Some pollutants have far field effects and can be assessed based upon total load delivered while others must be looked at based on localized effects. For instance, an aggregate approach can be done for TN, TP, and TSS because the TMDL allows the targets to be assessed for the City as a whole to ultimately achieve improvements downstream to the Chesapeake Bay. The bacteria numbers can also be aggregated to show the overall scale of needed reductions, but it must be remembered that bacteria allocations exist for specific watersheds, and those need to be met at the local scale, rather than at the aggregate scale. These aggregated targets are depicted in Table 6.14.

Table 6.14. Aggregated Annual Load Reduction Targets

	Existing Load	Waste Load Allocation	Load Reduction Target
TN (lbs)	647,042	1,658,110	(1,011,068)
TP (lbs)	66,943	104,658	(37,715)
TSS (lbs)	8,992,191	9,467,508	(475,317)
Bacteria (BCFU)	17,124,789	3,691,552	**13,433,236**

While Table 6.14 shows (on an aggregated scale) targets for TN, TP, TSS are already met, bacteria still needs additional reductions in order to meet targets. These targets can be compared to the load reductions achieved by the strategies, shown previously in Table 6.6.

Costs

Financial constraints referred to in Figure 6.1 include the costs of the strategies and supporting actions and cost effectiveness of these strategies. Affordability is considered the overarching mechanism within which these elements can be paid for in an affordable manner by DPU. Each of these factors is discussed in more detail below.

Strategy Costs

The cost associated with the full implementation of the strategies included in Table 5.1 was also estimated (Table 6.15). For the purpose of estimating costs most consistently across strategies, the assumption was that the strategy would be implemented in the first year of the permit (capital costs) with maintenance being required for the strategy in years two through five of the permit.

Table 6.15. Cost of main strategies broken out by capital and maintenance

Main Strategy	Capital	O&M	Total
Riparian Areas	$900,000	$200,000	$1,100,000
Green Infrastructure in the MS4	$10,500,000	$2,000,000	$12,500,000
Green Infrastructure in the CSS	$2,600,000	$750,000	$3,350,000
Stream Restoration	$1,700,000	$1,200,000	$2,900,000
Native/ Invasives	$70,000	$95,000	$165,000
Trees	$1,600,000	$600,000	$2,200,000
Land Conservation	$ -	$ -	$ -
Water Conservation	$220,000	$ 50,000	$270,000
Pollution Identification & Reduction[8]	$16,385,000	$ -	$16,385,000
CSO Infrastructure[9]	$374,800,000	$17,400,000	$392,200,000
Total	**$408,775,000**	**$22,295,000**	**$431,070,000**

The cost of additional supporting actions was also estimated in Table 6.16.

[8] As street sweeping and catch basin clean-outs are ongoing efforts for the City, these activities are calculated for each of the five years of the permit.

[9] Note that the cost for the CSO Infrastructure strategy is over 30 years, while the costs of the other nine strategies are over five years.

Table 6.16. Cost of supporting actions

Supporting Actions	
Partnerships	$700,000
Monitoring, Assessments & Planning	$1,300,000
Incentives/ Credits	$1,250,000
Regs/ Ordinance/ Code	$ -
Outreach	$500,000
Total	**$ 3,750,000**

The source of all cost information as well as any assumptions that were made in association with the calculation of final cost estimates is discussed further in Appendix E.

Cost Effectiveness

While cost is important from the perspective of how it can be achieved within a certain budget, cost effectiveness of a particular strategy can be more informative because it provides an indication of the return on the investment. Cost effectiveness was evaluated for each strategy for the permit-driven metrics (TN, TP, TSS, bacteria) discussed above, and expressed as cost per unit pollutant removed. Cost effectiveness comparisons in Table 6.17 are also based on the strategies that included the fill size/acreage/ resources (again it should be noted that the Natives & Invasives strategy and the Land Conservation strategy are not included in this table because neither, as they are written, results in the reduction of these key pollutants).

Table 6.17. Pollutant reduction and associated cost effectiveness of strategies

	Riparian areas	GI in MS4	GI in CSO	Stream restoration	Trees	Water conservation	Pollution Identification	CSOs / WWTP Infrastructure
Average yearly TN load reduction (lbs)	19	414	74	188	30	11	448	7,066
Average yearly TP load reduction (lbs)	4	90	16	170	4	1	162	903
Average yearly TSS load reduction (lbs)	1,081	42,397	7,393	75,013	447	422	57,893	116,843
Average yearly E.coli load reduction (billion cfu)	83	3,531	40,642	0	0	0	0	3,551,112
Cost	$1,100,000	$12,500,000	$3,350,000	$2,900,000	$2,200,000	$270,000	$16,385,000	$392,200,000
Cost per pound TN removed	$58,902	$30,181	$45,270	$15,467	$72,158	$24,092	$36,597	$55,507
Cost per pound TP removed	$292,553	$138,687	$209,375	$17,059	$520,833	$195,744	$100,882	$434,293
Cost per pound TSS removed	$1,017	$295	$453	$39	$4,925	$639	$284	$3,357
Cost per billion E.coli removed	$13,190	$3,540	$82	--	--	--	--	$110

The green highlighted items in Table 6.17 identify those strategies that are most cost effective for the various pollutants.

Affordability

The intent of the Clean Water Planning process is to make sure that each dollar spent gets the greatest environmental benefit. While this is important to rate payers in general, it is additionally important because the City already has a large number of people who are below the poverty line and currently can't afford their utility bills. So, while the City was evaluating ways to make smart water quality decisions, it was also looking for ways to keep rates affordable.

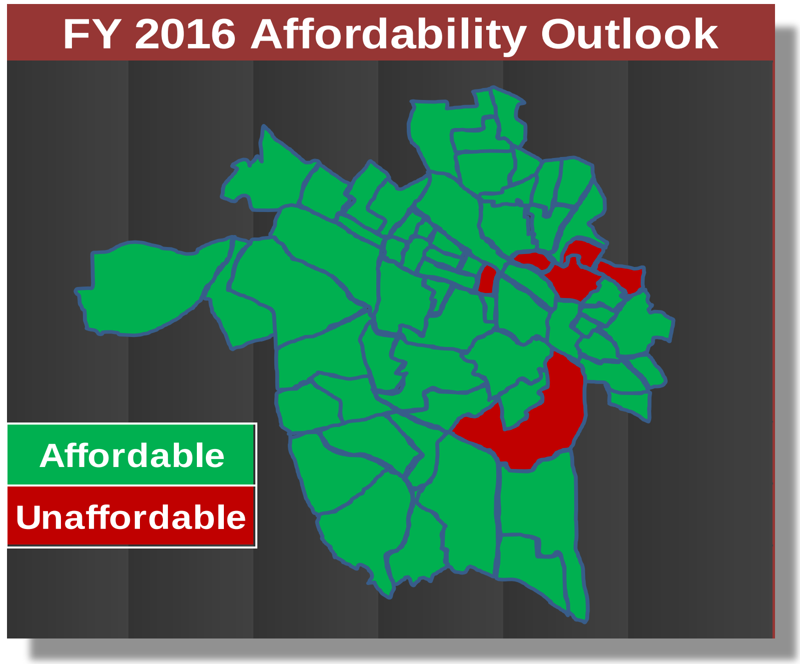


Figure 6.2 With current rates, those census tracks that cannot afford utility rates in 2016

While developing its Integrated Plan, DPU analyzed the impact annual spending would have on rates over time, and subsequently customer bills. This analysis was done to define and measure affordability, so that unaffordable bills and financial impacts can be mitigated to the greatest degree on an annual basis.

To accomplish this, DPU evaluated customer impacts on a localized level (at the census track level shown here) throughout the City by measuring bill impacts against various affordability and income metrics, like "living wages".

The results of this affordability analysis are summarized in Figure 6.2, demonstrating where rates are unaffordable by census tract. Between 2016 and 2045, the financial model shows the situation would get much worse (assuming rate increases remain at their current pace and economic conditions remain constant).

What this also shows is that if the City continues to attempt to comply with various water quality regulations with the "do everything, everywhere simultaneously" approach this is the probable outcome. Alternatively, the Clean Water Plan focuses strategic decisions for cleaner water faster, but in a more affordable way.

The budget within which strategies will be implemented within the Clean Water Planning effort have been set, or constrained, by affordability. It is important to note that a high cost of a given strategy may not take it off the table, but simply require it to be implemented over time or other strategies are prioritized ahead of it.

Strategy Prioritization

The various "pieces of the puzzle", discussed above, were used to understand how to best prioritize activities for implementation. As each of these analyses tells only a piece of the story, it is important to look at these analyses collectively. What these analyses have shown is that no one strategy consistently scores the highest or performed the best across the analyses, however, several strategies consistently performed well (a summary of the analyses are included in Table 6.18; green highlighted information depicts those that consistently score highest).

To allow for the consideration of multiple factors in determining priorities, it was determined that rather than ranking 10 strategies individually, that strategies would be grouped into one of three tiers based on effectiveness (Figure 6.3). Tier 1 includes those strategies that best address metrics associated with the pollutants of concern (TN, TP, TSS, bacteria) as well as the non-pollutant related metrics. These strategies were also the most cost effective. Tier 2 also addressed pollutant and non-pollutant related metrics, but not as efficiently or cost effectively as those in the Tier 1 grouping. Tier 3 includes those strategies that do not address the pollutants of concern.

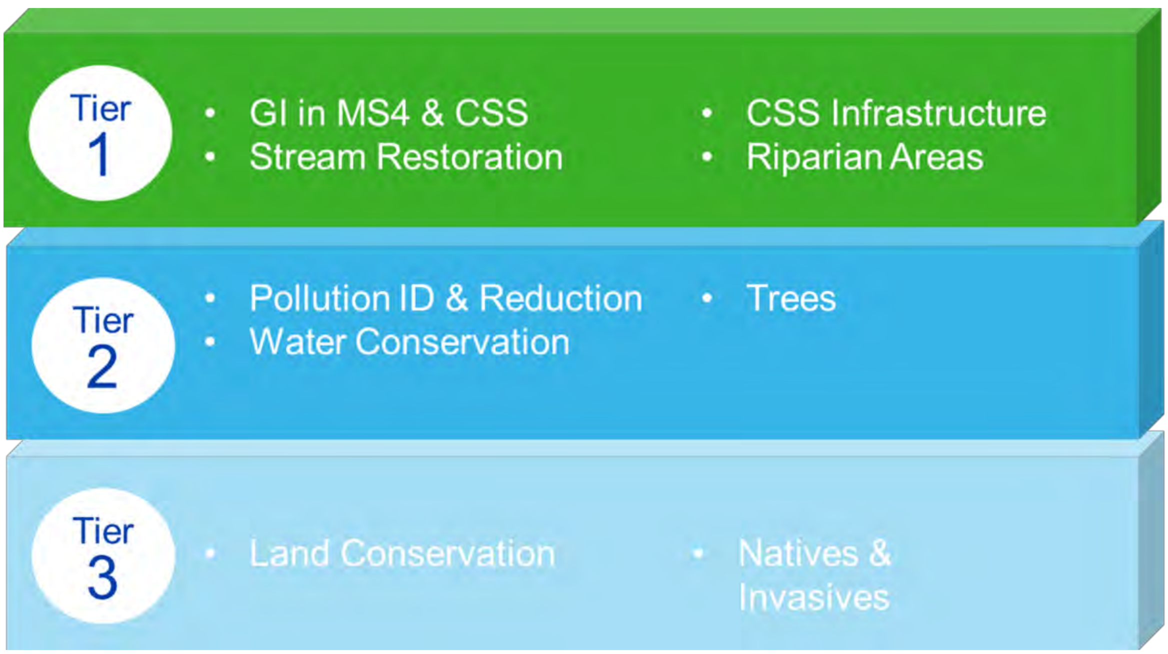


Figure 6.3. Organization of strategies into tiers for prioritization

It is important to note that while select strategies may be *prioritized* it does not mean that the remaining strategies will be disregarded. Implementation of these strategies will be assessed based on additional resources available to DPU or priorities and resources available from other City departments or other partners.

It is also important to note that this analysis was done at a high level. As DPU moves toward implementation and conducts a more refined evaluation of strategies, there may be modifications to this prioritization. For instance, the Green Infrastructure strategy includes bioretention, green roofs, permeable pavement, engineered tree boxes, rain barrels, and stormwater pond retrofits. If other green infrastructure practices are identified as alternatives, details, such as cost, amount of pollutant reduction, and how the practices achieves other metrics, will all be taken into consideration.

Table 6.18 Summary of Strategy Analysis and Strategy Prioritization

Rank	Pollutants of Concern Metrics	Pollutants of Concern Metrics: Standardized*	All Metrics	All Metrics: Standardized*	Cost Effectiveness (TN)	Cost Effectiveness (TP)	Cost Effectiveness (TSS)	Cost Effectiveness (bacteria)
1	**CSO Infrastructure**	**Stream restoration**	**GI in MS4**	**Stream restoration**	**Stream restoration**	**Stream restoration**	**Stream restoration**	**GI in CSS**
2	**Stream restoration**	**GI in CSS**	**Riparian areas**	**Riparian areas**	Water conservation	Pollution ID and reduction	Pollution ID & reduction	**CSO Infrastructure**
3	Pollution ID & reduction	**GI in MS4**	**Stream restoration**	**GI in the CSS**	**GI in MS4**	**GI in MS4**	**GI in MS4**	**GI in MS4**
4	**GI in MS4**	Water conservation	**CSO Infrastructure**	Water Conservation	Pollution Identification	Water conservation	**GI in CSS**	**Riparian areas**
5	**GI in CSS**	**Riparian areas**	Water Conservation	**GI in MS4**	**GI in CSS**	**GI in CSS**	Water conservation	Water conservation
6	**Riparian areas**	Trees	Trees	Land Conservation	**CSO Infrastructure**	**Riparian areas**	**Riparian areas**	
7	Trees	Pollution ID & reduction	Natives/ invasives	Natives/ invasives	**Riparian areas**	**CSO Infrastructure**	**CSO Infrastructure**	
8	Water Conservation	Natives / invasives	Land Conservation	Trees	Trees	Trees	Trees	
9	Natives/ invasives	Land Conservation	**GI in the CSS**	Pollution Identification				
10	Land Conservation		Pollution ID and reduction					

*WWTP/CSO strategy cannot be evaluated on a 10-acre basis so it is not included herein

7. Implementation Program

As discussed in Chapter 5, high-level strategies to achieve goals and objectives were developed to include quantifiable targets that DPU can work towards implementing (e.g., 10 acres of riparian buffer restoration, implementation of 104 acres of green infrastructure in the MS4 area of the City, etc.). An important part of this Clean Water Plan is developing an approach that can help the City implement these strategies in the most efficient and cost effective manner possible.

Framework Planning

In order to most efficiently and effectively implement its IWPM Plan, DPU will use a "Framework Planning" approach. The Framework Planning approach provides a methodology that ties together different strategies (and, subsequently, site-specific projects) and, where possible, aligns these strategies with other City or stakeholder-driven initiatives.

This Framework Planning approach is intended to be:

- A comprehensive and action-oriented blueprint for near- and long-range decision making
- A planning guide for the implementation of a set of strategies and serves to create a "framework" around multiple other efforts (e.g. Master Plan, guidelines for new/existing development, other City planning efforts, etc.) to guide planning in a cohesive way
- Designed for flexibility and choices that will enable different entities (City Departments, partners, etc.) to act both collaboratively and independently, over different periods of time, but in a coordinated way

The goal of the Framework Planning approach is to identify and sequence a blend of activities that yield the greatest environmental benefit (as measured by identified metrics) in the most cost-effective (and affordable) manner.

Framework Planning Process

As discussed in previous chapters, the Clean Water Planning process involved the development of goals and objectives, and high-level strategies that could meet these goals and objectives. For implementation purposes, these strategies will be translated into projects (e.g., 104 acres for the Green Infrastructure in the MS4 strategy could be implemented as 50 engineered tree boxes, 10 acres of permeable pavers, etc., which will, in total, drain 104 acres).

As depicted in Figure 7.1, strategies are prioritized (into Tiers, as discussed in Chapter 6) (#1), but they are still disparate strategies (#2). An example is the Green Infrastructure in the MS4 area strategy (which targeted 104 acres, 44 acres of which were estimated to include bioretention). Assuming each of these bioretention facilities drains one acre, 44 facilities would then be implemented across the City's MS4 area. Implementing these facilities in a piecemeal approach would still meet the target of implementing 44 acres and would still achieve pollutant load reductions estimated for these facilities.

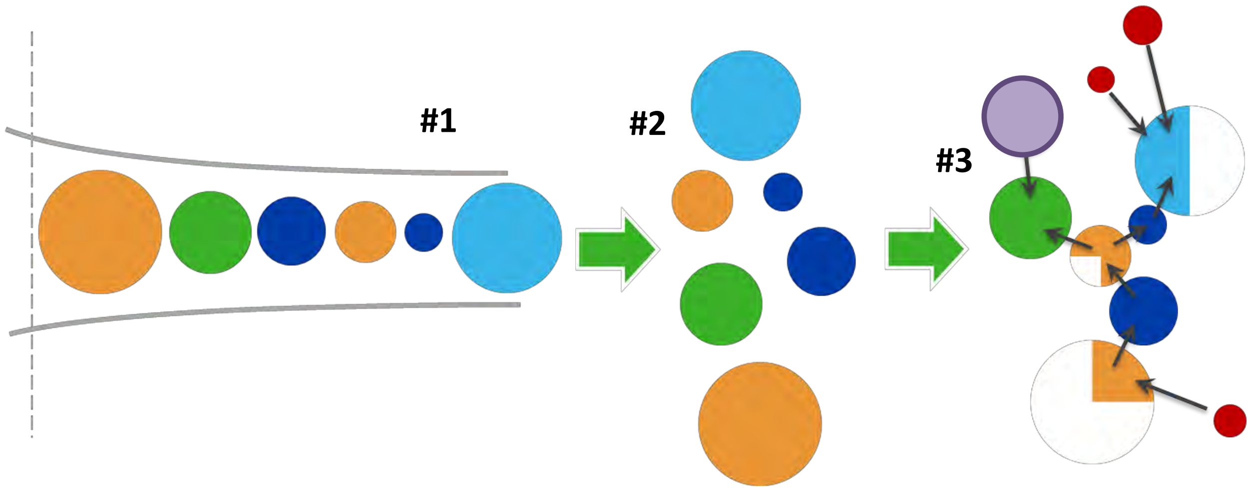


Figure 7.1 Framework Planning includes the interface of various elements together in the landscape in a way that makes the most sense for implementation.

Alternatively, DPU and its stakeholders can look collectively at the City for not only where the opportunities are for implementing bioretention, but where these practices can be implemented within the context of a more comprehensive planning and coordination effort under a Framework Planning umbrella. This Framework Planning process provides the structure for implementation of strategies/projects in a more integrated and cohesive way by leveraging opportunities with other city-led projects such as, for example, Richmond's Riverfront Plan, or stakeholder efforts such as, for example, EnRichmond's tree planting efforts (shown with the red and purple circles in Figure 7.1, #3). The Framework Planning process may also lead to the identification of new ideas and opportunities that can be pushed forward by DPU itself.

While DPU recognizes that some implementation may need to occur in a piecemeal fashion, its goal, where feasible, is that Framework Planning will drive implementation of the strategies. Framework Planning will meet the objectives and goals of the Clean Water Plan, while at the same time supporting and leveraging the overall growth and planning at the City or Stakeholder level.

An example of a Framework Planning-based clustered project is depicted in Figure 7.2, which is included in Arkansas' Conway Urban Watershed Framework Plan (2016). This example depicts Green Streets and parks that tie together the implementation of various types of green infrastructure while addressing other community needs, such as traffic calming, inclusion of recreational opportunities, and expanding parking. Figure 7.3 shows another example from the Conway Urban Watershed Framework Plan, which includes transportation corridors (streets and trails) and recreational amenities with riparian area restoration and green infrastructure. Additional detail on the Conway Framework Plan is included in the Case Study below, and provides additional context about what Framework Planning includes, and is consistent with the Clean Water Plan Framework Planning approach.

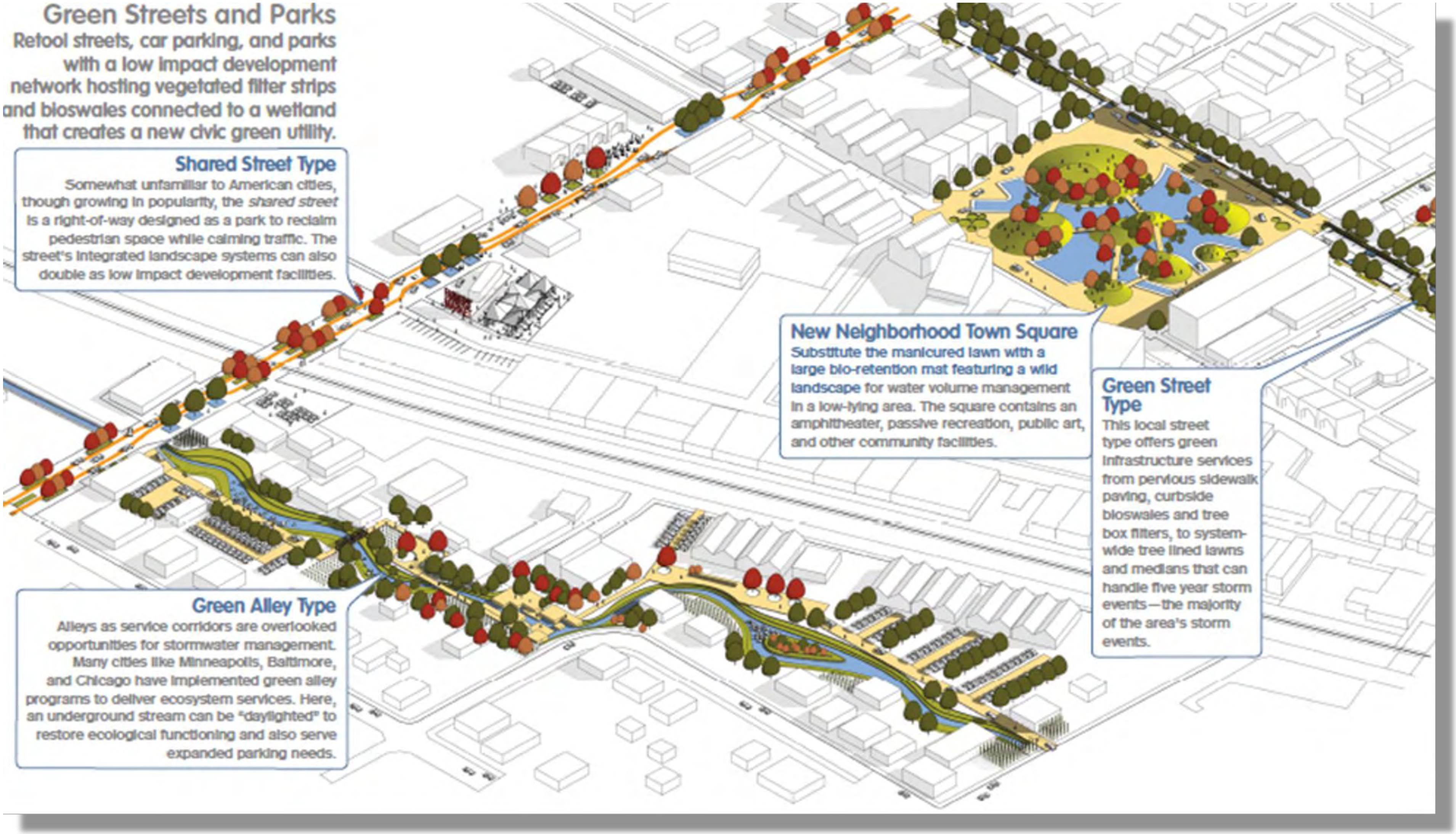


Figure 7.2. Example from the Conway Urban Watershed Framework Plan that shows how multiple strategies (green infrastructure, trees, riparian areas, natives/invasives) can be implemented in holistic way that also addresses other City priorities (traffic calming, recreation, beautification, etc.)

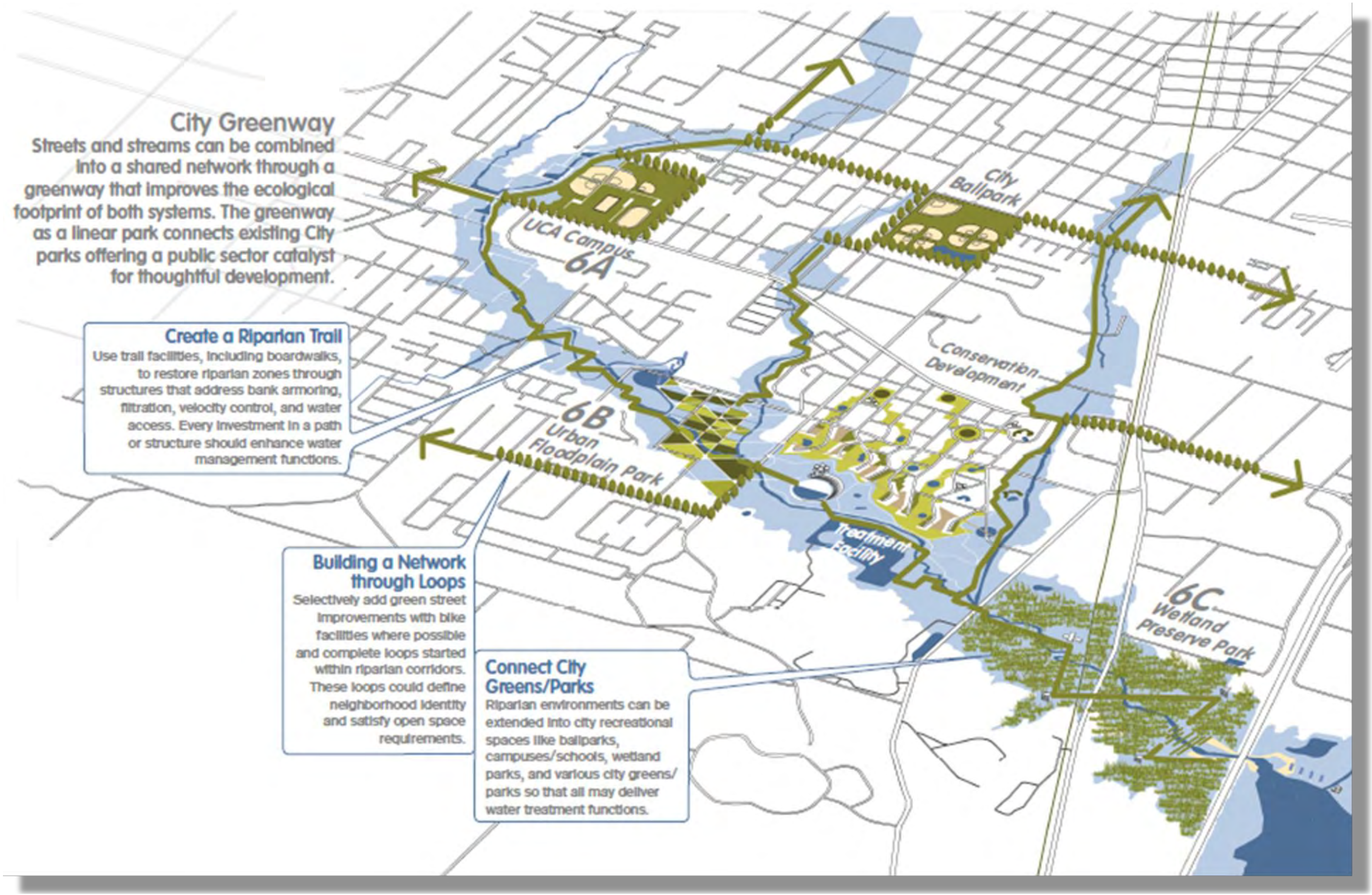


Figure 7.3. Example from the Conway Urban Watershed Framework Plan that shows how Greenways can incorporate strategies like green infrastructure and riparian area restoration with transportation corridors, parks, etc.

Case Study on Urban Framework Planning: Conway, Arkansas

An excerpt from the Conway Urban Watershed Framework Plan

The Framework Plan operates evolutionarily through a set of retrofit types that are incremental, contextual, and successional. The Framework Plan is incremental, relying on participation from various interests— public, private, or a combination thereof—to develop projects as funding and opportunity permit. Projects can be implemented step-wise and successively across various fronts in the urbanized area. Unlike the master plan which is totalizing and shows only a climax condition, the Framework Plan can be pioneered beginning with modest cumulative efforts that cohere from shared ecological design practices.

The Framework Plan is contextual, working through landscape architectural adaptations responsive to local ecologies and urban water problems. Soft engineering accounts for local soils, and vegetative and wildlife communities in place-based solutions that substitute for universal metrics and costly "over-engineered" outcomes driven by worst-case scenarios. The goal is to deliver ecological services through installing sustainable soft infrastructure. Soft engineering's use of adaptive management lessens long-term maintenance burdens associated with hard-engineered infrastructure.

The Framework Plan is successional, understanding that cities are not built at once and that pioneer stages of development are rudimentary as they minimize start-up costs. The Framework Plan works initially through tactical demonstration projects, which if approved after assessment, can be mainstreamed into future projects and policies. This way the city or project developer can evaluate new practices without committing permanently to an untested development and business model. Cities do not have to retool policies without the chance to pursue due diligence. Stakeholders in decision-making, including the city and the area's new watershed alliances (e.g., the Lake Conway-Point Remove Watershed Alliance), can collaborate as learning communities removing adversarial relationships so redolent in municipal planning processes. Without demonstration projects, conventional development approaches will remain entrenched despite the presence of more value-added approaches.

The Framework Plan places Conway ahead of the curve in addressing the greatest ongoing challenge to planning: development of urban form in human-dominated ecosystems. More cities are tasking urban infrastructure with regeneration of diminished ecosystems to support livable communities. Besides solving for water management problems like flooding, the collateral benefits of implementing the plan include greater livability, sustained economic development, improved community resilience to disruption and shocks, and exemplary beauty in the civic realm that creates enduring value and symbolism.

(University of Arkansas Community Design Center 2016)

The Framework Planning approach includes the following elements that are discussed further below:

1) Data and information gathering
2) Identification of potential opportunities
3) Prioritization
4) Plan development
5) Implementation

Data and Information Gathering

A significant data gathering effort was undertaken early in the City's Clean Water Planning process with the development of the Watershed Characterization Plan and Water Quality Model that helped characterize Richmond's watersheds and the James River and tributaries. The type of data that was collected for these two efforts included, for example, impervious surfaces, impaired waterways, City-owned properties, existing stormwater BMPs, and water quality sampling data. The Framework Planning process will facilitate the identification of additional information deemed important to the City and stakeholders, including information such as, for example, ongoing or planned restoration projects or watershed-scale initiatives, places (parks, neighborhoods) that draws people in, and areas challenged by socio-economic issues. DPU initiated discussion of such information at its March 21, 2017 Technical Stakeholder meeting (Figure 7.4). This initial meeting included discussion of what stakeholders felt were existing needs or challenges in the City. This included not only water quality-related issues, but transportation or other socially-driven challenges.

Figure 7.4. Initial Technical Stakeholder brainstorming session on challenges and opportunities to be considered in the Framework planning process

Figure 7.5 depicts examples of other data types that will be looked at collectively through this process, including location of parks (or lack thereof), bike paths, priority conservation areas, commercial areas targeted for revitalization, etc.

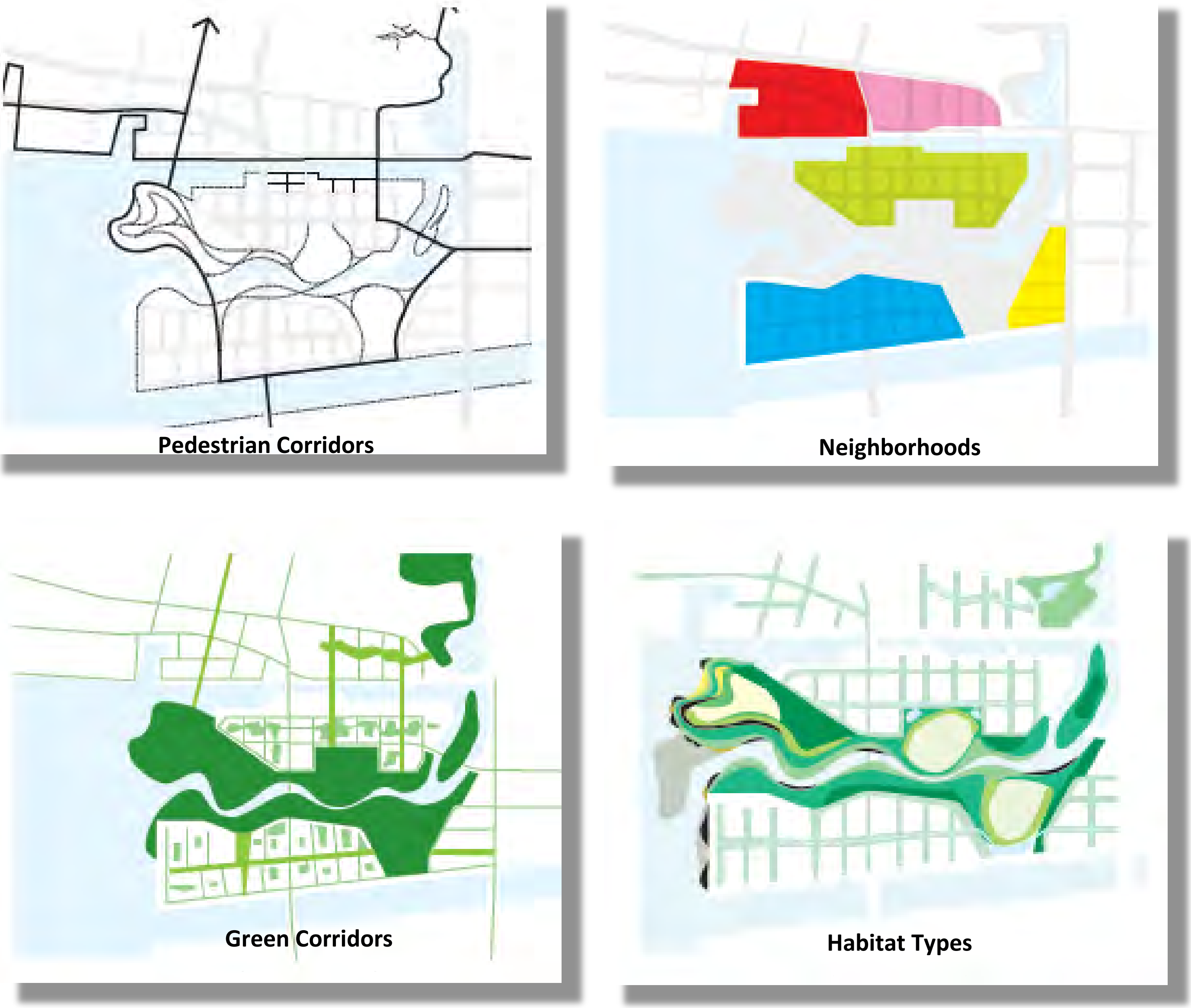


Figure 7.5 Examples of data types that will be considered within the Framework Planning Process

Several additional brainstorming meetings are scheduled to occur with Technical Stakeholders over the course of this project. Additionally, DPU will meet with other City departments to discuss opportunities for collaboration that will allow DPU to not only address its goals and objectives, but those of the City as a whole.

Identification of Potential Opportunities

As meetings with stakeholders and City staff continue, they are expected to evolve from identifying available information, concerns, and areas of interest within the City, to evaluating and assessing this information, and ultimately identifying areas of potential opportunities where strategy implementation could occur through the leveraging of planned or existing initiatives.

For example, a stream, such as Goodes Creek requires bacteria reductions per the James River bacteria TMDL. In this same watershed, there are also Commercial Area Revitalization Effort (CARE) neighborhoods (yellow areas in Figure 7.6) that could be targeted for tree planting or implementation of green infrastructure for beautification purposes. Additionally, GIS analysis has identified stretches of Goode Creek as having deficient stream buffers (pink lines within the circled area in Figure 7.6). DPU and

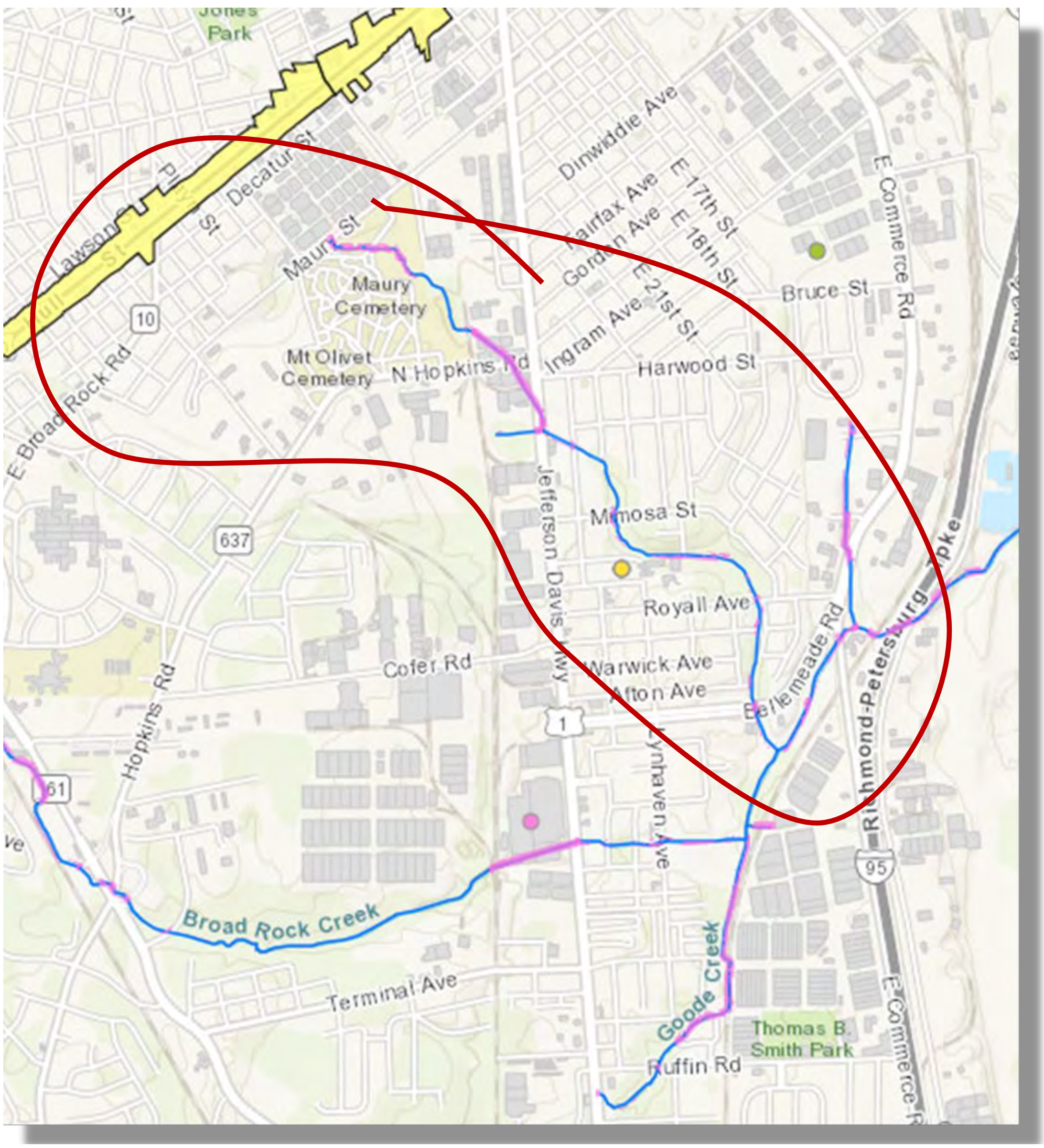


Figure 7.6. ArcGIS online map depicting the region near Goode Creek that contains City park property (Maury Cemetery), CARE neighborhoods (yellow), and buffer deficient streams (pink)

its stakeholders could identify potential project clusters such as these for additional evaluation of opportunities for strategy implementation.

Prioritization

Once data and information have been assessed and opportunities for projects or project clusters have been identified, these must be prioritized for further analysis and subsequent implementation. Regardless of projects being implemented piecemeal or in an integrated manner, there may continue to be diverging priorities driving implementation. A key element of this Framework Planning effort will involve identifying criteria by which these projects or project clusters are prioritized. This criteria development process will involve discussions with Technical Stakeholders over the summer of 2017. Several examples of criteria that may be used to evaluate projects or project clusters include if they:

- Address priority pollutants (and how much)
- Address other metrics identified by stakeholders (and how much)
- Address public health concerns
- Can be enhanced by partner resources (staff, funding, etc.)
- Include an educational component
- Address the social or economic elements of the Triple Bottom Line (Figure 7.7)
    - Are environmental justice concerns addressed?
    - Are lower SES neighborhoods targeted?
- Account for the City's Affordability Analysis
    - Can it be implemented with existing resources or does it require additional funding?
- Have stakeholder support

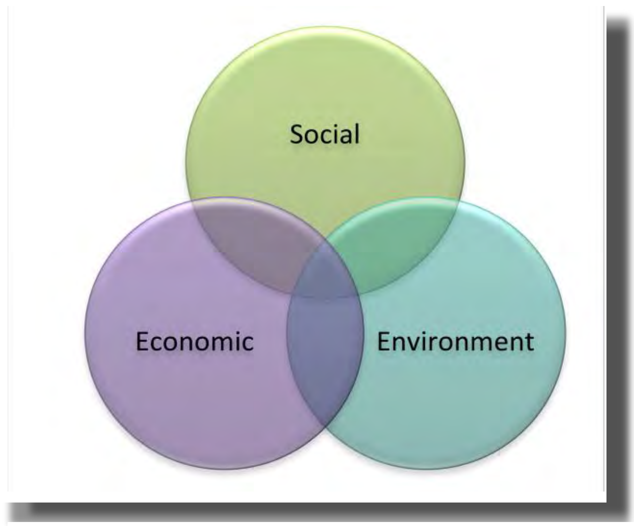


Figure 7.7 Elements of the Triple Bottom Line

Based on the number of criteria met, the projects/project clusters will be sorted into "very high", "high", "medium", and "low" priority projects. Additional detail on this prioritization process will be developed over the summer of 2017.

Plan Development

The Framework Planning process and the identification and prioritization of projects and project clusters will be documented in the Framework Plan. The Framework Plan will also demonstrate how the projects and project clusters will meet the goals and objectives of the Clean Water Plan, including the numeric targets of the strategies.

Schedule

The Framework Plan will reflect efforts to be implemented over the course of the five year permit cycle. While most of the strategies that have been developed for the Clean Water Plan are based on a five year timeframe, other, more resource intensive projects, such as those related to the CSO Infrastructure strategy, may require a longer time frame for full implementation. NPDES permits typically allow flexible compliance schedules for meeting the state WQS. These schedules can be as long as necessary to achieve the water quality objectives. The federal regulations specifically require the schedule in the permit to achieve limits “as soon as possible.”

Funding

An appropriate level of funding will be important to the success of the City’s approach to integrated planning on a watershed basis. The various programs involved in this planning process (i.e., stormwater, wastewater, CSOs, drinking water) have funding mechanisms available to them. Specific project funding will be developed concurrently with the development of the City’s annual budget cycle. DPU’s funding sources will be evaluated to determine the anticipated costs, funds available, and any anticipated funding gaps. Overall, it will be imperative that implementation takes into account the findings of the City’s affordability analysis, which is expected to be finalized in 2017.

Implementation

The framework planning process will lead to the identification and prioritization of projects or project clusters that the City will fund for implementation. The sum of these projects will be consistent with the high level strategies defined in the Clean Water Plan.

There are several important concepts that will be taken into account through implementation. For instance, it is envisioned that implementation will occur incrementally over the course of the permit cycle (e.g., 10 acres of riparian buffers will not necessarily be restored all at once or within only one project, but may be addressed through the implementation of several projects/project clusters). Additionally, it may be determined that once more refined analysis is performed during or prior to the design/build phase of a project, that a particular project or project element cannot be achieved in its entirety. Flexibility is incorporated into implementation through adaptive management. If it is found that one strategy cannot be implemented in whole or in part, DPU will work to identify an alternative approach to achieving the same or similar pollutant reductions and other identified goals and objectives.

Implementation of projects, particularly those that involve stakeholders or other City departments, will require significant coordination. In addition to regular Technical Stakeholder meetings to provide updates on progress, DPU will convene a workgroup of those organizations involved in these implementation efforts. As projects are implemented, associated benefits (pollutant reductions, area treated, other metrics addressed) will be tracked as well. Measuring progress made under the Clean Water Plan as a result of project implementation is discussed further in Chapter 8.

8. Measuring Progress

Once targets have been established and strategies have been identified to address watershed goals, an approach must be developed to monitor and measure progress made in association with these implementation efforts. As the City's implementation moves forward, measuring progress will include determining if goals have been met, if progress has been deemed sufficient, or if changes should be made within the program to try to improve the level of progress made.

Determining the level of progress that has been made as a result of the City's investments is a key element to the success of the Clean Water Plan and its ultimate support by the public, stakeholders, and elected officials. Measuring progress; however, can be complex. Targets may be established at various scales (i.e., site scale, sub-watershed, watershed, city scale). Implementation actions can also include a wide range of options including structural and non-structural practices as well as practices that address various source sectors (i.e., stormwater, wastewater, non-point sources). As a result, the approach used for measuring progress under the City's program must be flexible enough to account for these variations in scale and options that will be employed to mitigate pollutants and meet the City's goals.

Measuring progress will be done in a holistic manner based on data from the City's monitoring programs, modeling efforts, and other programmatic information (e.g., implementation targets, such as miles of stream buffers restored per year or number of residents reached by outreach efforts). Each of these elements is outlined in Table 8.1 and is discussed further below.

Table 8.1. Monitoring activities and associated outcomes implemented under the Clean Water Plan

	Activities	Outcomes
Water Quality Monitoring	Instream water quality, biological (e.g., macroinvertebrates), CSO and WWTP discharge monitoring	Progress made toward pollutant reduction targets in permit
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
		Identify sources, stressors, or pollutants of concern
		Identify trends over time
	BMP monitoring	Effectiveness of specific BMPs or source reduction efforts
		Progress toward achieving WQS (e.g., measure improvement in aquatic life designated use)
Programmatic Monitoring	Tracking strategy implementation	Progress made toward strategy implementation goals (e.g., acres of green infrastructure implemented)
		Progress made in pollutant reduction through strategy implementation (e.g., pounds of TN reduced through green infrastructure implemented)

		Progress made toward pollutant reduction targets identified in permit
Modeling	Receiving water, CSS, and watershed modeling and analysis	Progress made in bacteria WQS compliance
		Progress made in bacteria load reduction
		Progress made in reduction of CSO events or volume discharged

Each element of this process to evaluate Clean Water Plan progress will occur on a regular/annual basis over the course of the permit. Reporting on each of these elements will occur annually per VPDES permit requirements. At the end of the permit cycle a more comprehensive review of the progress made within this integrated planning framework will be compiled and included with the next VPDES permit application.

Water Quality Monitoring

As part of the watershed characterization effort, described in Chapter 3, historical water quality monitoring was compiled and evaluated including:

- James River monitoring carried out by VCU and other agencies
- In-stream monitoring of streams like Gillies Creek and other small tributaries within the city
- End-of pipe monitoring of CSO and WWTP discharges
- Data on other sources of pollution within the City

These data were organized and incorporated into a GIS-based geo-database. These water quality data were used to assess spatial and temporal trends, identify data gaps, and provide the water quality monitoring data needed to assess baseline conditions. Once implementation of the projects and programs in the Clean Water Plan has commenced, newly collected monitoring data can be used to evaluate changes from these baseline conditions.

Monitoring Program Development

Drivers behind the development of a monitoring program are often the regulatory requirements specifying monitoring objectives or collection of specific data elements. For DPU, these requirements will stem from the VPDES permit. As the Clean Water Plan and associated integrated watershed-based VPDES permit is finalized, DPU will assess its existing monitoring program to determine if it will provide the data needed to achieve the objectives of the permit. Examples of monitoring objectives include:

- Assess spatial and temporal trends of monitoring sites along the James River and its tributaries
- Evaluate the performance of specific BMPs or source reduction efforts
- Evaluate the health of the City's waterbodies
- Identify or evaluate parameters of concern
- Identify or evaluate potential sources of stressors
- Assess progress toward permit targets

Permit-driven objectives along with the identification of any additional data needs will ultimately determine the monitoring design. For instance, to evaluate stressors in a watershed, targeted monitoring would be conducted upstream and downstream of a key source(s). Monitoring could include sampling during different environmental conditions (e.g. dry and wet weather, high and low flow, seasonal effects), and point source and BMP flow and quality sampling. Conducting biological and habitat assessments also provide links between instream conditions and pollutants.

Alternatively, to evaluate the overall health of the City's waterbodies, a probabilistic monitoring design would be developed that includes multiple randomly selected sites throughout the City. This approach would allow DPU to show overall conditions and, as Clean Water Plan implementation occurs over time, how integrated planning is benefitting the City's waterbodies.

In addition to DPU's own objectives, the City may want to determine if other local stakeholders have monitoring objectives that complement its own. Broader coordination can result in the development an integrated monitoring program that could broaden the scope of the monitoring plan while identifying efficiencies to reduce resources directed at monitoring efforts.

Programmatic Monitoring

As a number of the City's watersheds reach past Richmond's borders and are impacted by sources outside the City's control, water quality monitoring efforts alone will not necessarily provide an accurate representation of the City's progress in achieving the goals and objectives of the Clean Water Plan. In addition to water quality monitoring, a programmatic approach will be evaluated to determine its effectiveness.

As discussed in Chapter 4, an extensive effort was undertaken to develop goals and objectives for this Clean Water Plan as well as strategies that would achieve these goals and objectives. Tracking these strategies to measure progress will occur in several ways.

Tracking Strategy Implementation Targets

Each strategy was written to include quantifiable targets for implementation (e.g., acres of green infrastructure, acres of riparian area restored, miles of stream reengineered, etc.). Evaluating the extent to which the strategies are being implemented and targets are being met will be an important mechanism for tracking progress. If targets are not being met or strategies are not being implemented, the City will evaluate why this is the case and determine if other alternatives are available that will result in achieving the same or similar progress towards goals and objectives.

Strategies are comprised of multiple implementation efforts (e.g., all of the projects that would result in 104 acres of green infrastructure implementation in the MS4 area). DPU will continue to use several tools to track these projects. Currently, a database is used to track practices as they are implemented. The City's existing GIS will also serve as the basis for this tracking effort.

Tracking Strategy Pollutant Reductions

Tracking the anticipated pollutant reductions associated with these strategies will also be an important component of measuring progress of the Clean Water Plan. EPA's Chesapeake Bay Program (CBP) has established pollutant reduction credits for many of the stormwater BMPs proposed in association with the Clean Water Plan strategies. To ensure consistency with the CBP and the targets established for the City through the Chesapeake Bay TMDL, these BMP credits will be used as the basis for tracking of pollutant reductions through implementation of strategies.

As strategies are implemented, associated pollutant reductions for total nitrogen, total phosphorus, and total suspended solids will be calculated. These credits will be tracked in a geodatabase, which will allow for the geolocation of associated projects within the City's various watersheds.

While the Chesapeake Bay TMDL pollutants have established pollutant reduction credits assigned to various practices, bacteria, the other key pollutant in this Clean Water Plan does not. As a result, bacteria reductions achieved through strategy implementation will be based on literature values as well as the results of modeling efforts (discussed further below).

Comparing Pollutant Reductions to Targets

As discussed previously in Chapter 6, pollutant reduction targets (see Table 6.6) will be included in the City's VPDES permit. Tracking of progress toward these targets will help assess strategy implementation in the various watersheds[10]. This will help DPU determine if sufficient progress is being made, if larger implementation efforts are required, if more funding is necessary, or if additional partners are needed to increase implementation. To help make these determinations, funding and other staff resources and amount of stakeholder participation will be evaluated in comparison to implementation of programs and practices and, ultimately to environmental improvements. Based on Clean Water Plan evaluation, modifications will be made to the program as part of the Plan's adaptive management approach.

Evaluating pollutant reductions as well as locations of these reductions within the City will help DPU not only determine if targets are being achieved, but if various watersheds or sections of the City should receive additional focus for implementation.

Modeling

The Modeling Framework will continue to be used as needed to evaluate the water quality improvements related to the implementation of projects and strategies. Metrics that will be evaluated by the Modeling Framework include progress made in bacteria WQS compliance, progress made in overall bacteria load reduction, and progress made in reducing CSO events or volume discharged. The quantification of these metrics will be used as part of the programmatic monitoring efforts (as discussed in the previous section).

[10] While water quality monitoring will be used, in part, to evaluate progress toward achieving targets, EPA's CBP promotes tracking of progress through credits applied to various implementation types. This approach will also be used to evaluate Clean Water Plan progress.

9. Next Steps

The Clean Water Plan has resulted in a comprehensive understanding of the City's watersheds and associated water resources. This includes an understanding of the pollutant sources and stressors within the City; the monitoring data that has been collected to date, as well as where additional data area needed; and the characteristics of the watersheds, such as soils and impervious surfaces. Additionally, the Clean Water Planning process has identified the goals and objectives and associated metrics that will guide the City moving forward. It also includes a plan for identifying control projects and programs that can be updated and adapted throughout the plan's implementation.

The next step is to use the Clean Water Plan to develop a watershed-based VPDES permit. Watershed-based permitting has been long supported by EPA and allows multiple pollutant sources to be managed under one permit. For Richmond, these pollutant sources are CSO, wastewater, and stormwater via the MS4 and direct drainage. The Clean Water Plan provides the planning framework and strategies to manage these sources and prioritize control projects based on their improvements to local waterways. Therefore, the Plan will be included in the VPDES permit as a source of data and provide information to be included in the "Special Condition" section related to BMPS to be implemented and additional monitoring to be done to track progress. The Clean Water Plan will also be included in the Permit Fact Sheet as an information source.

Once the watershed-based VPDES permit is issued to the City, next steps include implementing the projects and programs in the Clean Water Plan and conducting monitoring and modeling to measure progress towards the goals of the plan. While this first permit cycle will include targets consistent with the strategies identified in the planning process, continued implementation will be a long-term process that will span multiple five-year VPDES permit cycles. Therefore, the Clean Water Plan will require updating for each successive VPDES permit using the adaptive management approach described in the previous section. Future VPDES permits will be pursued as watershed-based permits until the Clean Water Plan is fully implemented.

The City will also continue to engage stakeholders to inform them of activities and associated progress towards the goals of the Clean Water Plan, and solicit their input on Plan updates. This engagement process will likely be simplified now that the considerable effort to develop the initial Plan has been completed.

More information on EPA's perspective on watershed-based permitting as it pertains to a watershed-based VPDES permit for the City is provided in the following section to illustrate the consistency between its requirements and the Clean Water Plan elements.

Adaptive Management

The adaptive management approach to water resources and regional wastewater management is increasingly recognized as the most appropriate and economically efficient way to identify problems, assess alternative solutions, and implement targeted corrective actions. The adaptive management approach has been, and will continue to be, implemented during each step of the Clean Water Planning process.

Adaptive management will be critical for the success of Richmond's plan as any new data collected through the course of this effort will need to be reviewed on a regular basis and used to refine/modify the Clean Water Plan so it is up-to-date and accurate. An adaptive management approach will also be a key component of the framework the City will use to monitor the progress made through the Clean Water Plan. As mentioned above, assessment of progress will involve periodic comparison to the various targets established through previous steps of this process.

While strategies include targets, the Clean Water Planning process includes an adaptive management component that provides flexibility should some unforeseen issue arise regarding a particular strategy. For example, it may be determined over time that green infrastructure in the MS4 is only feasible on 80 acres (rather than 104 acres), or it may be riparian area restorations will require more implementation on private land than originally calculated. In such situations, the City will have to evaluate ways to expand other strategies/opportunities to work toward achieving the Clean Water Plan's goals and objectives. This may include expanding other strategies so that a similar pollutant reduction is accomplished or measures of additional metrics are reached. Alternatively, as implementation moves forth, stakeholders or additional Departments within the City may participate more than originally planned. This could add resources, expand implementation, and potentially result in efficiencies that can further streamline the Clean Water Plan effort.

Adaptive management can also be informed by the monitoring conducted by the City. If water quality monitoring data are not showing expected improvements, the Clean Water Plan can be modified to increase levels of implementation, accelerate implementation schedules, alter BMP types planned for the watershed, etc. For example, a watershed where BMPs have been implemented, but in which the water quality or biological communities do not show improvement, may need additional implementation efforts. Alternatively, upstream water quality monitoring (e.g., from outside the City's boundaries) may show that the water quality upstream is also not meeting WQS, which may explain the lack of improvement despite BMP implementation. In contrast, improved water quality or functioning of biological communities may show that the implementation has been successful. It should be emphasized, however, that BMP implementation often results in a significant (years, decades) lag time in instream response to this implementation. This will be taken into consideration when evaluating progress. An alternative situation may occur where WQS are not being met, but a local biological community is no longer impaired. In such an instance, a use attainability analysis (UAA) may be warranted and would offer an alternative to expending money and resources to implement projects in areas that are not causing exceedance of the WQS.

While adaptive management will play a key role in keeping the City's planning efforts on track, it should be noted that implementation of a sufficient amount of control to meet the City's goals may take many years. Once controls are implemented, it may take even more time for in-stream benefits to be measurable, especially in the biological community or habitat conditions. The tracking framework will take long-term implementation into account and will be reflected within the tracking of targets.

Watershed-based VPDES Permit

The intent of the Clean Water Plan is to feed into an Integrated VPDES permitting process. The CWA (§ 402) established the NPDES permit (VPDES in Virginia) as the primary tool for controlling point source discharges, and therefore municipal discharges. An integrated approach would then allow the City to address all of its regulatory requirements (stormwater, CSOs, wastewater) as well as source water protection within the same plan thereby providing better and more efficient coordination of requirements.

Watershed-based permitting is an integrated approach to developing VPDES permits for multiple point sources within a defined geographic area (watershed boundaries).

The primary difference between this and the traditional approach to permitting is the consideration of watershed goals and the impact of multiple pollutant sources and stressors, including nonpoint source contributions, to receiving waters.

For many years, the EPA has supported and encouraged a watershed approach to addressing water quality problems. The approach is very flexible so watershed-based permitting can encompass a variety of activities ranging from synchronizing permit issuance, review and renewal of NPDES permits within a basin, to developing water quality-based effluent limits using a multiple discharger modeling analysis. One key component in the overall watershed-based permitting process is the integration of programmatic requirements. The watershed-based permitting framework provides the structure for examining a specific area and all of the stressors within that area, data related to the stressors and water quality goals, and prioritizing actions based on those data.

US EPA Support of Watershed-based Permitting

As discussed in more detail in Richmond's Methodology for Integrated Watershed Management (2014), EPA developed several guidance documents upon which the City has based its approach for Watershed-based permitting. These guidance documents include:

- Committing EPA's Water Program to Advancing the Watershed Approach (2002)

- Watershed-based National Pollutant Discharge Elimination System (NPDES) Permitting Implementation Guidance (2003)

- Watershed-based NPDES Permitting Technical Guidance (2007)

Additionally, as described in EPA's 2003 Watershed-based Permitting Policy:

> *A holistic watershed management approach provides a framework for addressing all stressors within a hydrologically defined drainage basin instead of viewing individual sources in isolation. Within a broader watershed management system, the watershed-based permitting approach is a tool that can assist with implementation activities. The utility of this tool relies heavily on a detailed, integrated and inclusive watershed planning process. Watershed planning includes monitoring and assessment activities that generate the data necessary for clear watershed goals to be established and permits to be designed to specifically address the goals.*

This Clean Water Plan provides the mechanism for identifying goals and pollutant sources that may impact the goals. This Plan also provides the framework for consolidating DPU's sources (MS4, CSO, WWTP) together and determining the best distribution of investment in these sources to produce the greatest environmental gain.

The watershed-based permitting process provides the tools to apply resources to protect the goals and serves as the mechanism to drive integrated planning in the City. The permit will include a "Special Condition" that will recognize specific components of the Clean Water Plan. The permit will require data collection that will serve to support the evaluation of program effectiveness. The permit will also include controls (limits or pollutant reduction targets) that look collectively at DPU's various sources and allow the City to work toward the goal of greater environmental benefit.

This approach was successfully demonstrated with the issuance of the watershed-based permit to Clean Water Services in Oregon. The permit provided for trading between point and nonpoint sources to address temperature issue in the receiving water. Additionally, the Neuse River Compliance Association holds a permit for discharges from 20 WWTPs in the watershed. These entities all share a collective nutrient limits that they must achieve collectively.

In the case of Richmond, a single permit will be appropriate given the discharges are all controlled by DPU. Regardless of format, the permit will focus on watershed needs.

References

EPA. 2007. Watershed based National Pollutant Discharge Elimination System (NPDES) Permitting Technical Guidance. EPA 833-B-07-004.

EPA. 2008. Handbook for Developing Watershed Plans to Restore and Protect our Waters. EPA 841-B-08-002.

EPA. 2011. Memorandum from Nancy Stoner and Cynthia Giles on Achieving Water Quality through Integrated Municipal Stormwater and Wastewater Plans. October 27, 2011.

EPA. 2012a. Memorandum from Nancy Stoner and Cynthia Giles on Integrated Municipal Stormwater and Wastewater Planning Approach Framework. June 5, 2012.

EPA. 2003. Watershed-based National Pollutant Discharge Elimination (NPDES) Permitting Implementation Guidance. EPA 833-B-03-004.

EPA. 2013. A Quick Guide to Developing Watershed Plans to Restore and Protect our Waters. EPA 841-R-13-003.

Richmond DPU. 2002. Combined Sewer Overflow (CSO) Study: Long-term CSO Control Plan Re-evaluation

Richmond DPU. 2015. Watershed Characterization Report.

Richmond DPU. 2016. Richmond James River Bacteria TMDL Action Plan.

Saarikoski, H.; Barton, D.N.; Mustajoki, J.; Keune. H.; Gomez-Baggethun, E. and J. Langemeyer. 2015. Multi-criteria decision analysis (MCDA) in ecosystem service valuation. In: Potschin, M. and K. Jax (eds): OpenNESS Ecosystem Service Reference Book. EC FP7 Grant Agreement no. 308428. Available via: http://www.openness-project.eu/sites/default/files/SP_MCDA.pdf

Virginia DEQ. 2016. Final 2014 Integrated Report

Appendix 1. Modeling Report

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1 Executive Summary

1.1 Introduction

In 2014, the City of Richmond began a multi-year effort to develop an Integrated Water Resources Management Plan (herein after called the RVA Clean Water Plan). The goal of this plan is to achieve improvements to water quality that will help the city meet its regulatory obligations under the Clean Water Act (CWA). Part of the Clean Water Plan involves developing strategies for the coordinated management of the City's water utilities, including wastewater treatment, drinking water treatment, stormwater runoff, combined sewer overflows (CSOs), and sanitary sewer overflows (SSOs), all of which are assets that are typically permitted and managed separately. By holistically considering all of the City's water utilities in the development of the Clean Water Plan, the City will be more efficient and cost-effective with their ratepayer-funded resources, and provide greater benefit to local waterways than the traditional siloed approach used for permitting and management.

A key step towards the development of the Clean Water Plan was the development of a water quantity and quality modeling framework. The purpose of the modeling framework is to quantify present day bacteria (*Escherichia coliform [E.coli]*) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the RVA Clean Water Plan-related strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. Additionally, the modeling framework provides a platform for comparing the CSO reduction projects included in the City's CSO Long Term Control Plan (LTCP) against alternative CSO reduction projects that may provide similar benefits but at a reduced cost.

The purpose of this report is to document the development, calibration, and application of these models.

1.2 Model Development

Three models were used to achieve the modeling objectives, and together they comprise the modeling framework (Figure 1-1). These three models include:

- A watershed model to simulate flow and bacteria loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system (CSS) service area. This model was developed using the EPA Storm Water Management Model (SWMM) software.
- A collection system model to simulate flow and bacteria loads from the CSS. The CSS model is an existing model that is used by the City of Richmond for Wastewater Master Planning to support implementation of the CSO Long Term Control Plan and to prepare the Annual CSS Reports. This model was developed using the EPA SWMM software, and was adapted for use in this study.
- A receiving water quality model that computes bacteria concentrations in the James River resulting from the various sources of bacteria to the river. The outputs of the watershed and CSS models are used as inputs to the receiving water quality model. The receiving water quality model was developed using the EPA-supported Environmental Fluid Dynamics Code (EFDC) software.

Water quality data were used to inform the development and calibration of the models. Section 2.2 contains detailed figures showing the extent and key features included for each model.

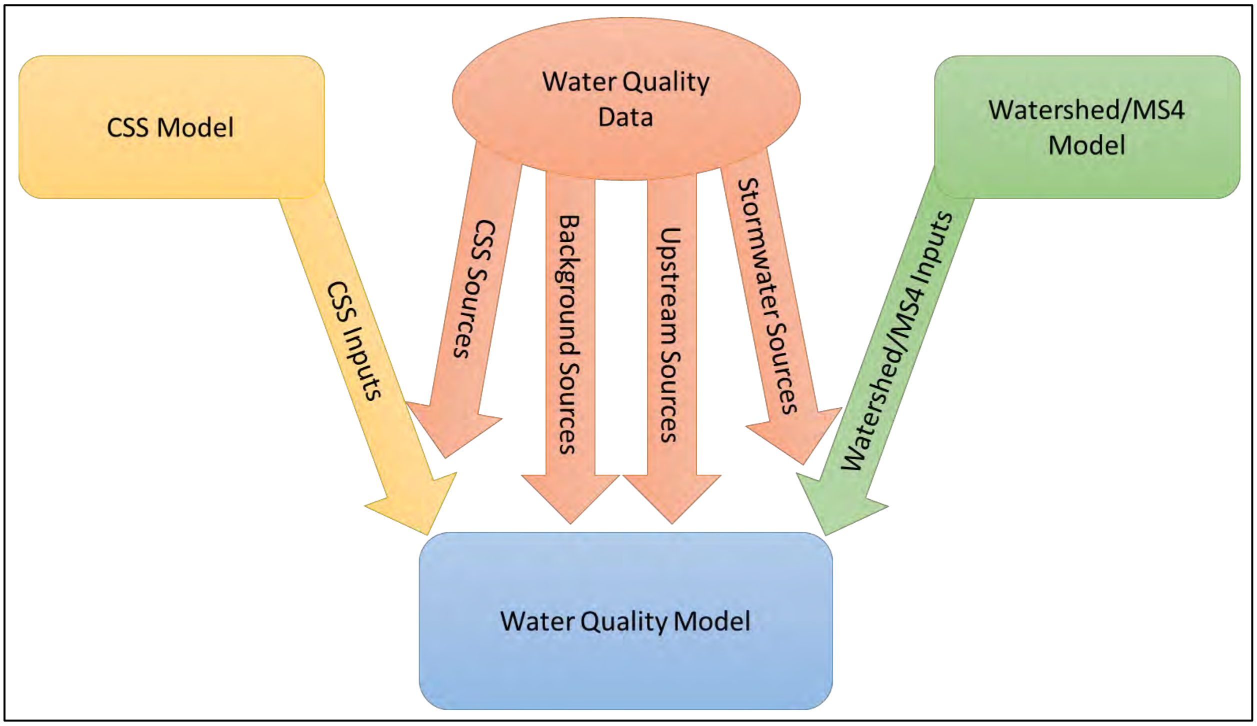


Figure 1-1: Modeling Framework Schematic

1.3 Model Calibration

- Model calibration is the process of adjusting model parameters and assumptions within defensible ranges to achieve reasonable agreement between modeled and observed environmental conditions. The calibration process demonstrated that the modeling framework is sufficiently well calibrated to support the following modeling objectives:
- Design the modeling framework to provide a reliable and reasonably complete accounting of bacteria sources to the James River;
- Develop the modeling framework using sufficiently complete and accurate site specific data;
- Calibrate the models using reasonable assumptions consistent with the site data, literature, and professional judgment;
- Achieve a level of model accuracy that is adequate to support decision making;
- Apply the models for a period including a wide range of common environmental conditions (i.e. river flow and precipitation conditions); and,
- Evaluate and synthesize model output to interpret major sources of current bacteria water quality impairment and to forecast future bacteria water quality conditions.

1.4 Model Application

After the water quality modeling tools were developed and calibrated, they were jointly applied to assess water quality benefits associated with the selected strategies. For this purpose, the model was applied for a 3-year simulation period, 2011 through 2013, that includes an average rain year (2011), a dry year (2012, less than normal precipitation), and a wet year (2013, more than normal precipitation). To date, the model has been applied to evaluate the following conditions or strategies:

- Current conditions: Best representation of current conditions, and includes all the combined sewer system improvement projects that were included in Phase I and Phase II of the CSO Long Term Control Plan.
- Baseline Conditions: represents the current conditions, plus all the currently funded Phase III CSS improvement projects from the LTCP.
- Green Infrastructure in the MS4 Area Strategy: represents the baseline conditions, plus the implementation of 104 acres of green infrastructure on city-owned area in the MS4.
- Green Infrastructure in CSS Area Strategy: represents the baseline conditions, plus the implementation of 18 acres of green infrastructure on city-owned area in the CSS area.
- CSS Infrastructure Strategy: Implementation of CSS projects included in the LTCP: represents the baseline conditions, plus all the remaining unfunded Phase III collection system improvement projects from the LTCP.

The sequencing of the modeling applications is shown in the figure below.

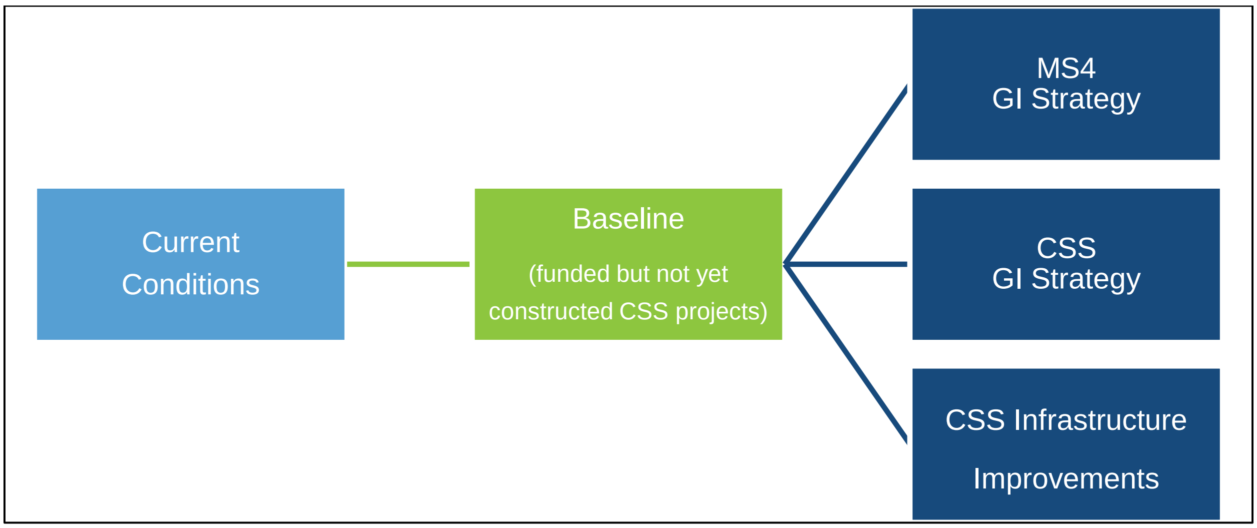


Figure 1-2: Sequencing of Model Applications

These strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges (which can include pollutant loads from the City's MS4), expressed as billion CFU per year
- Overall average percent increase in monthly geometric mean (geomean) water quality standard (WQS) compliance in the James River at the downstream city limit
- Reduction in number of CSO events per year
- Reduction in CSO volume, expressed as million gallons per year

These water quality benefits were then entered into an Excel-based strategy scoring calculator tool that integrates the benefits of strategies across a wide range of Goals and Objectives. More information on the strategy calculator can be found in Appendix D of the RVA Clean Water Plan. Water quality benefits were also assessed on a monthly basis relative to the two existing water quality standards: a monthly geometric mean standard and a statistical value threshold (STV) standard.

1.5 Major Model Findings

Major findings of the water quality modeling are as follows:

- Current *E.coli* bacteria water quality standards are sometimes exceeded in the James River in Richmond.
- The two largest contributors to exceedances of WQS are sources upstream of the City of Richmond and CSOs.
- Eliminating the City of Richmond bacteria sources alone would not achieve compliance with WQS in the James River.
- Reducing CSOs via the RVA Clean Water Plan strategies would improve compliance with WQS.

1.6 Future Use of Model

The Modeling Framework will continue to be used as needed to evaluate the water quality improvements related to the implementation of projects and strategies. Additionally, it is anticipated that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost. Metrics that will be evaluated by the Modeling Framework include progress made in bacteria WQS compliance, progress made in overall bacteria load reduction, and progress made in reducing CSO events and volume discharged.

2 Introduction

In 2014, the City of Richmond began a multi-year effort to develop an Integrated Water Resources Management (IWRM) Plan (herein after called the RVA Clean Water Plan). The goal of this plan is to achieve improvements to water quality that will help the city meet its regulatory obligations under the Clean Water Act (CWA). Part of the Clean Water Plan involves developing strategies for the coordinated management of many of the City's water utilities, including wastewater treatment, drinking water treatment, stormwater runoff, combined sewer overflows (CSOs), and sanitary sewer overflows (SSOs), all of which are assets that are typically permitted and managed separately. By holistically considering all of the City's water utilities in the development of the Clean Water Plan, the City will be more efficient and cost-effective with their ratepayer-funded resources, and provide greater benefit to local waterways than the traditional siloed approach used for permitting and management.

A key step towards the development of the RVA Clean Water Plan was the development of a water quantity and quality modeling framework. The purpose of the modeling framework is to quantify present day bacteria (*Escherichia coliform [E.coli]*) loads and concentrations in the James River and to predict future bacteria loads and concentrations under the Clean Water Plan-related strategies. The modeling framework also allowed for the quantification of discharge flows and volumes, as well as the occurrence of CSO events. The purpose of this report is to document the development, calibration, and application of these models.

2.1 Model Purpose, Objectives, and Functions

The purpose of the modeling framework is to quantify present day *E.coli* concentrations in the James River and to predict future *E.coli* concentrations under management strategies that were developed by the city and stakeholders. The following modeling objectives supported the attainment of this project goal:

- Design the modeling framework to provide a reliable and reasonably complete accounting of *E.coli* sources to the James River;
- Develop the modeling framework using sufficiently complete and accurate site specific data;
- Calibrate the models using reasonable assumptions consistent with the site data, literature, and professional judgment;
- Achieve a level of model accuracy that is adequate to support decision making;
- Apply the models for a period including a wide range of common environmental conditions (i.e. river flow and precipitation conditions); and,
- Evaluate and synthesize model output to interpret major sources of current water quality impairment and to forecast future water quality conditions.

The following report documents how these objectives were achieved through the process of selecting, developing, calibrating, and applying the water quality modeling framework.

2.2 Model Selection

Three models, which comprise the Modeling Framework (Figure 2-1), were used to achieve the modeling objectives. These three models include:

- A watershed model to simulate flow and *E.coli* loads from contributing areas of tributaries to the James River within the greater Richmond area, as well as from Richmond's Municipal Separate Storm Sewer System (MS4), but excluding the combined sewer system service area;
- A collection system model to simulate flow and *E.coli* loads from the combined sewer system (CSS); and
- A receiving water quality model that computes *E.coli* concentrations in the James River resulting from the various sources of *E.coli* to the river.

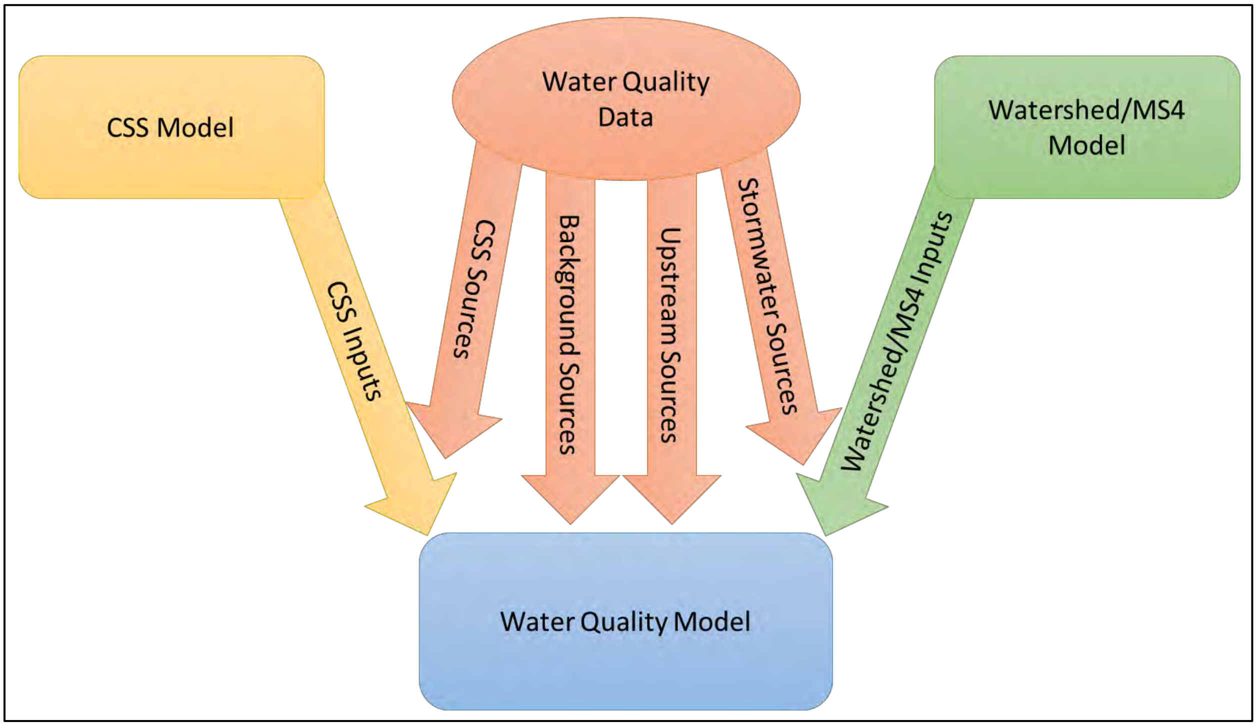


Figure 2-1: Modeling Framework Schematic

2.2.1 Watershed Model

Many watershed model software packages are available and these models vary in their recognition by USEPA and their applicability to the James River and its tributaries. The watershed model framework applied for this project is EPA Storm Water Management Model (SWMM), which is supported by the USEPA and has been successfully applied by the project team at similar sites and for related purposes. SWMM is a dynamic rainfall-runoff simulation model used for single event or continuous simulation of runoff quantity and quality from primarily urban areas (USEPA, 2015). Additionally, the CSS model was also developed using the SWMM software, so choosing SWMM for the watershed model provides consistency.

A variety of enhanced SWMM platforms are available that integrate the EPA SWMM software with user friendly interfaces and GIS capabilities. For this project, PCSWMM, developed by Computational

Hydraulics International (CHI), was used. The watershed model was developed using SWMM engine version 5.1.010, which is consistent with the version used for the CSS model.

2.2.2 CSS Model

The combined sewer system (CSS) model used for this study is based on the Wet Weather Combined Sewer (WWCS) model developed by Greeley and Hansen (GH) to support Richmond's wastewater collection system master planning, Long Term Control Plan (LTCP) implementation, and combined sewer system annual reporting. The CSS model is based upon the EPA Storm Water Management Model (SWMM) framework and uses the SWMM engine version 5.1.010. The model is operated within the PCSWMM environment.

2.2.3 Receiving Water Quality Model

The receiving water quality model was developed based on the EFDC modeling framework (Environmental Fluid Dynamics Code). This model has been applied to support numerous CSO water quality projects and is suitable for representing hydrodynamic conditions occurring in the James River, including the transition from riverine to estuarine conditions, and low head dam hydraulics. EFDC is a state-of-the-art finite difference model that can be used to simulate hydrodynamic and water quality behavior in one, two, or three dimensions in riverine, lacustrine, and estuarine environments (TetraTech 2007a, 2007b). The model was developed by John Hamrick at the Virginia Institute of Marine Science in the 1980s and 1990s, and it is currently maintained under support from the USEPA. The model has been applied to hundreds of water bodies, including Chesapeake Bay and the Delaware River.

The EFDC model is both public domain and open source, meaning that the model can be used free of charge, and the original source code can be modified to tailor the model to the specific needs of a particular application. As a result, EFDC provides a powerful and highly flexible framework for simulating hydrodynamic behavior and water quality dynamics in the James River.

2.3 Model Extent

The model extent defines the spatial or geographic boundary to which the model applies. The extents of the three models are described further below.

2.3.1 Watershed Model

The watershed model incorporates watersheds for 23 tributaries that contribute flow to the portion of the James River that falls within the receiving water quality model extent, and is shown in Figure 2-2 below. The tributaries represented in the watershed model were selected based on two criteria: they have been classified as impaired for *E.coli* on the 2014 VADEQ 303(d) list, or they are expected to contribute significant flows or *E.coli* loads to the James River receiving water quality model. Key features represented in the model include time-variable meteorology, watershed land use and land cover, topography (slopes), land use based pollutant loading, CSO flows and *E.coli* loads (simulated with the CSS model) to tributaries, and basic stream network geometry. The area serviced by the combined sewer system was excluded from the watershed model, as this area is represented in the CSS model. The final watershed model includes 44 square miles within the City of Richmond and 133 square miles outside the city.

2.3.2 CSS Model

The City of Richmond Collection System model simulates all sanitary flows from areas that are connected to the wastewater treatment plant as well as surface runoff from within the combined area. The model is described in the Wastewater Collection System Master Plan (Greeley and Hansen, 2015), and includes the following major features, as shown in Figure 2-3:

- The model contains 227 subsheds, including 99 subsheds representing 44,346 acres of sanitary area and 128 subsheds representing 11,523 acres of combined area. Storm water runoff from the sanitary areas is included in the watershed model.
- The total length of sewer pipes in the model is 235,683 ft. (44.6 miles) distributed over 1,020 individual pipe elements with diameters between 12 inches and 120 inches.
- The model represents all currently active CSO outfalls (29) plus the WWTP outfall used to discharge treated effluent.
- The model represents the Shockoe Retention Basin as well as the Hampton – McCloy Storage Tunnel.

2.3.3 Receiving Water Quality Model

The James River receiving water quality model extends from South Gaskins Road upstream of the Richmond city boundary, to Osborne Park downstream of the Richmond city boundary. The upstream limit of the model was chosen to be just upstream of Richmond's city limits. The downstream limit was chosen to be downstream of Cornelius Creek and near a frequently sampled water quality station. Twenty three miles of the James River are represented in the model with average grid cell dimensions of 140 feet wide and 340 feet long. Each grid cell spans the average depth of the river within their cell boundary. Six cells typically span the width of the river. Key features represented in the model include upstream James River flows; low head dams; the James River Falls near downtown Richmond, runoff; base flow, and *E.coli* loads from tributaries and MS4 areas; the City wastewater treatment plant, CSO discharges and *E.coli* loads; and tidal conditions in the Lower James River. Several of these features are shown in Figure 2-4.

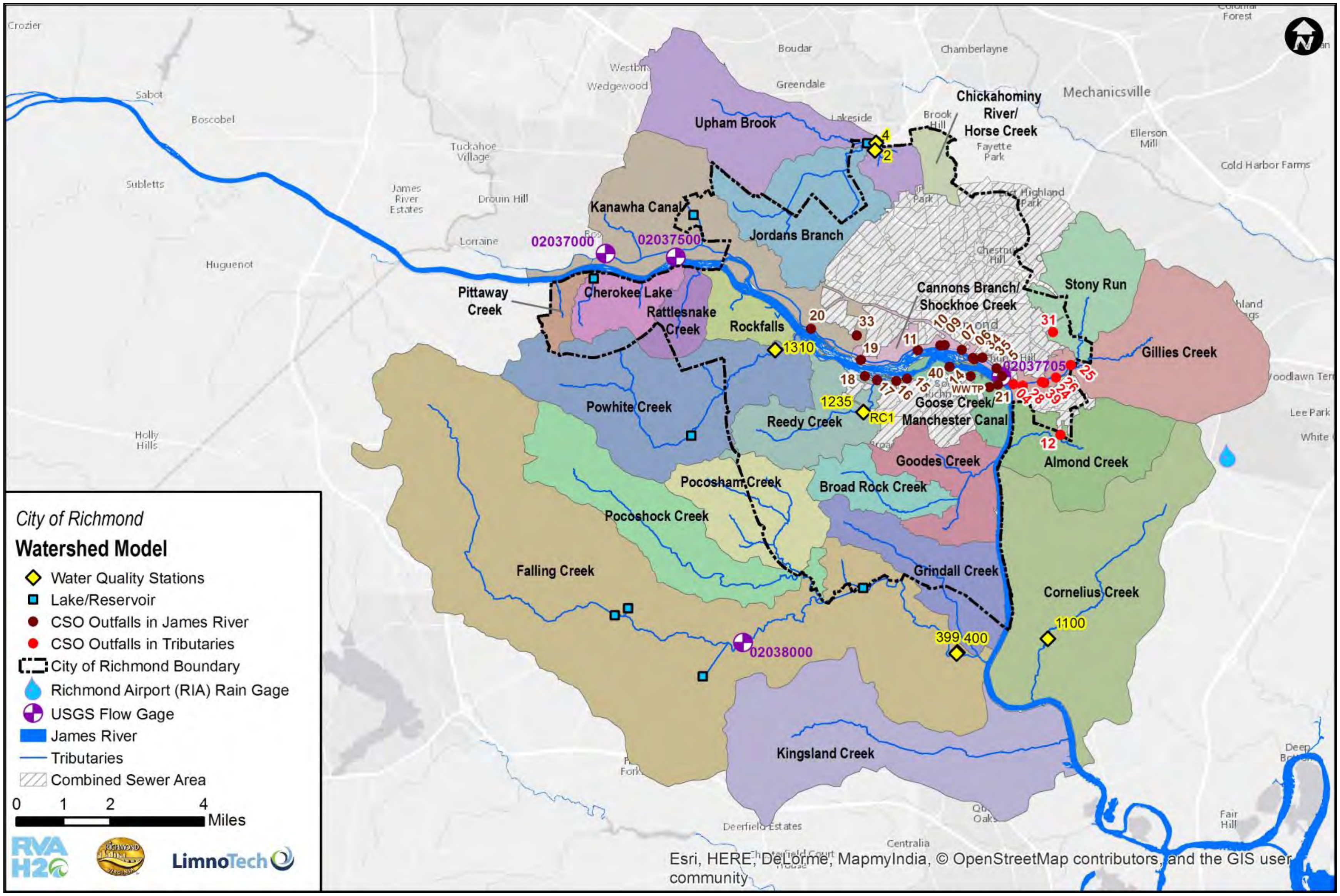


Figure 2-2: Extent and Key Features of the Watershed Model

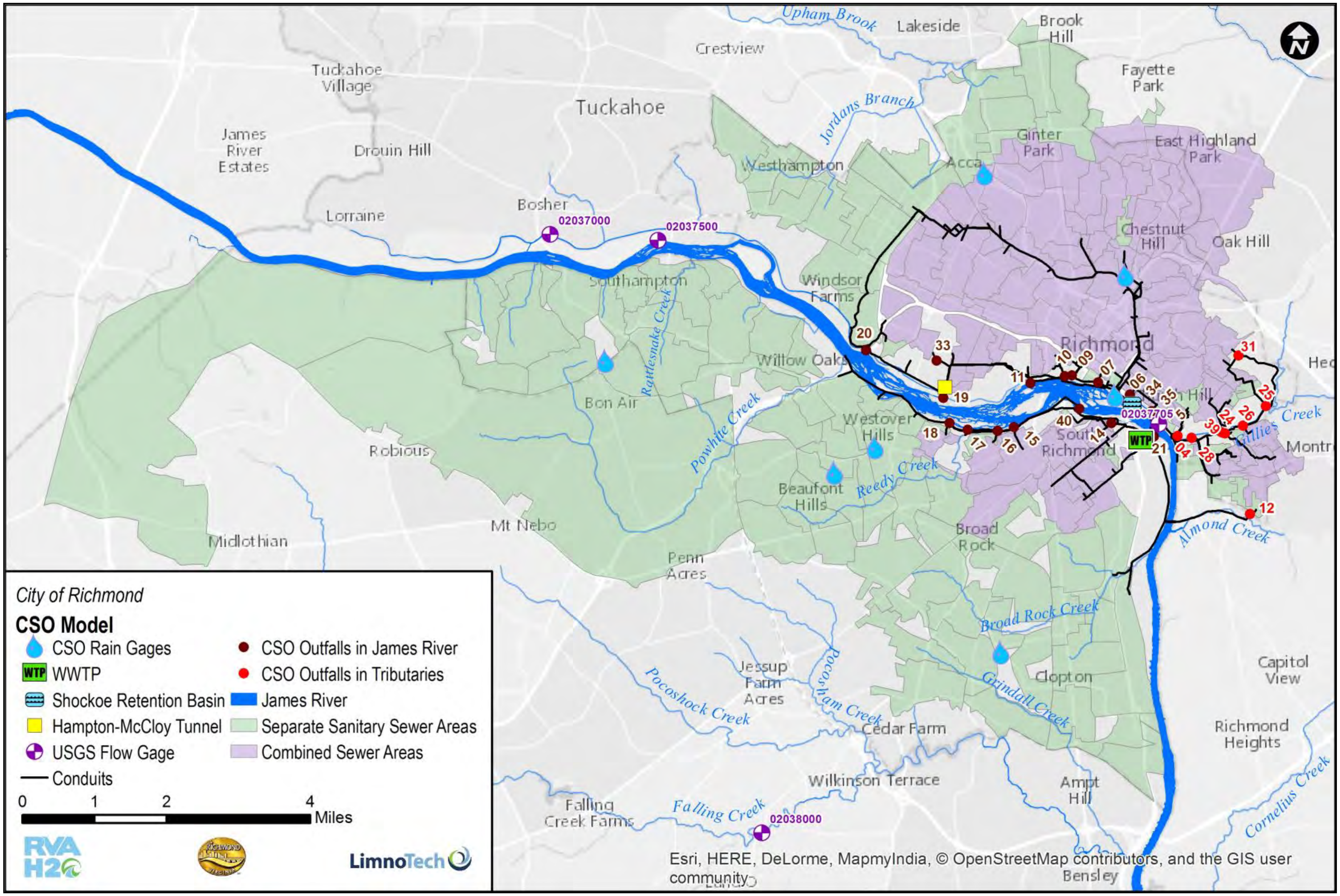


Figure 2-3: Extent and Key Features of the Richmond CSS Model

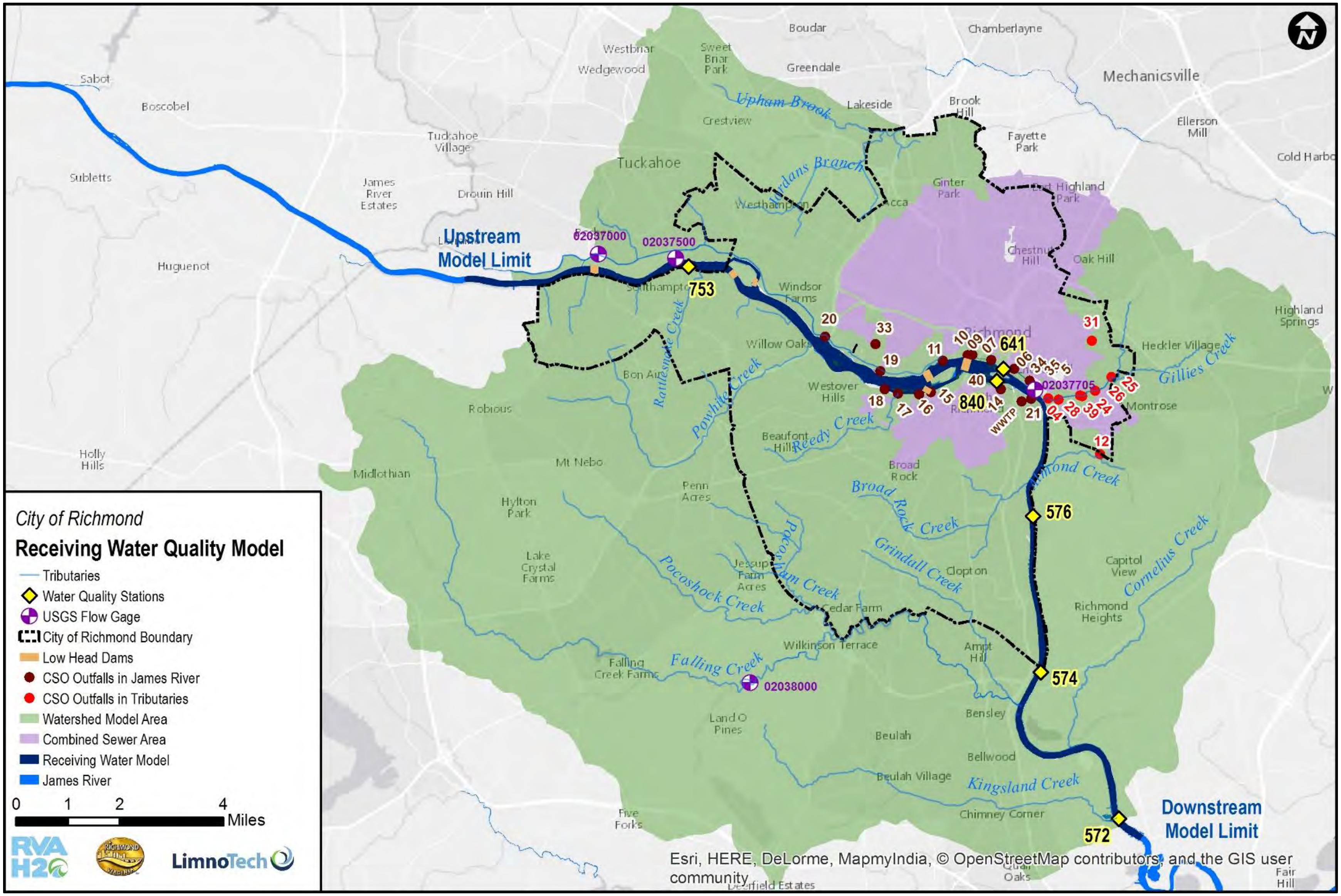


Figure 2-4: Extent and Key Features of the Receiving Water Quality Model

3 Model Development

Model development is the process of configuring a model to represent certain conditions of interest (e.g. combined sewer overflows, or bacteria concentrations) at a particular site. The model development process for the James River water quality modeling framework included definition of 1) important physical and chemical processes, 2) model inputs and assumptions influencing the modeled processes, 3) the spatial extent of model calculations, and 4) the time span of model calculations. This process is described below for each of the three components of the modeling framework.

3.1 Watershed Model

The Richmond watershed model consists of a set of subcatchments (representing the hydrology of the system) that are connected to a network of streams and impoundments (representing the hydraulics of the system). During wet weather events, runoff and associated pollutants are transported from the subcatchments to the stream network, and ultimately discharge to the James River (representing water quality in the system). To set up the watershed model in SWMM, processes influencing the system's hydrology, hydraulics, and pollutant transport must first be characterized. Several different types of data are needed to properly develop a SWMM model. These data characterize the properties that affect the hydrology and hydraulics of a SWMM model. The processes that were modeled and the relevant data that were collected and analyzed for the purpose of setting up the Richmond watershed model are described below.

3.1.1 Process Model Selection

The first step in model development is determining what hydraulic and water quality processes should be included. SWMM is capable of modeling six processes: rainfall/runoff, infiltration, snow melt, groundwater, flow routing, and water quality. To meet the objectives of this model four of these processes were used: rainfall/runoff, infiltration, flow routing, and water quality. It was assumed that snow melt typically does not generate significant runoff in the Richmond area. The contribution of groundwater to stream flow was approximated using a baseflow time pattern for select model nodes, so explicitly modeling groundwater was unnecessary.

3.1.2 Hydrology

3.1.2.a Subcatchments

The 23 tributary watersheds (Figure 2-2) were divided into smaller subcatchments through interpretation of a digital elevation model (DEM), political boundaries, and consideration of culverts, major roads, and water quality stations.

For several watersheds, delineated subcatchments existed from previous modeling efforts by Greeley and Hansen for the Richmond Stormwater Master Watershed Plans (Greeley and Hansen, 2012-2014). For these watersheds, the Greeley and Hansen delineations were re-evaluated using the above considerations, and the subcatchment boundaries were adjusted to meet the needs of this modeling effort. In total, the watershed model is comprised of 427 subcatchments.

To simplify model characterization, some subcatchments located outside of the Richmond city limits were replaced with inflow time series when data was available. Four subcatchments in the upstream portion of the Kanawha Canal watershed were replaced with data from USGS gage #02037000, which had an instantaneous flow time series available from 2007-2015.

3.1.2.b Meteorology

SWMM requires two meteorological inputs: a precipitation time series to generate runoff, and temperature data to calculate evaporation. Complete time series for precipitation (hourly and daily), daily minimum temperatures, and maximum temperatures were available at Richmond International Airport (RIA) from 1949 through current condition. All meteorological data at RIA were obtained from the National Centers for Environmental Information[1] (NCEI) which is operated by the National Oceanic and Atmospheric Administration (NOAA).

3.1.2.c Baseflow

Baseflow comprises the majority of stream flow during extended periods of dry weather, and can be estimated from measured flow data time series. The only gaged tributary within the model extent is in the upper portion of the Falling Creek watershed (USGS 02038000, Figure 2-2), so the flow record from this gage was used to approximate baseflow for all tributaries within the model. Using 30 years of flow data (1965-1994), monthly 7Q10 flows were calculated using methods from Risley et al (2008). These values were then normalized to watershed area (in mi^2) and applied to subcatchments that contribute to the streams and creeks that are included in the watershed model (Figure 3-1).

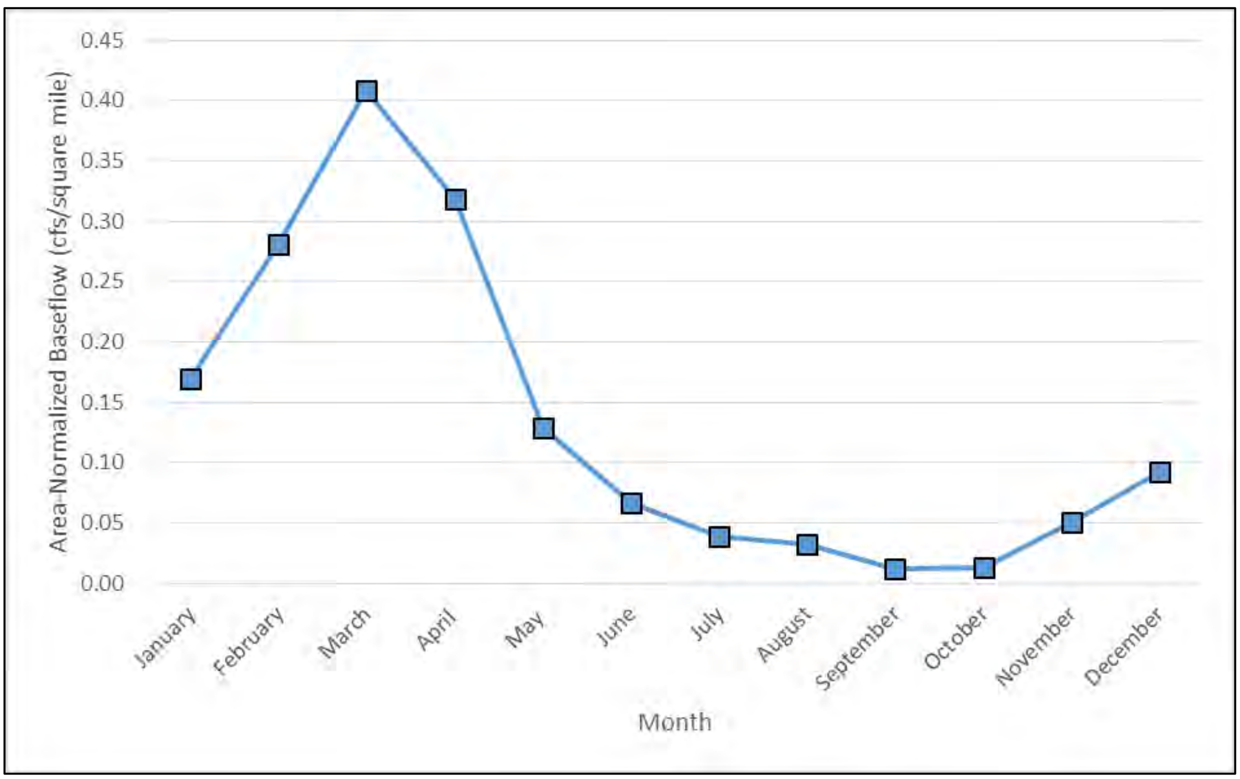


Figure 3-1: Monthly Baseflow Values Used in the Watershed Model

[1] Formerly the National Climatic Data Center (NCDC). In 2015 NCDC merged with the National Geophysical Data Center (NGDC) and the National Oceanic Data Center (NODC).

3.1.2.d Soil infiltration

SWMM offers several methods for soil infiltration (listed in order of increasing complexity): Curve Number, Horton's, and Green-Ampt. The Green-Ampt method requires site-specific knowledge to characterize infiltration parameters, which were not readily available for this project. Therefore, the Horton method was selected for the watershed model. Horton's method uses a set of parameters that defines the maximum infiltration rate, the minimum infiltration rate, the decay rate for changing from maximum to minimum infiltration rates, a recovery rate for changing from minimum to maximum infiltration rates, and an overall maximum infiltration volume. These parameters are determined based on the hydrologic soil groups that are present in the watershed model extent.

The hydrologic properties of soils influence the how quickly and how much precipitation is converted to runoff. In general, soils can be classified by hydrologic soil group (HSG). There are four basic HSGs, called HSG A, HSG B, HSG C, and HSG D. Soils in group A have the lowest runoff potential, while soils in group D have the greatest runoff potential (Mockus et al., 2004). These four basic classifications can then be broken down into dual classifications such as A/D or B/D. Dual classifications represent soils that are classified as group D because of a high water table, making them behave as though they have a high runoff potential. However, if the water table were lowered, these soils would have a lower runoff potential (such as group A or B).

To characterize the soils within the model extent, data were downloaded from the Soil Survey Geographic (SSURGO) database provided by the National Resources Conservation Service (NRCS). A wide range of HSGs are represented within the SWMM model extent (Table 3-1). In addition to the four standard categories (HSG A through D), several dual classifications are also represented. These dual classifications were assumed to be undrained, and were therefore assigned the same soil properties as HSG D. There were also nine soil types with no official hydrologic soil group classification (Table 3-2). Based on the descriptions provided by NRCS, it was assumed that most of these unclassified soils were poorly drained and would have a high potential for runoff (Mockus et al., 2004). Therefore, they were assigned the same soil properties as HSG D.

The soil infiltration parameters associated with each HSG were estimated from tables provided in the *User's Guide to SWMM 5* (James et al., 2010). An average minimum and average maximum value from the suggested range was used for the infiltration rate. In the absence of detailed soil data, the decay constant and drying time were assumed to be the same for all soil types within the model extent, and a maximum infiltration volume was not specified.

Table 3-1: Description of hydrologic soil groups within watershed model extent

Hydrologic Soil Group	Description	Area (mi^2)	% Total
A	Soils with low runoff potential	17.9	9.1%
A/D	Soils with high runoff potential unless drained. Otherwise classified as HSG A.	0.4	0.2%
B	Soils with moderately low runoff potential	75.8	38.7%
B/D	Soils with high runoff potential unless drained. Otherwise classified as HSG B.	20.0	10.2%
C	Soils with moderately high runoff potential	30.3	15.5%
C/D	Soils with high runoff potential unless drained. Otherwise classified as HSG C.	10.9	5.6%
D	Soils with high runoff potential	5.5	2.8%

Table 3-1: Description of hydrologic soil groups within watershed model extent			
Hydrologic Soil Group	**Description**	**Area (mi^2)**	**% Total**
Unknown	See Table 3-2	33.0	16.8%
Water	N/A	2.2	1.1%
	TOTAL	**196.0**	**100.0%**

Table 3-2: Description of the "Unknown" Hydrologic Soil Group within watershed model extent			
Hydrologic Soil Group	**Soil Type**	**Area (mi^2)**	**% Total**
Unknown	Urban land	20.1	10.2%
Unknown	Udorthents-Dumps complex, pits	6.7	3.4%
Unknown	Udorthents, loamy, borrow pits	0.2	0.1%
Unknown	Udorthents, loamy	1.4	0.7%
Unknown	Gravel pit	2.2	1.1%
Unknown	Udorthents, clayey	0.001	0.0%
Unknown	Borrow pit	0.004	0.0%
Unknown	Orthents-Udults-Mine pits complex	0.4	0.2%
Unknown	Made land	2.0	1.0%
	TOTAL	**33.0**	**16.8%**

3.1.2.e Impervious Area and Slope

Percent impervious area and percent slope strongly influence the amount of precipitation that becomes stormwater runoff. Large amounts of impervious area and/or high slopes can lead to high-volume and "flashy" runoff. To estimate median percent impervious area for each subcatchment, a percent impervious area raster was downloaded from National Land Cover Database (NLCD) (Xian et al., 2011). Percent slope for each subcatchment was estimated using the National Elevation Dataset (NED) (Gesch et al., 2002).

3.1.2.f Additional Subcatchment Parameters

In addition to the major subcatchment parameters listed in the sections above, there are five additional parameters that were characterized for each subcatchment: Manning's n coefficient for overland flow over pervious and impervious areas, depression storage for pervious and impervious areas, and percent of impervious area with zero depression storage. These parameters can be used to adjust the shape and the timing of the hydrograph. For simplicity, these parameters were set to constant values for all subcatchments. The values were selected based on literature values from the SWMM5 manual (James et al., 2010)

Table 3-3: Additional SWMM Subcatchment Parameters			
Parameter	**Value**	**Description**	**Source**
Manning's n for overland flow over impervious area	0.018	Average value	Mc Cuen et al. (1996)
Manning's n for overland flow over pervious area	0.25	Dense grass	Mc Cuen et al. (1996)
Depression storage for impervious area	0.075	Average value for impervious surfaces	ASCE (1992)
Depression storage for pervious areas	0.15	Average value for lawns	ASCE (1992)
Percent of impervious area with no depression storage	25%	Default value in SWMM	

3.1.3 Hydraulics and Routing

SWMM offers three methods for routing water through the stream network (listed in order of increasing complexity): steady flow, kinematic wave, and dynamic wave. Dynamic wave was selected for the routing portion of the model. The dynamic wave model can account for channel storage, backwater, entrance/exit losses, flow reversal, and pressurized flow. The dynamic wave model allows for more complex flow conditions than the other routing methods, but requires the use of smaller computational time steps, so choosing this method generally increases the model run times. Theoretically, it produces more accurate results.

3.1.3.a Stream network

Modeling efforts focused on tributaries within the watershed model extent that are currently impaired for bacteria or have active or planned stream restoration projects. Some of these streams originate outside of the city of Richmond, but flow through the city. Two types of small, intermittent streams were not explicitly modeled: unimpaired tributaries within the City of Richmond and unimpaired tributary streams outside the City of Richmond. Unimpaired small tributaries within the city limits were omitted largely because there were no data on stream geometry or characteristics. Upon visual inspection of aerial photography, it was noted that most of these waterbodies were ditches. The small, intermittent streams outside the city were omitted because they are not within Richmond's service area.

The network of streams modeled was developed using two sources. Hydrography data were acquired from the National Hydrography Dataset (NHD Plus), which is developed by USEPA Office of Water and the US Geological Survey (USGS) (USEPA, 2005). This dataset includes nationwide spatial information about a variety of waterbodies, including streams, rivers, lakes, and ponds. NHD Plus was modified using a digital elevation model developed from LiDAR mass points. Modifications of the NHD Plus flow lines were made to align with the lowest nearby digital elevation model (DEM) elevation and with aerial photographs.

The DEM was also used to characterize irregular transects for each section of the stream channel. Using the DEM, one transect was drawn for each subcatchment in the model. Each transect was drawn at a location that was considered to be most representative of the stream channel within a subcatchment.

3.1.3.b Infrastructure

The modeling of culverts was limited to structures that were located on modeled tributaries. Culvert data were provided by the City of Richmond for portions of the watersheds within the city limits. Culvert locations and geometry were estimated for culverts located outside of the city. An initial estimate of culvert geometry was based on aerial photos from Bing maps and the DEM. Initial estimates were then adjusted during calibration under the assumption that culverts were designed to avoid flooding roadways.

The hydrology calibration process revealed that lakes and reservoirs significantly influence the timing of peak flows and their magnitudes. Nine lakes and impoundments were identified through the NHD dataset and subsequently modeled within the model extent, including Cherokee Lake, Cornelius Creek Lake, Falling Creek Reservoir, Gregory's Pond, Lower Beaver Pond, Lower Young's Pond, Rock Creek Park Lake, Upper Lake Bexley, Upper Young's Pond, and Westhampton Lake. When possible, data for these impoundments, associated weirs, and spillways were obtained from the US Army Corps of Engineers (USACE, 1979-1981). Otherwise, impoundment, weir, and spillway characteristics were estimated from aerial photographs, 2-ft contours created from Light Detection and Radar (LiDAR) data, and the DEM. Two conditions constrained the hydraulic behavior of impoundments in the model. First, impoundments were assumed to have a minimum constant water depth that was equal to the primary spillway elevation. Second, it was assumed that lakes and impoundments did not regularly overflow their banks. This seemed like a reasonable assumption because several of the impoundments are surrounded by buildings. If an impoundment regularly flooded in the model, the depth of the storage node was increased and the stage-storage curve was linearly extrapolated.

3.1.4 Water Quality

3.1.4.a Land use/land cover

For water quality modeling in SWMM, land uses must be defined in order to assign pollutant loading. To characterize land use within the model extent, land use data were acquired from the National Land Cover Database (NLCD). The data are generated by the Multi-Resolution Land Characteristics (MRLC) consortium and provided in a raster data format with a spatial resolution of 30 meters (MRLC 2016). NLCD 2011, the most recent version of this dataset, was used to characterize land use in the SWMM model (Homer et al., 2011).

The NLCD also provides data on percent impervious area (Xian et al., 2011), and this dataset was modified and used to estimate the median percent impervious area for each subcatchment. The modification of these data was necessary because the initial model runs during the hydrology calibration process underestimated gaged flows. This discrepancy was discovered through a watershed-scale analysis comparing NLCD impervious cover and a planimetric impervious layer provided by the City of Richmond. It revealed that the NLCD impervious layer underestimated the median percent impervious area, especially in less urban areas. A linear regression was used to develop a relationship between the two datasets and to adjust the NLCD impervious area to better match the planimetric data from the City. After the initial adjustment, the percent impervious area for each subcatchment was adjusted downward by 15%, in order to account for impervious areas that are not directly connected to a waterway or storm sewer. This is standard practice in watershed modeling because runoff from unconnected impervious areas typically first flow onto pervious areas where infiltration can occur, and any excess is then routed to the stream or storm sewer. Because the amount of directly connected impervious area is not known, this adjustment factor was used as a calibration parameter.

3.1.4.b Pollutant loading

In the watershed model, pollutants enter the tributaries in three ways: runoff from the tributary watersheds, baseflow, and CSO overflows. Build-up of pollutants on the watershed and their subsequent wash-off during runoff events are the dominant mechanisms for pollutant loading into tributaries. Pollutant concentrations in baseflow is effectively a calibration parameter that is set for consistency with dry weather pollutant data in the streams. CSO overflows to the tributaries are estimated using combined sewer model output and event mean concentrations (as described below in Section 3.3).

During dry weather periods, pollutants accumulate on subcatchments through a process called build-up. The two parameters that govern build up are the build-up rate, which is the rate at which pollutant accumulates on a subcatchment (expressed in units of cfu/acre/day), and the maximum buildup, which is the maximum amount of pollutant that can accumulate on a subcatchment (expressed in units of cfu/acre). Both of these parameters are represented in the model as a function of land use. To assign reasonable build-up rates and maximum build up to each land use, a review of literature values from across the country was conducted (see tables below). Literature values were not available for all land uses in the model, so in the absence of available data, the build-up parameters for the most similar land use were assigned. Initial model runs used the median build-up rate and the median of maximum build-up for each land use. These parameters were then were fine-tuned during calibration, using the 25^{th} and 75^{th} percentiles as reasonable limits on the range of potential values.

Table 3-4: Land Use Build-Up Rates (cfu/acre/day) Used in the Watershed Model

Land Use	Count	Q1	Median	Q3
Developed - High Intensity	21	6.24E+07	1.27E+09	2.12E+09
Developed - Low Intensity	12	8.13E+07	1.65E+09	2.60E+09
Developed - Medium Intensity	14	9.09E+07	1.50E+09	2.60E+09
Developed - Open Space	8	2.31E+08	1.57E+09	7.81E+09
Undeveloped	32	1.09E+08	1.43E+09	9.62E+09
Forest	9	5.07E+06	8.52E+06	1.41E+08

Table 3-5: Maximum Build-Up Rates Used in the Watershed Model

Land Use	Count	Q1	Median	Q3
Developed - High Intensity	7	9.57E+09	1.06E+10	1.41E+10
Developed - Low Intensity	4	1.06E+10	1.14E+10	3.44E+11
Developed - Medium Intensity	5	5.33E+09	1.02E+10	2.33E+11
Developed - Open Space	4	1.03E+10	1.40E+10	1.75E+11
Undeveloped	9	1.53E+09	2.95E+10	8.51E+10
Forest	5	1.53E+09	1.53E+09	1.67E+09

During wet weather periods, pollutants are depleted from subcatchments and delivered to streams through a process called wash-off. Similar to build-up, the amount of pollutant that washes off during a runoff event is dictated by land use-specific wash-off rate called the event mean concentration (EMC). EMCs for each land use were informed by a literature review. Runoff will continue to generate pollutant load until the available source of pollutant build-up has been exhausted. Literature values were not available for all land uses in the model, so in the absence of available data, the build-up parameters for the most similar land use were assigned. Initial model runs used the median EMC for each land use, and were then were fine-tuned during calibration, using the 25^{th} and 75^{th} percentiles as reasonable limits.

Table 3-6: Landuse Based E.Coli EMC Values Used in the Watershed Model

NLCD 2011	*E.coli* (CFU/100 mL)		
Cultivated Crops	1,945	8,440	26,567
Pasture/Hay	2,682	3,989	28,102
Forest	380	504	565
Wetlands (Woody/Herbaceous)	565	10,339	10,756

Table 3-6: Landuse Based E.Coli EMC Values Used in the Watershed Model			
NLCD 2011	***E.coli* (CFU/100 mL)**		
Developed - Open	2,479	2,479	25,856
Developed - Low Intensity	3,157	15,294	29,723
Developed - Medium Intensity	4,480	5,620	15,527
Developed - High Intensity	884	3,700	11,000

An *E.coli* baseflow concentration was assigned at each model location where baseflow was added. A literature review of urban TMDLs was conducted to determine a reasonable range of values. Initial model runs used the median *E.coli* concentration of 50 CFU/100 mL, which was then were fine-tuned during calibration, using the 25^{th} (28 CFU/100 mL) and 75th (599 CFU/100 mL) percentiles as reasonable limits. The assigned baseflow *E.*coli concentration is the same for each tributary, and is a constant value over time.

CSO flows from the CSS model and *E.coli* concentrations were added to more accurately reflect water quality within CSO-impacted tributaries. There are eight CSOs that overflow into two tributaries in the model: Gillies Creek and Almond Creek. Inflow time series for these eight CSOs were generated by the CSS model. EMCs were assumed for the CSO discharges and were based on previous work on typical fecal coliform concentrations for CSOs in Richmond. The fecal coliform values were then adjusted to represent *E.coli* concentrations using the VADEQ translator (Lawson, 2003). An *E.coli* EMC of 205,000 CFU/100 mL was used for seven of eight CSOs in Gillies Creek. An EMC of 215,000 CFU/100 mL was used for the remaining Gillies Creek CSO and the one CSO in Almond Creek. Further information on the values selected for the CSO EMCs can be found in Section 4.1.

3.1.4.c In-Stream Decay Rate

In-stream bacteria fate and transport processes include die-off, settling to and resuspension from the streambed. The net effect of these processes are represented in the model through the use of a first-order decay rate. Typically, all of the streams in a modeled system will have the same decay rate, with the resulting losses of bacteria in each waterbody varying as a function of travel time through the stream network. An initial in-stream decay rate was set to 1.0/d based on the initial decay rate estimated in the 2010 James River TMDL (MapTech, 2010). This parameter was then adjusted during calibration. The decay rate was varied incrementally between 0.5/d and 2.0/d during the calibration phase.

3.2 CSS Model

The combined sewer system (CSS) model used for this study is based on the Wet Weather Combined Sewer (WWCS) model developed to support Richmond's Long-Term Control Plan Re-Evaluation (Greeley and Hansen, 2002). This CSS model was recalibrated and revised by Greeley and Hansen (GH) between 2010 and 2015 as part of the Wastewater Collection System Master Plan (Greeley and Hansen, 2015). This version of the CSS model is currently used by the city to produce the Combined Sewer System Annual Reports. This CSS model relies on boundary forcings (operating rules, observed flow time series and control decisions) that makes it unsuitable for hindcasting extended time periods and modeling CSS operational alternatives.

The primary SWMM processes and parameters used in the CSS model are similar to the ones described in Section 3.1 above with the exception that the CSS model does account for evapotranspiration as part of the rainfall - runoff process and does not include any internal system pollutant loading (pollutant EMC are assigned to the outfall discharge only). During the CSS model calibration process, 7 local rain gages were used while the NCDC gage at Richmond Airport was used for the IRWMP, due to limited data availability and reliability of the 7 local rain gages.

To prepare the CSS model for use in this study, it was reviewed and modified by Brown and Caldwell, as described in the "CSO Model Review and Advancement Strategy" technical memorandum by Brown and Caldwell (Brown and Caldwell, 2016). As part of this work, the following major changes and modifications were done:

- Reduction of the number of pipe elements to focus on the main interceptor network and improve model stability. This reduced the number of model pipes from 2,357 to 1,019.
- Definition of standard operating procedures for the WWTP by replacing the flow boundary condition, which required an observed plant influent time series with a simple outflow pipe limited to the plant capacity (e.g. 75 MGD for the model calibration)
- Definition of standard operating rules to control the major facilities like the Shockoe Retention Basin and eliminating the need of an external time series forcing for flow boundary condition at this location.
- Elimination of various inactive control rules
- Reduction of the number of subcatchments (and receiving nodes) by deleting those that flow to the neighboring county collection system
- Reduction of the number of unit hydrographs describing the baseflow I & I conditions

These changes were necessary in order to be able to run the model in hindcast mode for a long-term continuous period, and in order to operate the model for evaluating CSS alternatives.

3.3 Receiving Water Quality Model

Site specific data supported the development of both the hydrodynamic and water quality components of the EFDC receiving water model. Bathymetric data from the current FEMA Flood Insurance Study (FEMA, 2014) and from a USACE survey of the estuarine reach (USACE, 2013) were averaged over the model grid. In the upper, riverine reach, a cross-sectional average bed elevation was computed for each row of grid cells. In the lower, estuarine reach, a DEM was computed from the detailed USACE elevation data and averaged over the model grid. The modeled James River bed elevation profile is illustrated in the figure below.

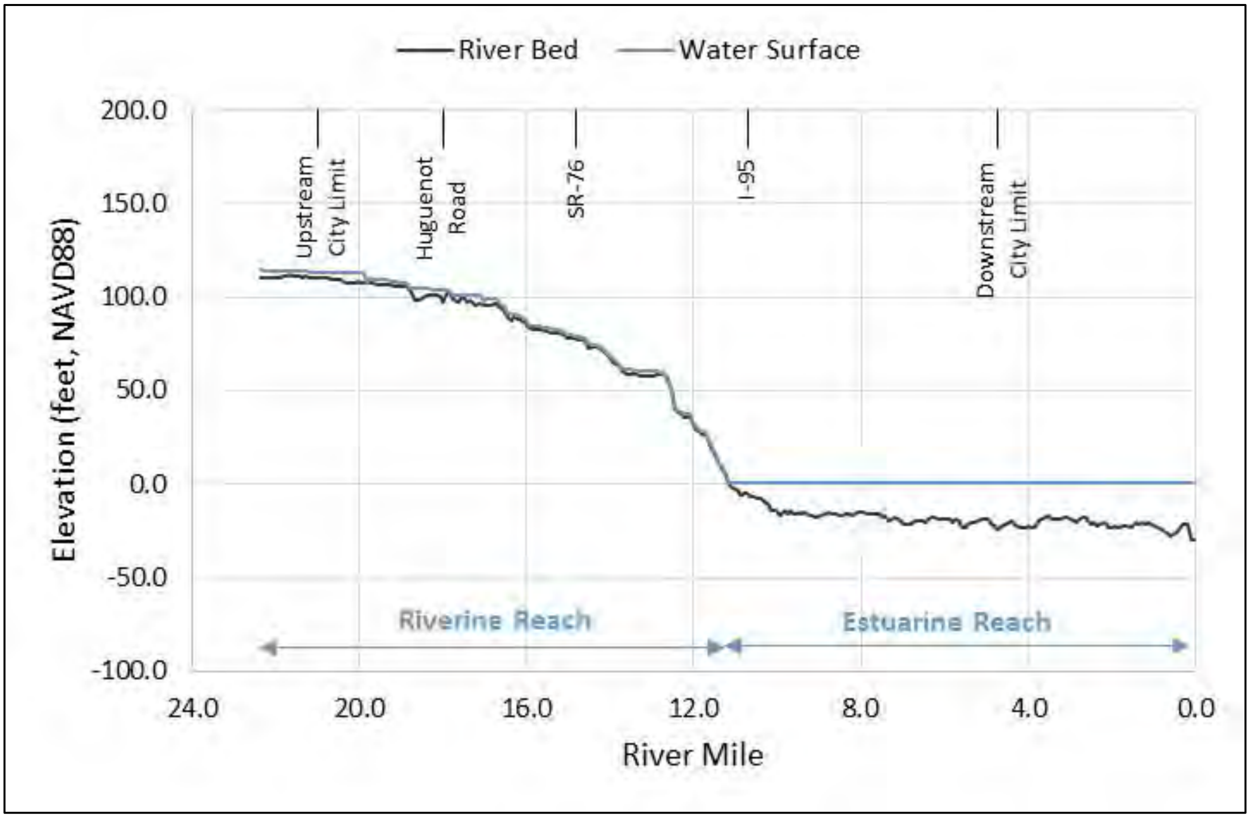


Figure 3-2: James River Elevation Profile

Tidal water levels from USGS Station #02037705 (James River at City Locks at Richmond, VA) were applied at the downstream boundary and the model was calibrated to adjust for the change in water levels between the gauging station and the downstream model boundary. This calibration, which is described in Section 4, accounts for differences in timing (phasing) of the tides between the two locations, and differences in non-tidal water levels associated with river flows.

Upstream James River flows from USGS Station 02037500 (James River near Richmond, VA) were directly applied at the upstream model boundary. For days when *E.coli* were sampled near the upstream boundary, these data were directly inputted to the model. For days when *E.coli* data were unavailable, upstream James River *E.coli* concentrations were estimated based on sampling data from a station at Huguenot Bridge. 112 samples at this location collected between 2011 and 2013 were used to develop a regression of flow and *E.coli* using the USGS LOADEST software package.

LOADEST is a program for "estimating constituent loads in streams and rivers" (USGS, 2017). The figure below illustrates the predicted relationship between James River flow and *E.coli* concentrations upstream of Richmond. The regression equation is as follows:

$$a_0 + a_1 * \ln Q + a_2 * lnQ^2 + a_3 * \sin(2pi * dtime) + a_4 * \cos(2pi * dtime)$$

Where:

- a_0, a_1, a_2, a_3, and a_4 are constants equal to 3.17, 1.27, 0.41, -0.79, and -0.04 respectively,
- Q is streamflow (cubic feet per second), and,
- dtime is time relative to the center time (days)

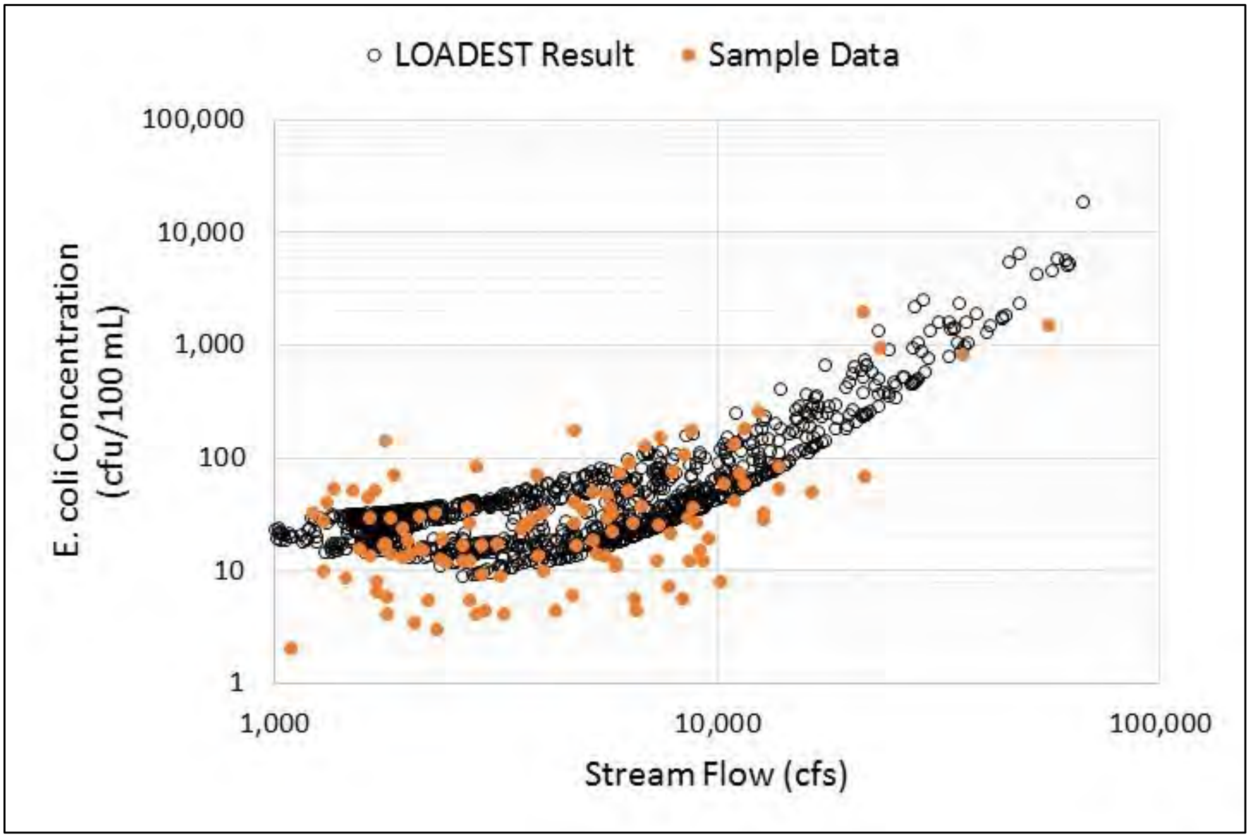


Figure 3-3: Regression of James River flow and *E.coli* concentration

Flows and *E.coli* concentrations associated with MS4 and watershed areas, and CSO discharges were computed from the watershed and CSS models, respectively. Flows and concentrations from the watershed model were input to EFDC at an hourly interval. Flows from the CSS model were input to EFDC at a five-minute interval due to the faster response time of the combined sewer system to rainfall relative to the watershed.

Fecal coliform event mean concentrations (EMCs) were previously calculated (and accepted by VADEQ) for the CSO discharges during the development of the Long Term Control Plan. These EMCs were calculated based on CSO outfall monitoring at several CSOs (Greeley and Hansen, personal communication, 11/15/2016). For this modeling effort, fecal coliform EMC concentrations were converted to *E.coli* concentrations using the VADEQ translator (Lawson, 2003). Table 3-7 summarizes the original fecal coliform EMCs and the translated *E.coli* values.

Consistent with the Long Term Control Plan, all influent to the WWTP was assumed to have an *E.coli* concentration of 235,000 CFU/100mL. It was assumed that influent receiving full treatment would result in an effluent concentration of 126 CFU/100 mL, consistent with the effluent concentration guidelines in the VAPDES permit (#VA0063177). For model application scenarios in which WWTP wet weather flow upgrades are proposed, effluent discharge concentrations were estimated based on the methods described in Section 5.

Table 3-7: Summary of fecal coliform and *E.coli* CSO EMCs				
CSO Districts	**CSO Drainage Areas**			
	Outfall Serial No.	**Outfall Location**	**Fecal Coliforms (#/100 mL)**	***E.coli* (#/100 mL)**
South Side James River Park	018	42nd Street	986,775	318,000
	017	Reedy Creek	986,775	318,000
	016	Woodland Heights	986,775	318,000
	015	Canoe Run	986,775	318,000
	040	CSO-1 OUT/SSJRP	986,775	318,000
North Side James River Park	011	Park Hydro	437,343	150,000
	010	Gambles Hill	437,343	150,000
	009	Seventh Street	437,343	150,000
	(008)[a]	(Sixth Street)[a]	437,343	150,000
	007	Byrd Street	437,343	150,000
	(036)[b]	(Virginia Street)[b]	437,343	150,000
Manchester Area (WWTP Area)	014	Stockton Street	86,266[d]	34,000
	013	Maury Street	86,266[d]	34,000
	021	Gordon Avenue	86,266[d]	34,000
Gillies Creek	005	Peach Street	612,230	205,000
	002	Orleans Street	612,230	205,000
	004	Bloody Run	612,230	205,000
	003	Nicholson Street	612,230	205,000
	(023)[c]	(Old Fulton Street Bridge)[c]	612,230	205,000
	024	White and Varina Streets	612,230	205,000
	025	Briel Street and Gilles Creek	612,230	205,000
	026	1250 feet east of Government Road	612,230	205,000
	(027)[c]	(Williamsburg Road and Gillies Creek)[c]	612,230	205,000
	028	800' North of Nicholson Street	612,230	205,000
	035	25th and Dock Streets	612,230	205,000
	039	550 feet Downstream from Government Road	612,230	205,000
Shockoe Creek	006	Shockoe Creek	315,369[d]	111,000
	034	19th and Dock Street	315,369[d]	111,000
Remote Locations	020	McCloy Street	647,000	215,000
	019	Hampton Street	647,000	215,000
	033	Shields Lake	647,000	215,000
	012	Hilton Street	647,000	215,000
	031	Oakwood Cemetery	647,000	215,000

4 Model Calibration

Model calibration is the process of adjusting model parameters and assumptions within defensible ranges to achieve reasonable agreement between modeled and observed conditions. Model parameters and assumptions are set to the extent possible based on site specific data. However, in some cases, calibration is necessary because site specific data are either limited or unavailable. The calibration process fine-tunes these parameters, within reasonable bounds, to improve model calculations.

4.1 Calibration Data

The calibration process relies heavily on site-specific data to guide the tuning of model inputs. Site specific data support identification of important spatial patterns or time trends in environmental conditions. These patterns often lend insights into the processes or sources most strongly influencing environmental conditions. In this way, the model calibration process involves interpreting site data to understand and bring the model into agreement with important conditions. Site data vary in their capacity to support such an interpretation depending largely on their quantity and locations. The following sections describe the site specific data available for calibration of the modeling framework and also describe the interpretation of these data.

4.1.1 Watershed Model

4.1.1.a Hydrology

The hydrology calibration for the watershed model relied on data from Falling Creek (USGS #02038000), which was the only continuous flow and water depth gage within the modeled area (

Figure 2-2). Daily average flow data was available from 1955-1994. It was assumed that calibrated parameters related to in-channel roughness, overbank roughness, and impervious area would be similar between Falling Creek and the remainder of the watershed. This assumption seems reasonable based on a comparison of key watershed characteristics that influence runoff, including impervious area, slope, and soil infiltration, in Falling Creek versus the other model subcatchments. This comparison is shown in the table below.

Table 4-1: Median value of key runoff parameters in Falling Creek compared to the rest of the model subcatchments

Key Runoff Parameter	Median Value in Model Subcatchments	Median Value in the Falling Creek Subcatchment
% impervious area	26%	22%
% slope	5%	7%
Min infiltration	2.5	2.7
Max infiltration	0.161	0.178

4.1.1.b Water quality

The selected water quality calibration period was calendar years 2011 through 2013. This time period had the greatest quantity of sampling data available and the greatest range of *E.coli* results, including high values that would be indicative of wet weather source impacts. Seven stations on five different tributaries were chosen to evaluate the water quality calibration (Table 4-2). Station selection was based on the quantity of available data during the calibration period, the proximity of the station to the mouth of the stream, distribution of stations in the model extent, and the size of the tributary. Stations near stream mouths were selected because they more accurately reflect the total *E.coli* load delivered to the James River for each tributary. Stations representing a varied spatial distribution and a variety of sizes were selected to evaluate the robustness of the calibrated parameters.

Table 4-2: Water quality monitoring stations used for watershed model calibration

Tributary	Station ID	*E.coli* Data (#)
Falling Creek	399/400	30
Cornelius Creek	1310	15
Powhite Creek	1100	12
Upham Brook	4	14
Upham Brook	2	7
Reedy Creek	1235/RC1	6

Similar to the hydrology calibration, the water quality calibration was limited by the available data. Because of the data limitations, the water quality calibration was viewed not so much as a definitive calibration, but as a reasonable estimate of tributary loads and their timing so that calibration of the James River receiving water quality model could move forward. If necessary, the watershed model calibration would be revisited if the results from the receiving water quality model indicated it was necessary. The final calibration of the watershed model would be considered complete once the water quality calibration of the James River model was complete. After initial tuning of the watershed model water quality parameters, tributary *E.coli* loads were passed forward to the James River receiving water model. The effect of these tributary loads on James River water quality was assessed through calibration of the James River model which is further described in 4.4.

Water quality data in the tributaries were limited in their capacity to describe wet weather conditions. Most of the data collected appeared to be sampled during dry weather periods, a time when *E.coli* concentrations are expected to be low. Additionally, for almost all stations, samples were collected once per day, and therefore do not capture the temporal variability of bacteria (also known as the "pollutograph") that is expected during a rainfall event.

4.1.2 CSS Model

The CSS model was calibrated by Greeley and Hansen in 2015 during the initial model development as described in the CSS model documentation of the Waste Water Collection System Master Plan (Greeley and Hansen, 2015). The calibration was done using monitoring data from 16 flow meters, 7 rain gauges, and one river level sensor near outfall CSO 06 (Figure 2-3). The monitoring period lasted 11 months, from July 2012 to June 2013. Several issues related to the metering were identified in the report, and not all data collected was suitable to be used for model calibration. Ten (10) wet weather events were selected from the monitoring period to perform the wet weather calibration.

4.1.3 Receiving Water Quality Model

The hydrodynamic calibration period for the James River receiving water quality model was calendar years 2011 through 2013. This is the same period used for the water quality calibration, and includes a wide range of James River flow conditions. Data from two USGS stations supported the hydrodynamic model calibration: one in the riverine reach (Station 02037500 at Huguenot Bridge) and one in the estuarine reach (Station 02037705 at the City Locks). Data from the riverine USGS station quantify the change in stream depth and velocity with river flow. Data from the estuarine USGS station quantify the amplitude and phasing of tidal water levels.

The water quality calibration period for the James River receiving water model was calendar years 2011 through 2013. As shown in Figure 4-1, this period contains nearly the greatest density of sampling data in the James River. It also represents a typical range of flow and precipitation conditions. While calendar year 2010 had the highest sample count, several of the samples resulted in non-detected *E.coli* concentrations so they were less informative for the model calibration.

Data from the six locations with the greatest quantity of samples with detectable *E.coli* concentrations guided the calibration. Three of these locations occur in the riverine reach and three occur in the estuarine reach. One station (#753) is upstream of all Richmond sources, two are near downtown Richmond and are influenced by CSOs (#641 and #840), and the remaining three are downstream of CSOs and beyond Richmond (#576, #574, and #572). These stations are shown in Figure 2-4.

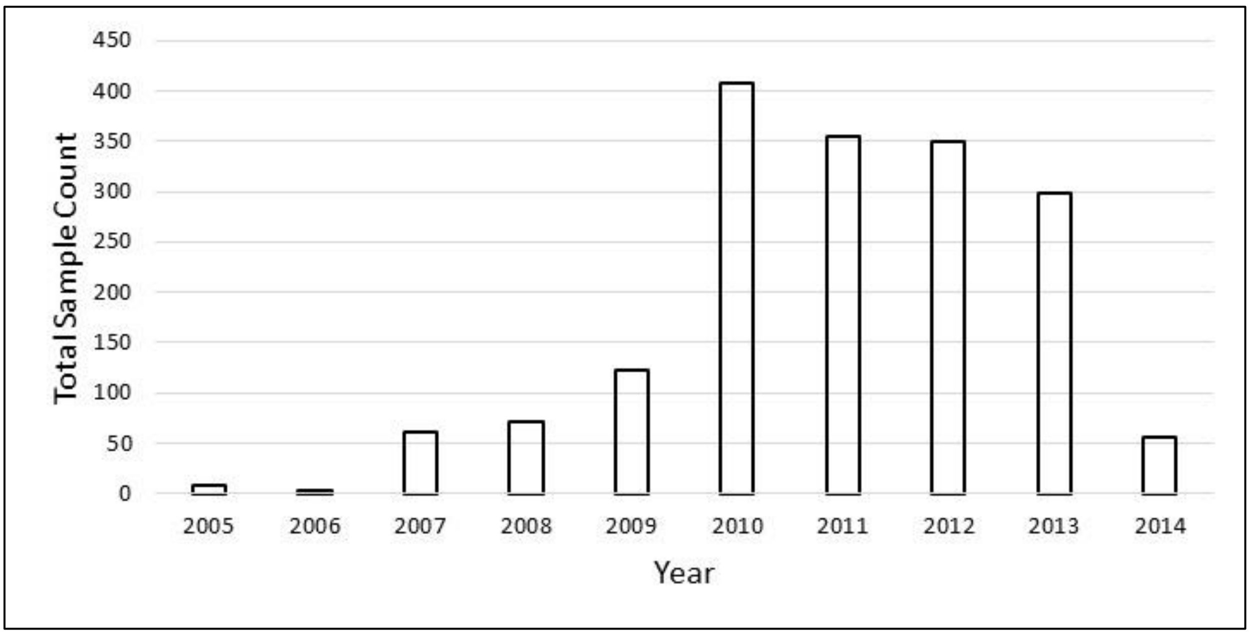


Figure 4-1: James River E.coli Water Quality Sample Count by Year

The calibration data were analyzed to identify patterns in water quality along the James River that would guide model calibration. Three significant observations were made. First, dry weather *E.coli* concentrations increase significantly moving from the upstream most station at Huguenot Bridge (station

753) to the downtown area (station 840).

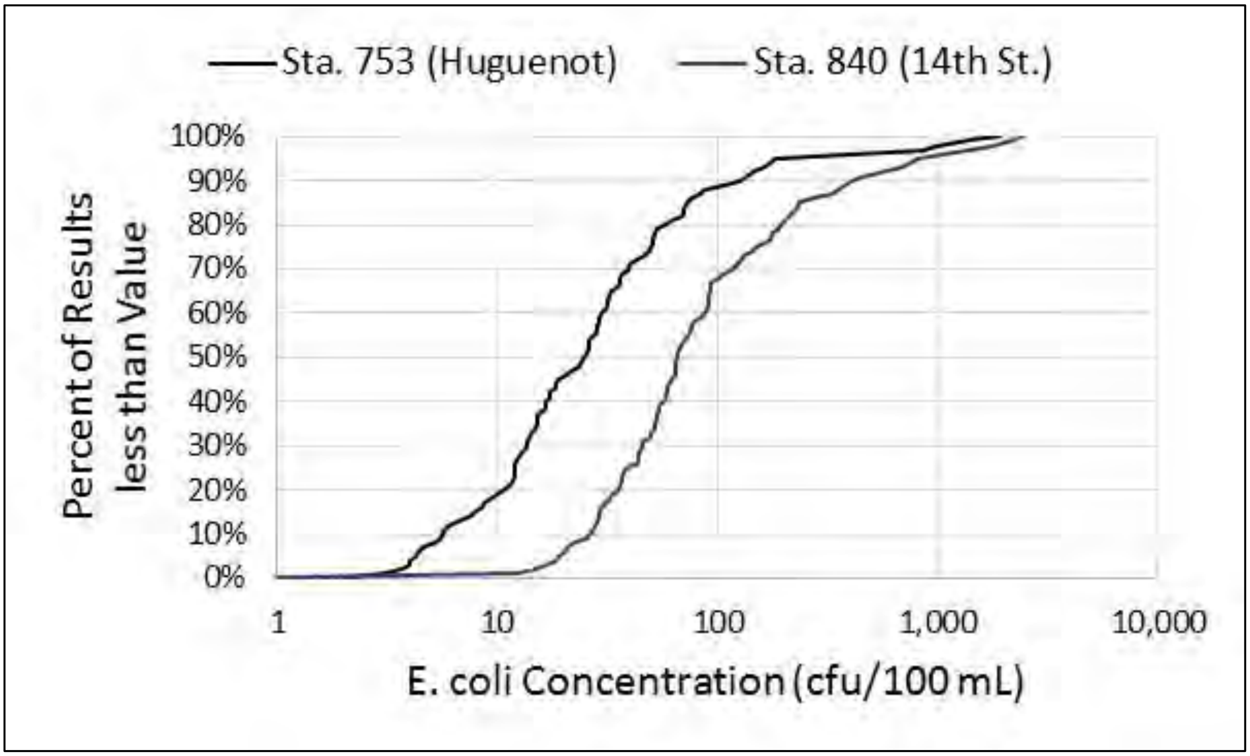


Figure 4-2 compares cumulative frequency distributions (CFDs) at the upstream station and a station near downtown. Median (50th percentile) *E.coli* concentrations increase from 25 to 66 CFU/100 mL, indicating a significant persistent source of *E.coli* to the river between these locations.

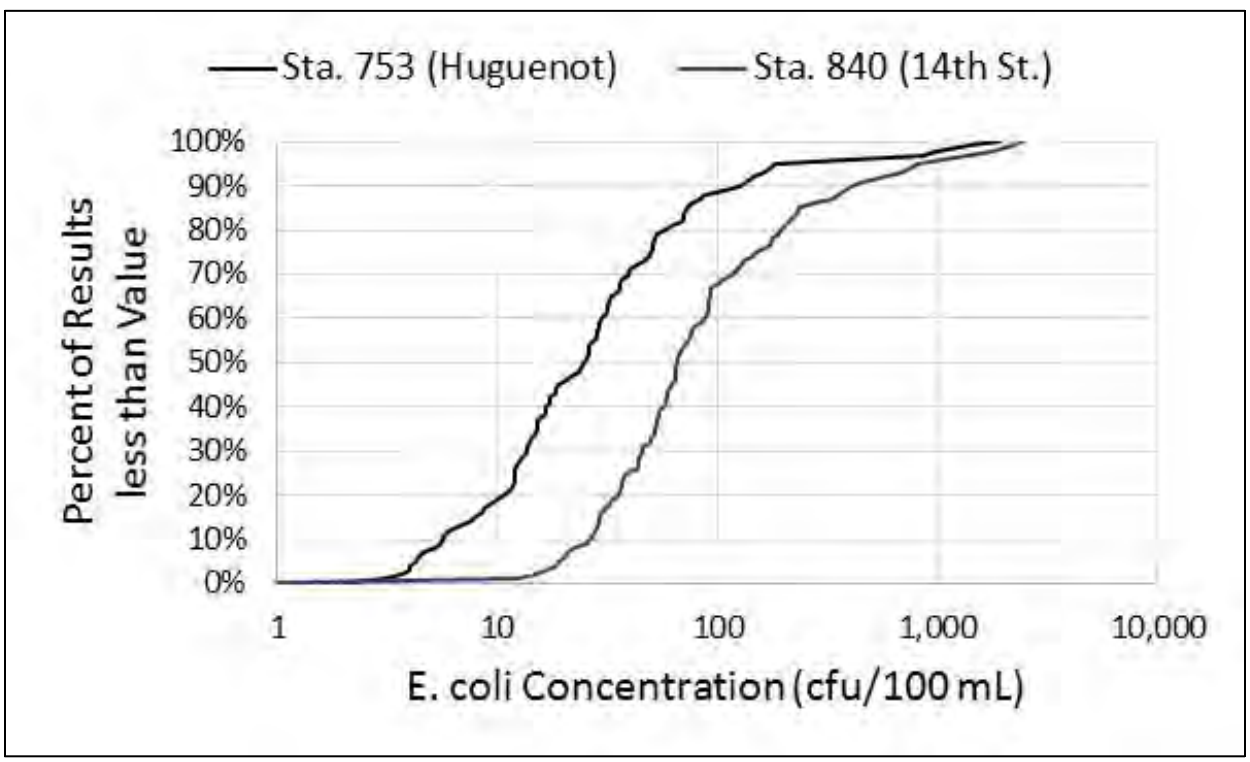


Figure 4-2: Increase in *E.coli* Concentrations from Huguenot Bridge to 14th St. Bridge

Second, *E.coli* concentrations are similar among station 840 on the south side of Mayo Island at 14th Street and stations 576, 574, and 572 which occur farther downstream in the estuarine reach.

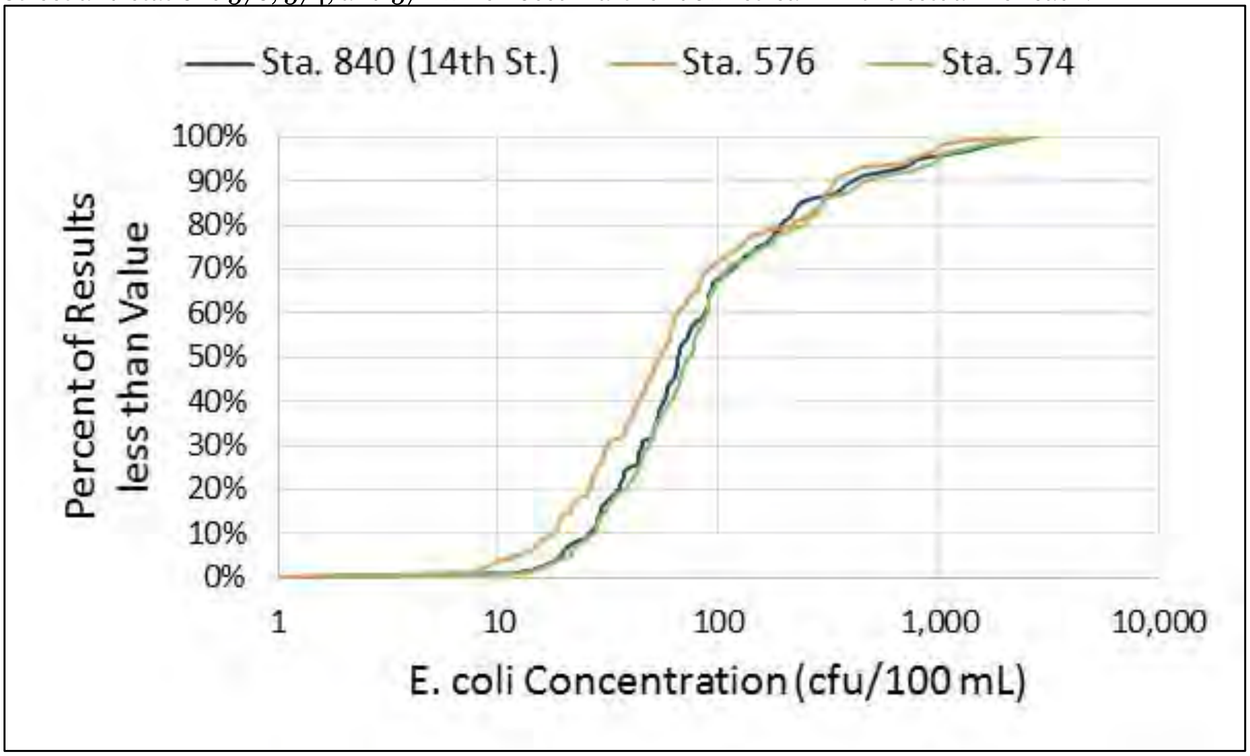


Figure 4-3 compares the cumulative frequency distributions (CFDs) among these stations. Similarities in the *E.coli* concentrations among these stations indicate that, most of the time, additional pollutant loads downstream of station 840 and on the north side of Mayo Island are small relative to the upstream *E.coli* load. Similarity in *E.coli* concentrations at these three locations also indicates that in-stream losses of bacteria are minor between stations 840, 576, and 574. Median (50th percentile) E.coli concentrations at stations 840, 576, and 574 are 66, 74, and 55 CFU/100 mL respectively.

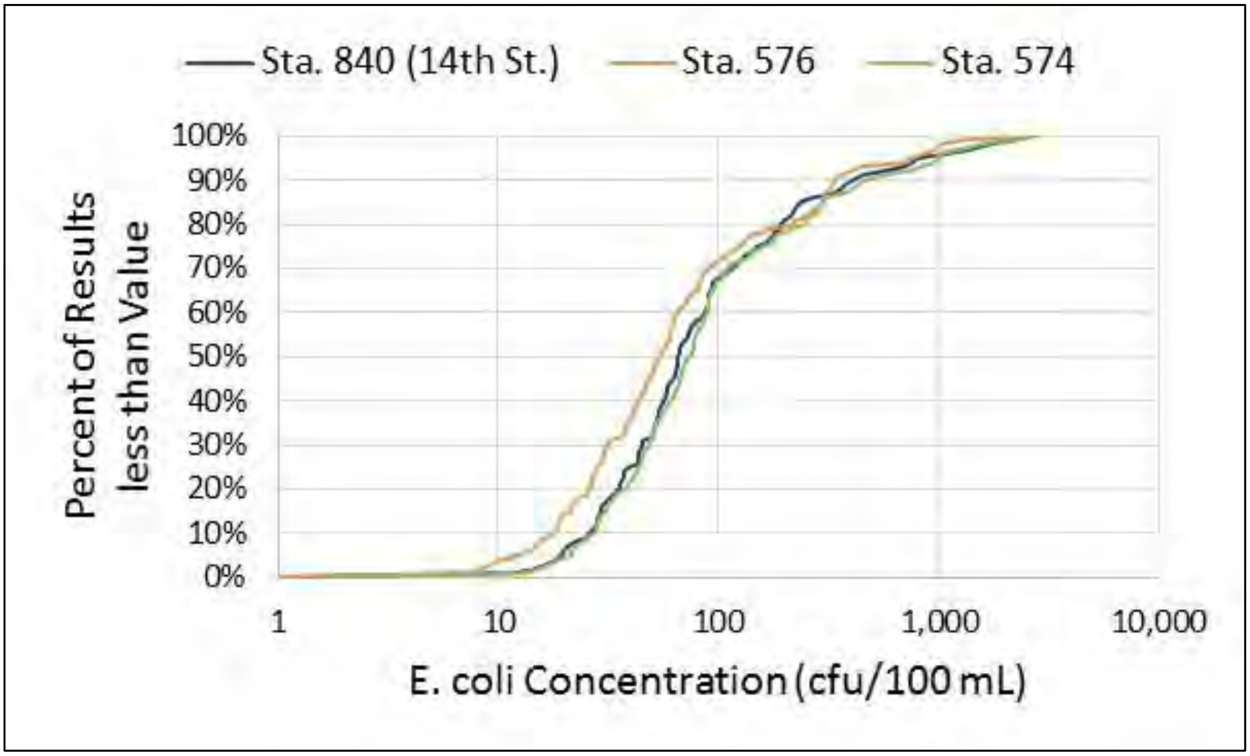


Figure 4-3: Similarity in *E.coli* Concentrations among Stations 840, 576, and 574

Third, *E.coli* concentrations at station 641 are significantly higher than at stations 840, 576, 574, and 572 and are assumed to be unrepresentative of ambient conditions on the north side of the island. If these data were representative of the total flow north of the island, then *E.coli* concentrations at downstream stations would be higher than data at station 841 on the south side of the island. Given the similarity in concentrations between stations 841, 576, and 574, it is assumed that samples at station 640 are not representative of the broader river flow north of the island. Samples at this location were taken within a protected embayment that receives discharge from CSO 06 (Shockoe Retention Basin discharge). The protected embayment may have flow properties different from the main section of James River (e.g. sheltered location, stagnant water, little flushing from the James River, direct CSO discharge) that may relate to the unrepresentatively high *E.coli* concentrations observed there.

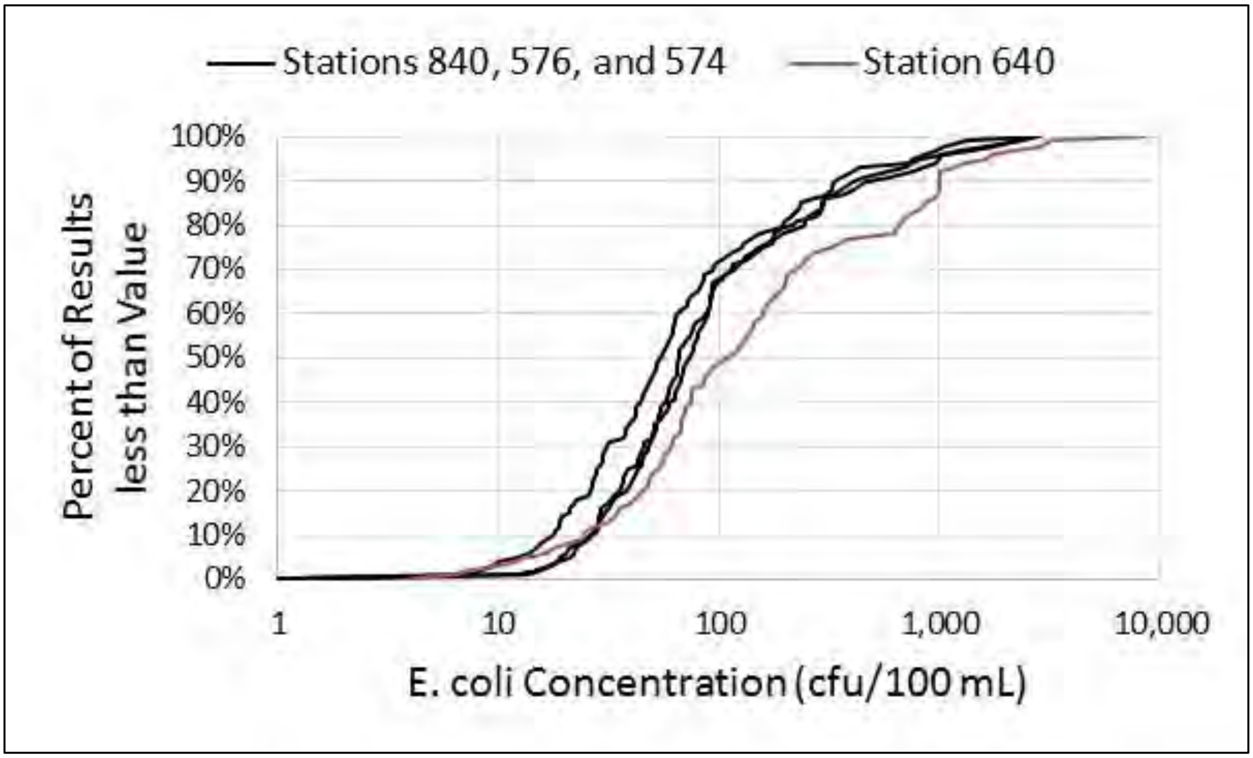


Figure **4-4** illustrates differences between *E.coli* concentrations at station 640 and the surrounding stations.

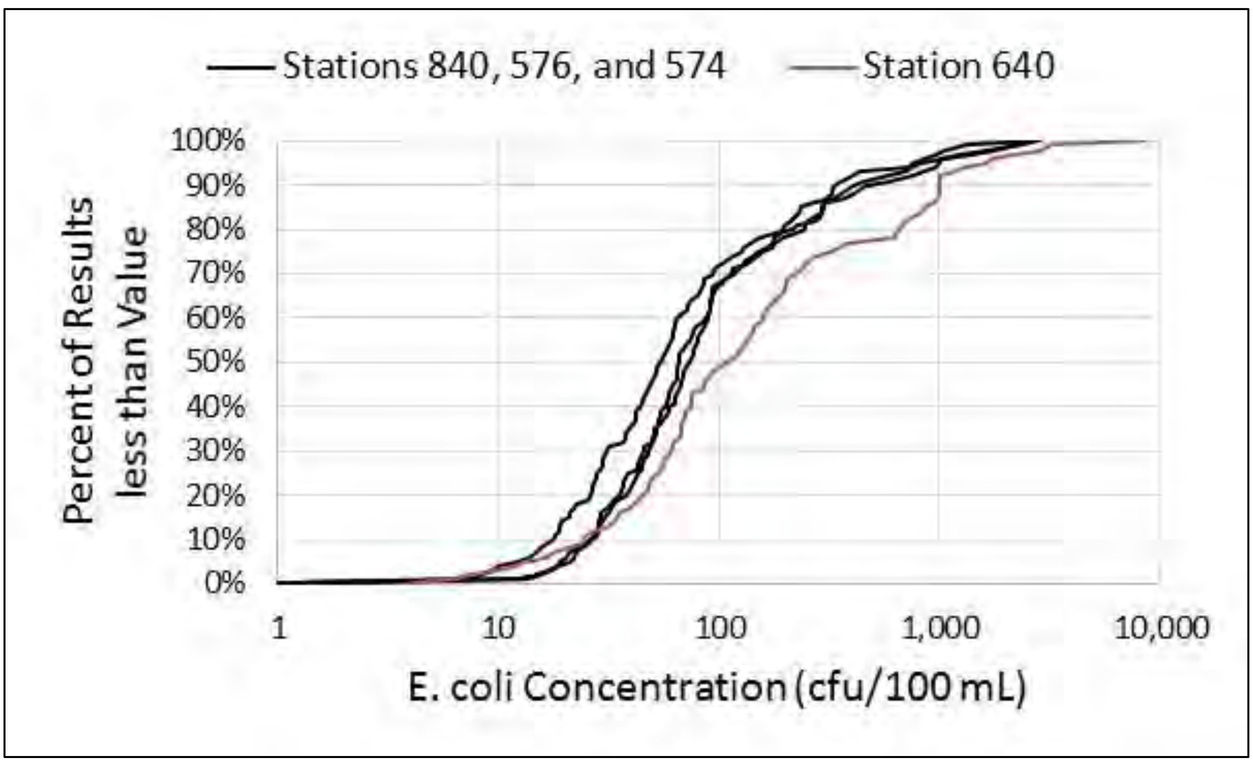


Figure 4-4: Differences in *E.coli* Concentrations between station 640 and other surrounding stations

These observations from the data represent the understanding of water quality patterns that guided James River water quality model calibration decisions, which are further described in the sections below.

4.2 Model Evaluation and Performance Criteria

Model evaluation and performance criteria are principles and standards for evaluating the success of a model calibration. In some cases, statistical evaluations of model output are useful in that they can be related to industry standards. In other cases, reliable statistical standards are unavailable and model calibration is guided primarily by visual evaluation of graphics comparing model and data. Considerations that guided the model calibration process are described for each model below.

4.2.1 Watershed Model

The evaluation of the hydrology calibration involved statistical and visual comparisons between the modeled flows at the outlet of the upstream portion of the Falling Creek watershed and observed flows at the Falling Creek USGS gage. Annual and cumulative modeled flow volume were evaluated. Comparisons were also made between model results and gaged flows for 18 individual storm events. For each event, model results were qualitatively and statistically evaluated based on the shape of the hydrograph, total event volume, and event peak flows.

The evaluation of the water quality calibration relied upon graphical summaries of model results. These summaries included boxplots, cumulative frequency distributions, and one-to-one plots of model results versus observed data. The primary calibration parameters were pollutant build-up and wash-off, baseflow concentration of *E.coli*, and in-stream *E.coli* decay rate. Due to the lack of available water quality data, the final calibration of the watershed model was completed as part of the water quality calibration for the James River EFDC model.

4.2.2 CSS Model

The performance evaluation of the original Wet Weather Combined Sewer (WWCS) model was conducted by Greeley and Hansen and included visual comparisons of flow hydrographs for individual wet weather events at the metering locations as well as 1:1 plots for comparisons of wet weather event flow volume and peak flows. The model evaluation is described in the Collection System Hydraulic model report of the Wastewater Collection System Master Plan by GH (Greeley and Hansen, 2012).

Brown and Caldwell evaluated the adjusted Clean Water Plan version of the CSS model (described in Section 3.2) against available flow observations as well as the underlying WWCS model by GH and the comparison described in detail in the IP Model Development documentation (Brown and Caldwell, 2016). This includes flow comparisons for individual wet weather events at meter locations (against observations) as well as volumetric comparisons at CSO locations on an event and annual basis against the WWCS model.

4.2.3 Receiving Water Quality Model

Evaluation of the hydrodynamic model performance relied on graphical summaries of model output. In the riverine reach, modeled depths and velocities were plotted against modeled discharge and compared against observed depths and velocities plotted against observed discharge. These relationships of depth and velocity versus discharge are strongly influenced by the hydraulic characteristics of the James River including bed slope, width, and channel roughness. In the estuarine reach, the model was evaluated using two other graphic types: time series and one-to-one plots. These tools were used to assess the phasing and amplitude of the modeled tides and the effect of river flows on water levels in the estuarine reach.

Evaluation of the water quality model performance also relied on graphical summaries of model output, including time series plots and cumulative frequency distributions (CFDs). Emphasis was placed on evaluating the model's consistency with elevated *E.coli* concentrations which would most significantly influence compliance with water quality standards.

4.3 Hydrology and Hydrodynamics Calibration Results

Hydrology and hydrodynamics describe the quantities and rates of water moving through a system. In the James River water quality modeling framework, this includes movement of storm runoff from the watershed into and through tributaries and storm water sewers, movement of water and wastewater into and through the combined sewer system and through the wastewater treatment plant and combined sewer overflows, and movement of water into and through the James River. Calibration of hydrology and hydrodynamics is important in that it strongly influences the concentrations and persistence of pollutants in an environmental system.

4.3.1 Watershed Model

The purpose of the hydrology calibration was to: 1) reasonably approximate the volume and timing of observed flows in Falling Creek and 2) develop hydrologic parameters that could be used for all subcatchments and stream channels in the watershed model extent. In the absence of robust site-specific data, it was assumed that all subcatchments and stream channels in the model would have similar hydrologic properties. This assumption was considered reasonable because median values are similar for subcatchment parameters, such as impervious area, percent slope, and soil properties between the gaged portion of the Falling Creek watershed and the other watersheds included in the model extent. The model was run for calendar years 1985 to 1994, and modeled cumulative flows and storm event hydrographs were compared to observed flows at the USGS gage. Subcatchment percent impervious area and stream channel roughness values were adjusted to bring the modeled results into alignment with observed values.

On a cumulative basis, the model results reasonably match observed flows for all years until spring of 1993 and spring of 1994 (Figure 4-5).

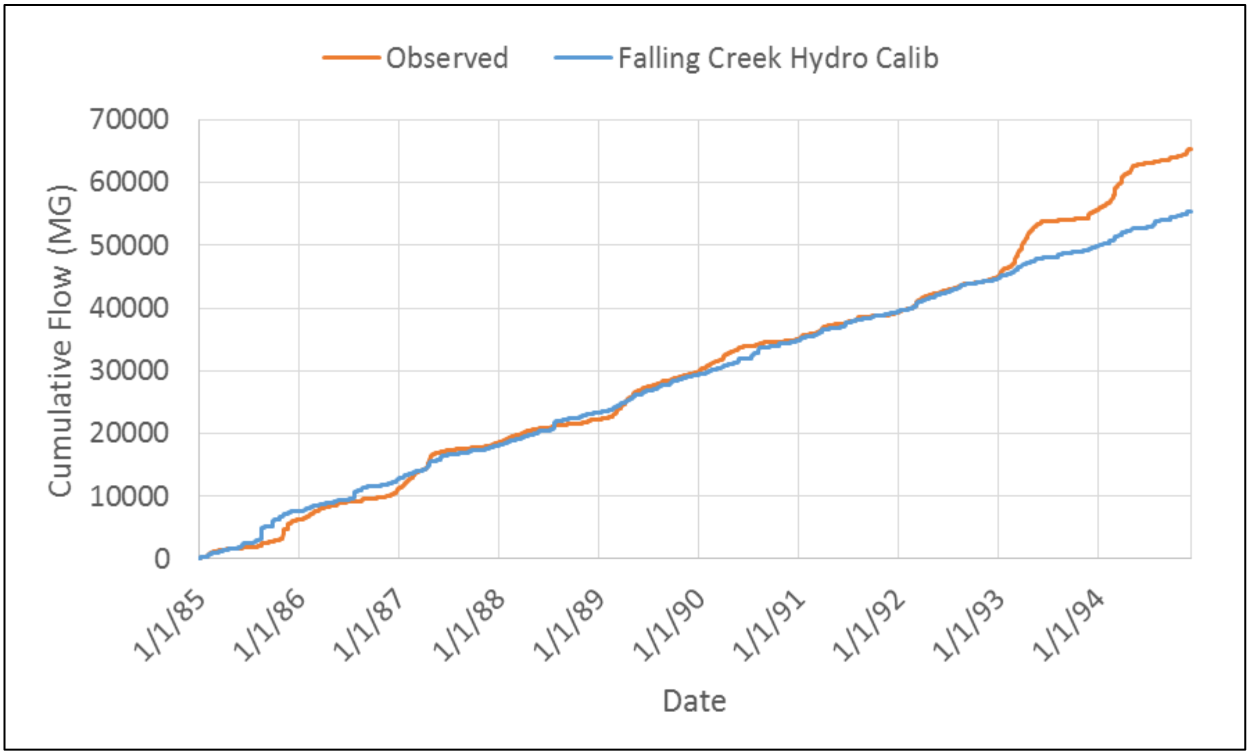


Figure 4-5: Observed and Modeled Cumulative Flow Volume at the Falling Creek Gage

For the period 1985 to 1994, the model underpredicted observed flows by approximately 15%. However, when the flows from 1993 and 1994 were excluded, the difference in cumulative volume between modeled and observed flows decreased to -0.5% (Table 4-3). The cause for the 1993 and 1994 increases in observed flows are unknown, but similar increases were observed in four other USGS gages in the region: Totopotomoy Creek near Studley, VA (USGS 01673550); James River near Richmond, VA (USGS 02037500); Appomattox River at Mattoax, VA (USGS 02040000); and Chickahominy River near Providence Forge, VA (USGS 02042500), indicating that this is not merely an instrumental problem at a single gage (Figure 4-6). Variations could be attributable to differences in rainfall in the Falling Creek watershed and at the Richmond Airport, which are approximately 11.7 miles apart as the crow flies.

Table 4-3: Observed and Modeled Annual Flow Volumes at the Falling Creek Gage

Year	Observed Total Annual Flow (MG)	Modeled Total Annual Flow (MG)	Percent Difference Between Modeled and Observed
1994	9,614	5,584	-41.9%
1993	10,740	5,181	-51.8%
1992	5,678	5,209	-8.3%
1991	4,214	4,609	9.4%
1990	5,253	5,521	5.1%
1989	7,566	6,110	-19.2%
1988	3,677	5,143	39.9%
1987	7,435	5,417	-27.1%
1986	4,875	5,066	3.9%

Table 4-3: Observed and Modeled Annual Flow Volumes at the Falling Creek Gage			
Year	Observed Total Annual Flow (MG)	Modeled Total Annual Flow (MG)	Percent Difference Between Modeled and Observed
1985	6,262	7,639	22.0%
OVERALL	**65,313**	**55,477**	**-15.1%**
OVERALL (excl. '93-'94)	**44,959**	**44,712**	**-0.5%**

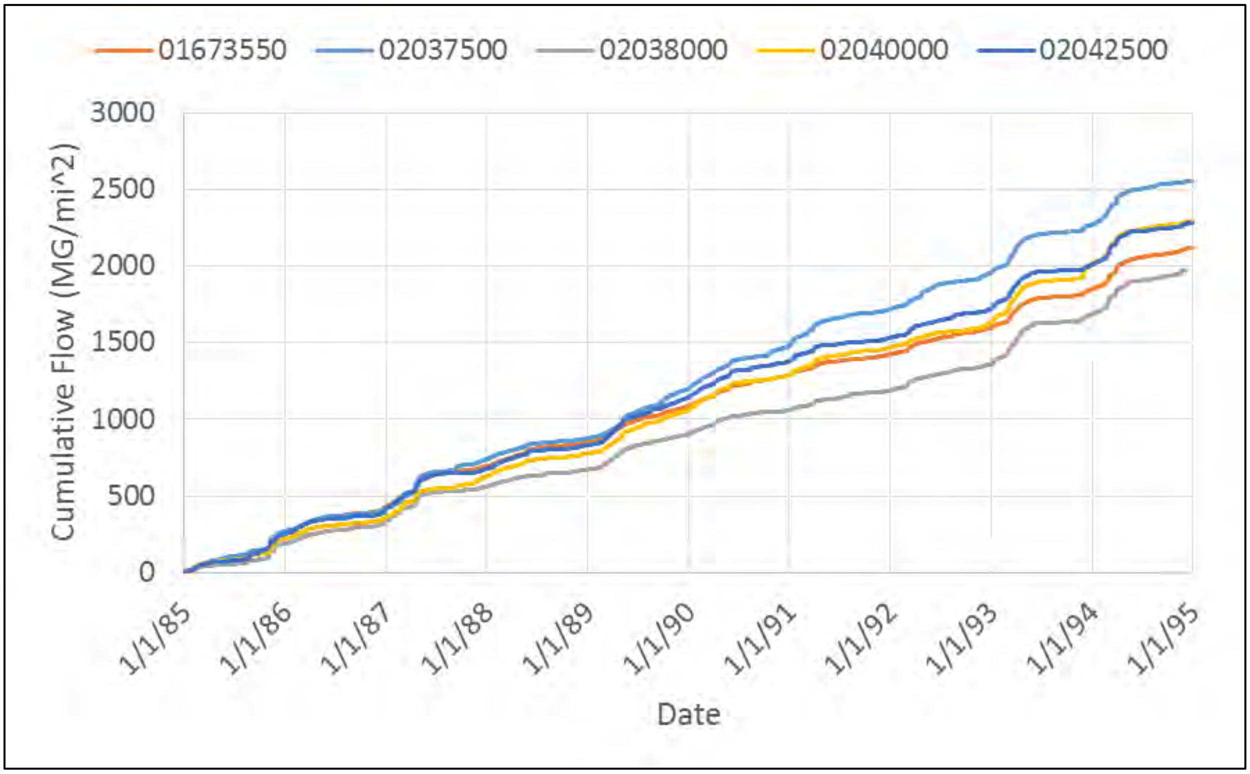


Figure 4-6: Area Normalized Cumulative Flow Volume for USGS Gages in the Richmond Region

On an event basis, model results tend to over predict event volumes and peak flows (Figure 4-7 and Figure 4-8), but the general shape of the hydrographs tend to match (Figure 4-9). The model currently only uses precipitation from one gage at Richmond International Airport (RIA). Variations on an event basis could be attributable to differences in rainfall in the Falling Creek watershed and at the Richmond Airport, which are approximately 11.7 miles apart as the crow flies.

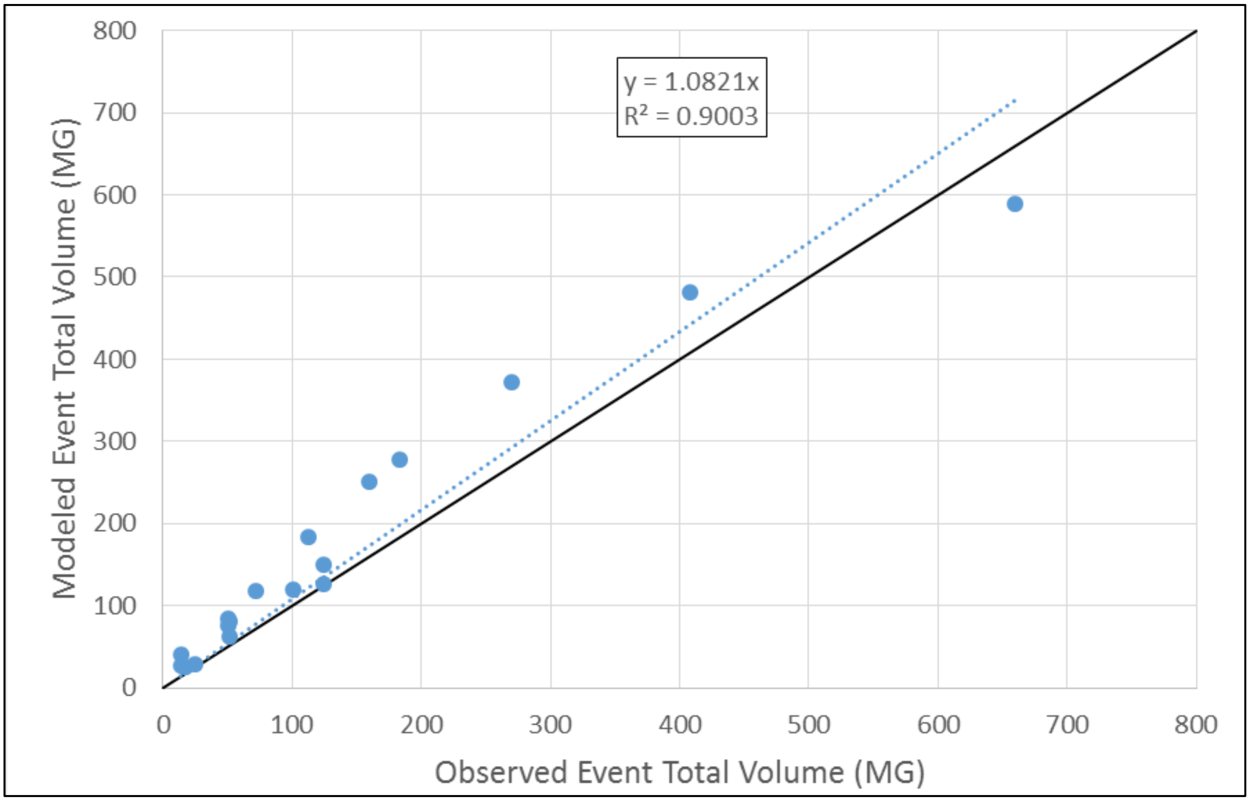


Figure 4-7: Modeled vs Observed Event Volume

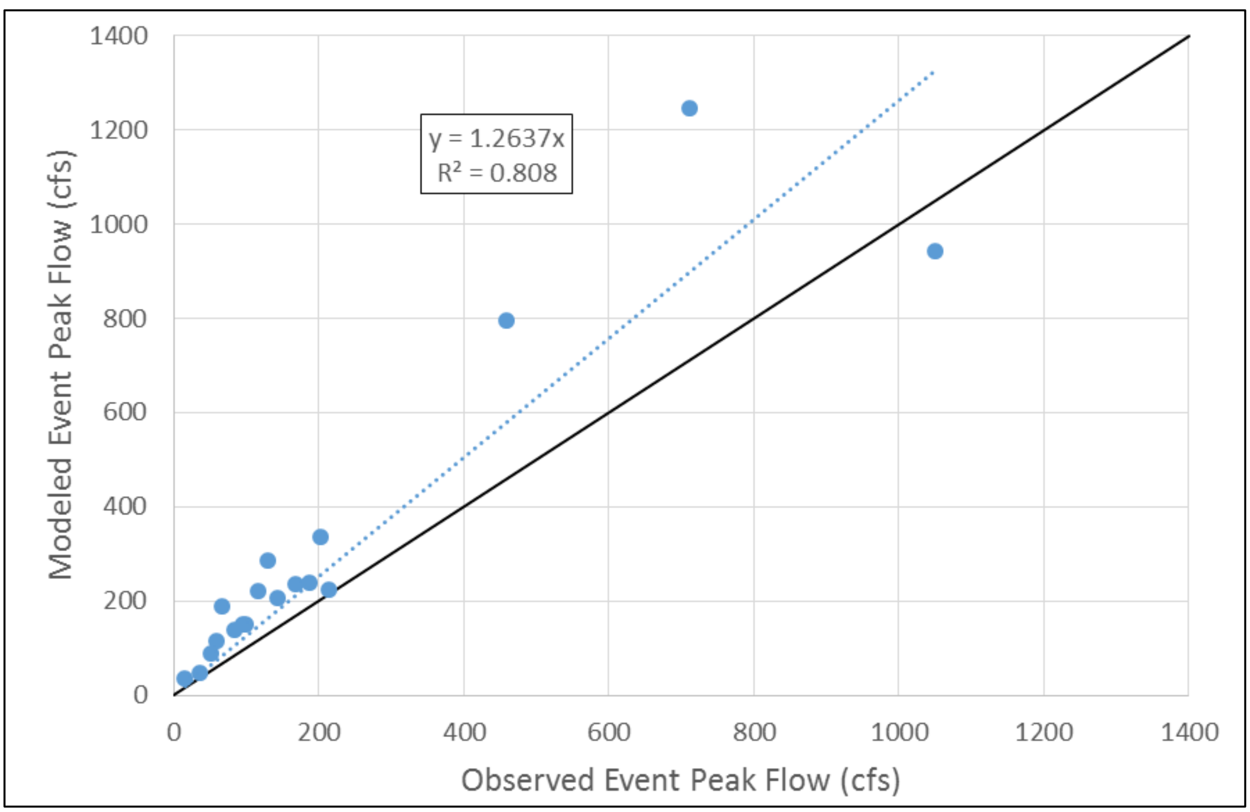


Figure 4-8: Modeled vs. Observed Event Peak Flow Rate

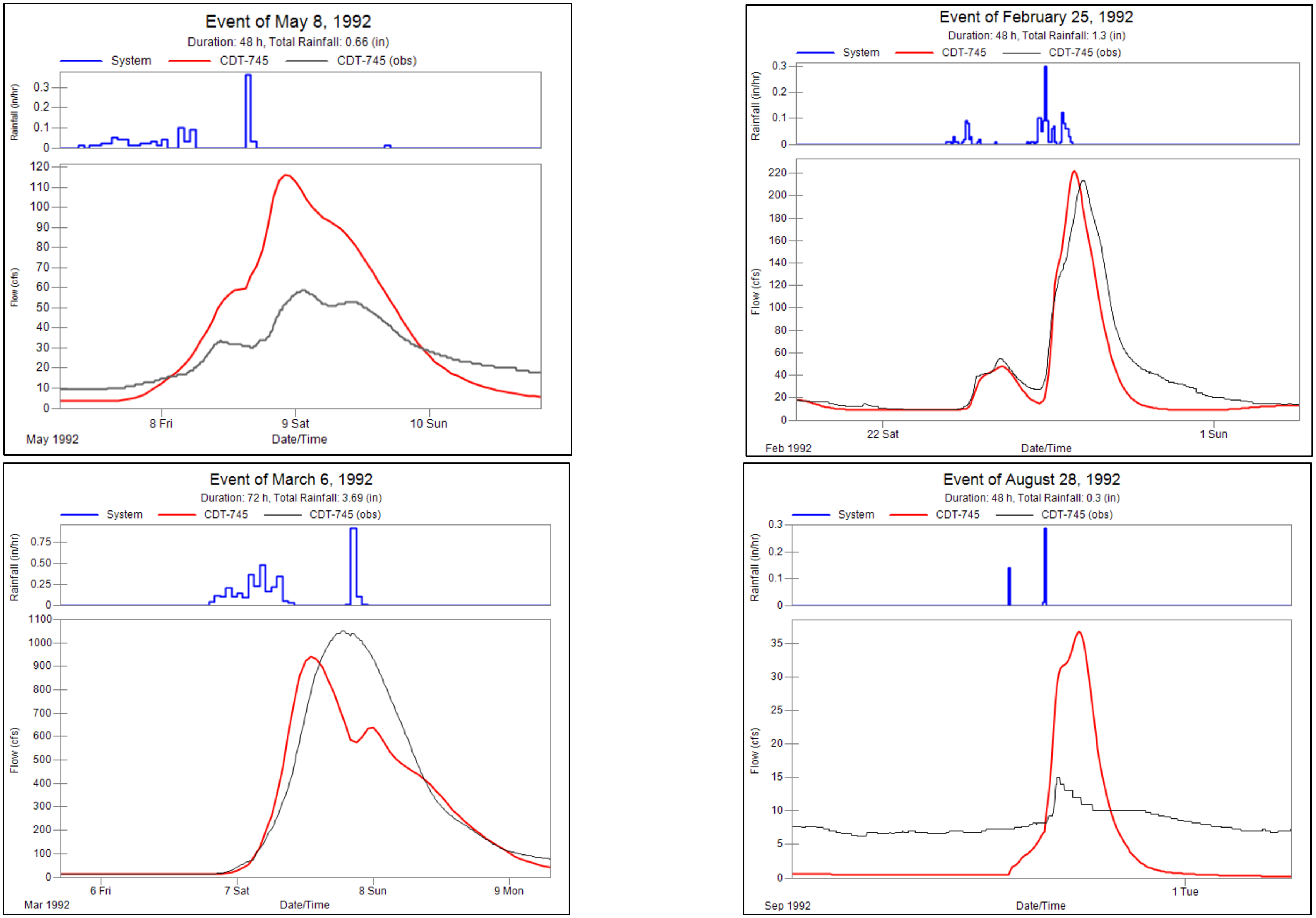


Figure 4-9: Modeled vs Observed hydrographs for four events at Falling Creek Gage

Three calibration parameters were used to adjust cumulative volumes, event volumes, and event peak flows: percent impervious area, Manning's N for in-channel roughness, and Manning's N for overbank roughness. Adjustments to modeled cumulative volume were made by adjusting the percent impervious area. Adjustments to event peak flows and the timing of peak flows were made by adjusting in-channel and overbank Manning's values. Manning's N for in-channel roughness was varied between 0.035 and 0.05 for a main channel that was assumed to be clean, winding and have some pools and shoals. Manning's N for overbank roughness was varied between 0.04 and 0.08 for overbanks that were assumed to have light brush and trees (Chow, 1959).

Impervious area is not typically a calibrated parameter, but initial model runs underestimated observed cumulative flows (dotted green line in Figure 4-10). To determine the cause of the underestimated flows, NLCD impervious cover data were compared to a planimetric impervious layer provided by the City of Richmond. The analysis revealed that the NLCD impervious layer underestimated the median percent impervious area, especially in less urban areas. To correct the underestimation of impervious area a linear regression was used to adjust the NLCD impervious area upwards for consistency with the planimetric data (dotted blue line in figure below). Finally, because the amount of directly connected impervious area is not known, the percent impervious area for each subcatchment was adjusted downward to account for impervious areas that are not directly connected to a waterway (solid blue line in figure below). Results from each run are summarized in Figure 4-10.

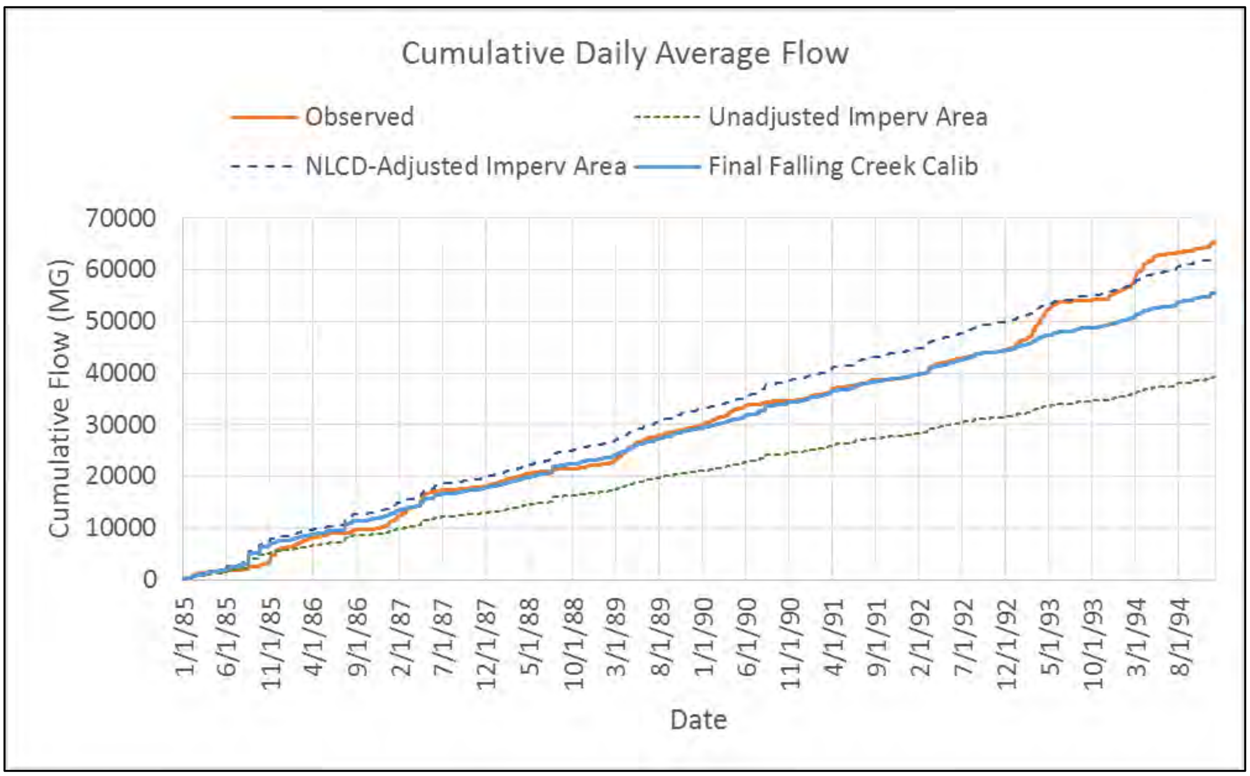


Figure 4-10: Model calibration results (impervious area)

4.3.2 CSS Model

The CSS calibration of the original Wet Weather Combined Sewer (WWCS) model focused both on achieving the appropriate volume and peak flows within the sewer system and on characterizing the discharge at the combined sewer outfalls, specifically at CSO 06 (Shockoe Retention Basin). While calibration within the sewer system was deemed acceptable and representative of conditions at that time, calibration at the Shockoe Retention Basin was more difficult to achieve due to the complex hydraulic situation in this area as well as to the manual overflow operations that occur at this location (Greeley and Hansen, 2015).

The original WWCS model was modified and adapted so that it could be used in hindcast mode for a long-term continuous period, and in order to operate the model for evaluating CSS alternatives. After the modifications, the performance of the resulting CSS IP model was checked against monitoring data as well as against the results from the underlying original WWCS model. A discussion of the results is included in the CSS model review memorandum (Brown and Caldwell, 2016). Overall, the CSS IP model predicts lower overall CSS volume discharges and events compared to the results documented in the 2002 LTCP re-evaluation report, as well as compared to the CSS Annual Reports. These differences can be attributed to two main reasons:

- Numerous changes to the CSS model were performed since the 2002 LTCP re-evaluation, and the CSS model was re-calibrated on a few different occasion. This results in the CSO discharge volumes and number of CSO events to be different from those reported in the 2002 LTCP re-evaluation. These differences are deemed justified based on the additional monitoring data that was used to conduct the re-calibration, and on the CSS model revisions, including operational and physical changes to the combined sewer system and waste water treatment plant system that were implemented since the 2002 Long Term Control Plan Re-Evaluation.
- The CSS IP model uses standard operating rules to model the CSO operations at the Shockoe Retention Basin, causing the CSO discharges modeled at this location to be different from those reported in the CSS Annual Report, where the CSO discharges are calculated by using the real-time operator logs and which are interweaved with the results from the CSS model.

4.3.3 Receiving Water Quality Model

The purpose of the hydrodynamic model calibration was to adjust model parameters within defensible ranges to achieve reasonable agreement between modeled and observed water levels and velocities. The model was run for calendar years 2011 through 2013, and the modeled relationships between river discharge and water level, as well as river discharge and velocity were compared to the observed relationships in the riverine reach. Modeled roughness heights, which represent both grain roughness associated with substrate and larger scale bed forms, were adjusted within bounds consistent with Manning's N roughness values cited in the FEMA Flood Insurance Study (FEMA, 2014). These adjustments were made to bring the modeled water levels and velocities in closer agreement with the observed data.

Figure 4-11 and Figure 4-12 illustrate the riverine model calibration and show sensitivity of the model results to varying roughness height inputs. The calibrated bed roughness heights varied from 5 to 50 millimeters corresponding to Mannings N values from 0.03 to 0.045. Roughness heights were halved in the sensitivity test named "Lower Roughness Test," and they were doubled in the sensitivity test named "Higher Roughness Test." Increases in bed roughness caused increases in modeled water surface elevations and decreases in current velocities. The calibrated roughness inputs provided a balance of accurately simulating both water surface elevations and current velocities.

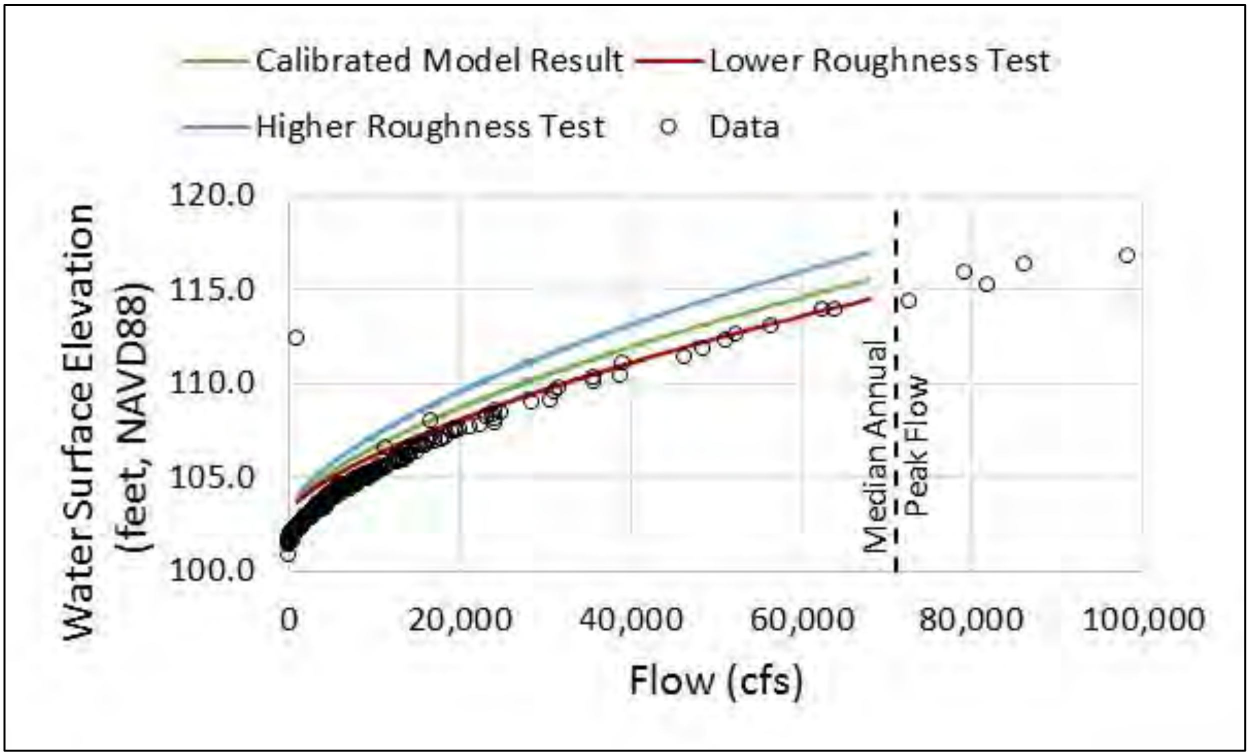


Figure 4-11: Comparison of Modeled and Observed Water Levels at upstream USGS gage

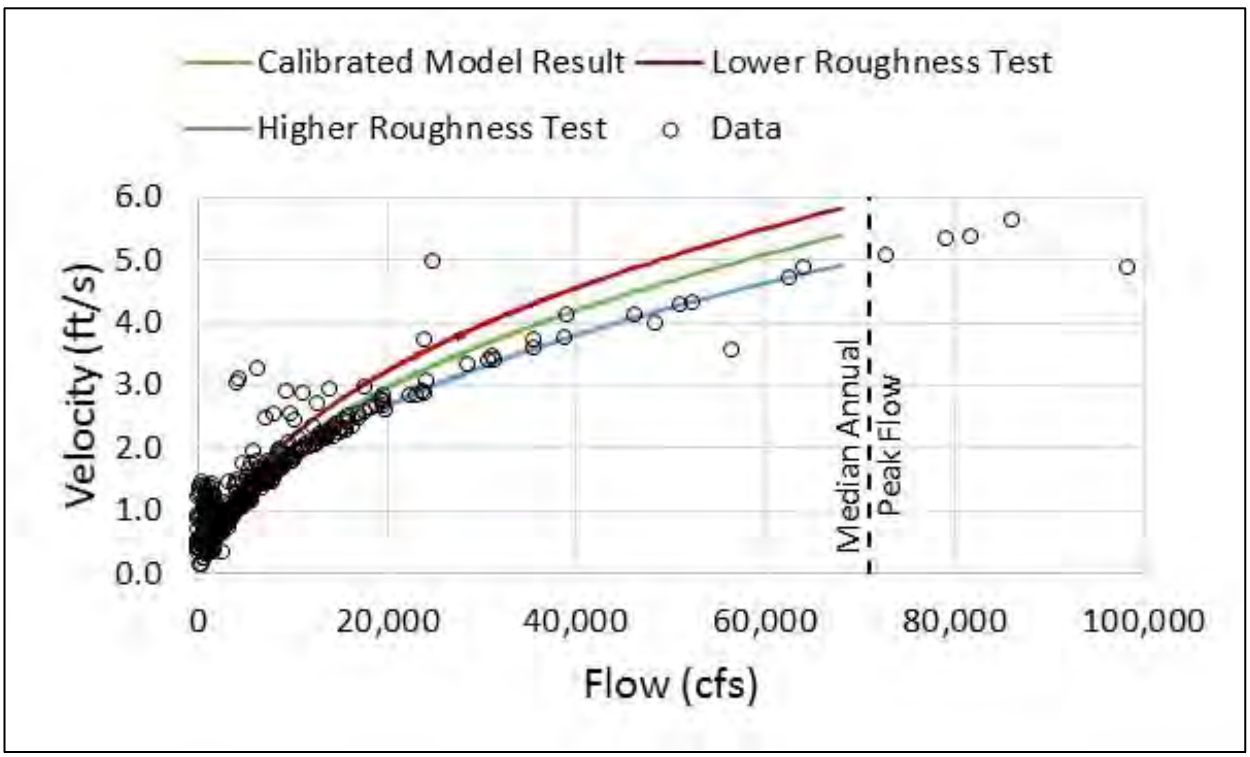


Figure 4-12: Comparison of Modeled and Observed Velocities at upstream USGS gage

Calibration to USGS water level data in the estuarine reach was achieved by adjusting the water level at the boundary to account for the effect of river flow on water levels. Water levels at the boundary were reduced relative to the gaged water levels to account for changes in water level between the gage and the model boundary. The data were adjusted according to the expression:

$$Z_{boundary} = Z_{Gage} - C * Q^n$$

Where:

- $Z_{boundary}$ is the estimated water level at the downstream boundary in feet
- Z_{gage} is the observed water surface elevation at the USGS gage (#02037705) in feet,
- C and n are constants which were determined via calibration to be 4.4e-7 and 1.5; and,
- Q is the James River flow rate in cubic feet per second

The data were also shifted by approximately three minutes backward in time to account for propagation of the tides from the model boundary to the gage location.

Figure 4-13 and Figure 4-14 illustrate the estuarine model calibration and Figure 4-15 shows how the model performed in the absence of this flow-based water level adjustment at the downstream boundary. Without this flow-based adjustment to water levels, modeled water levels are biased four feet high relative to the data during the highest flow conditions.

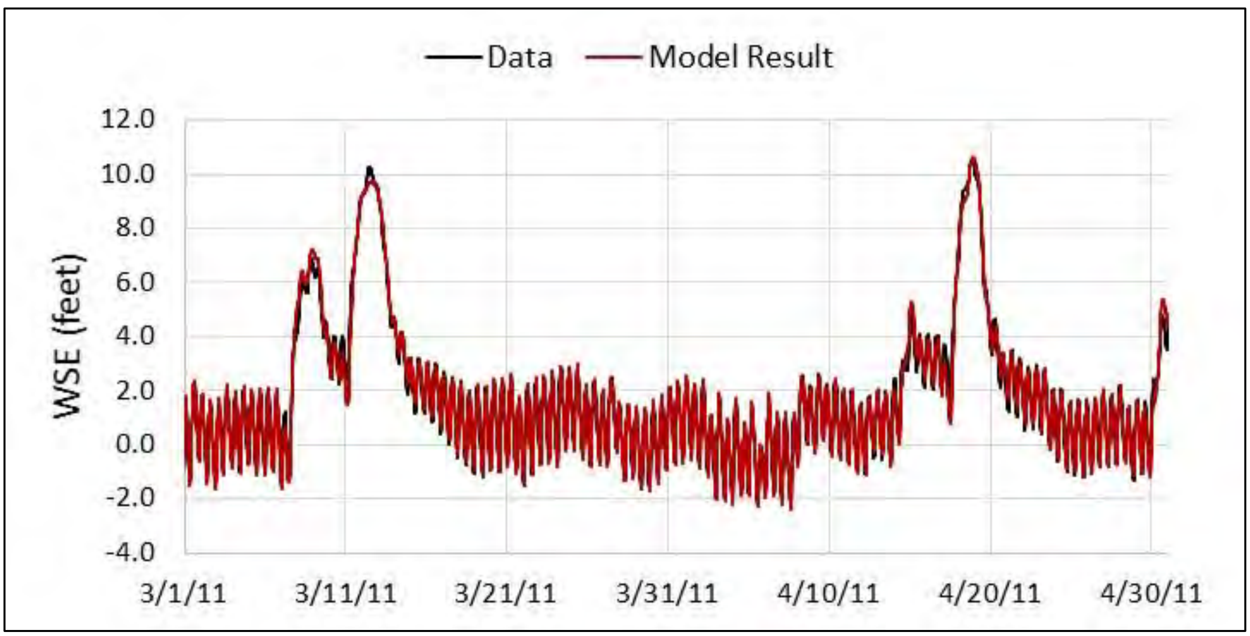


Figure 4-13: Time Series Comparison of Modeled and Observed Water Levels at downstream USGS gage

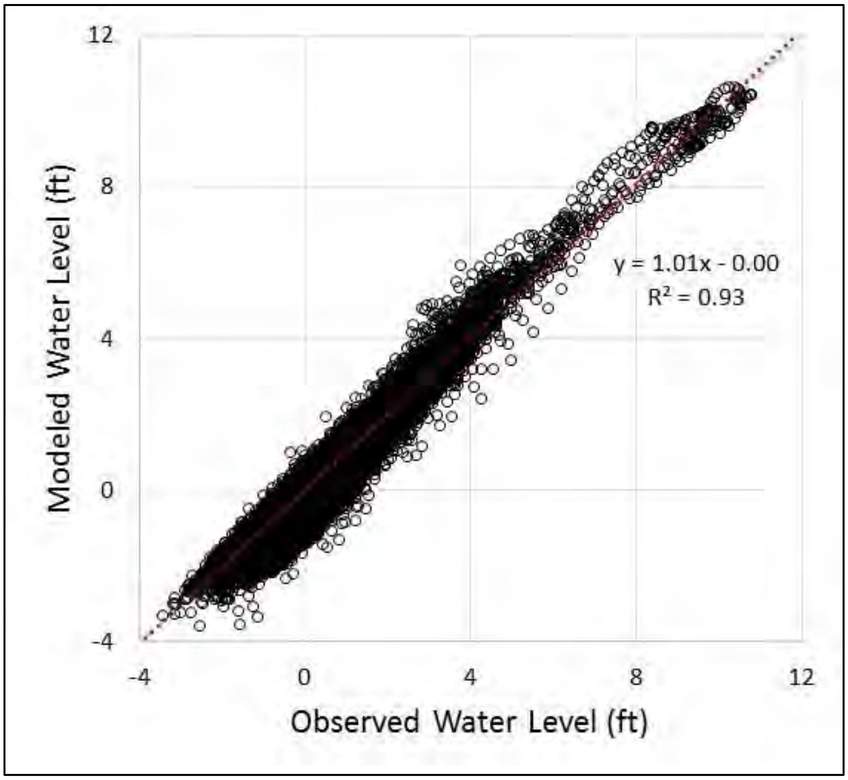


Figure 4-14: One-to-one Comparison of Modeled and Observed Water Levels at downstream USGS gage

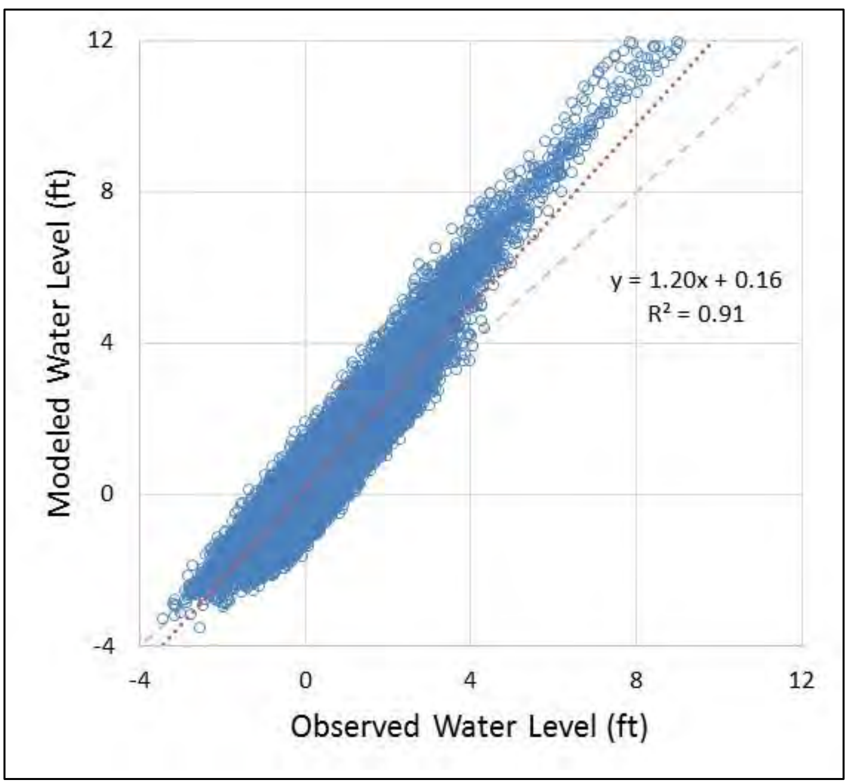


Figure 4-15: One-to-one Comparison of Modeled and Observed Water Levels at downstream USGS gage without calibration of water levels at the boundary

4.4 Water Quality Calibration Results

Calibration of water quality conditions involved adjusting inputs that influence the quantity, timing, and locations of *E.coli* delivered to the receiving waters and adjusting inputs that influence the survival of *E.coli* in the streams. *E.coli* sources in the water quality modeling framework include *E.coli* washoff from the watershed, persistent background sources of *E.coli* (e.g.: wildlife), *E.coli* in combined sewer overflows and treatment plant effluent, and *E.coli* originating from upstream locations in the James River watershed.

4.4.1 Watershed Model

The main objectives of the watershed water quality calibration were to estimate *E.coli* loading to the receiving water quality model and the approximate timing of these loads. To evaluate the first objective, the distribution of modeled *E.coli* concentrations was compared to observed data using boxplots. To evaluate the second objective, model results were compared to observed data using one-to-one plots, where the observed data is compared to the modeled data for a given model time step.

Data from the Falling Creek location were primarily used to calibrate the watershed model for two reasons: First, Falling Creek stations 399/400 have the greatest quantity of observed data. Second, since Falling Creek is the only tributary in the watershed model with a USGS flow gage, the modeled flows are likely to be the most accurately represented. Therefore, accurately modeling observed concentrations in Falling Creek would result in the best estimation of *E.coli* loads delivered to the receiving water quality model. Since there is a limited amount of data available in the tributaries, the initial calibration was considered complete and satisfactory once the modeled results from Falling Creek and the majority of the other five tributaries matched observed values within reason.

The model was run for the calendar years 2011 to 2013 and modeled *E.coli* concentrations were compared to observed results for six tributaries. Figure 4-16 and Figure 4-17 illustrate the watershed model water quality calibration. Model results at Falling Creek reasonably approximate the median observed concentration and the distribution of observed values. Modeled median values for four out of the other five tributaries also appear to be reasonable, with the modeled medians within one order of magnitude of the observed medians. Maximum modeled *E.coli* concentrations are generally greater than the observed data, which is assumed to be due to the lack of wet weather data collected in the tributaries. One-to-one plots were evaluated in light of the fact that in-stream *E.coli* concentrations can vary greatly in time and space (USEPA, 2010). To account for the natural variability that can occur when sampling *E.coli*, two additional sets of lines were added to the 1-to-1 plot: the first set of dashed lines represent a two-times (2x) confidence interval representing the variability in monitoring data results associated with field-collection efforts. The second set of dotted lines represents a ten-time (10x) confidence interval which represents the possible variability in monitoring data results associated with both the field collection efforts and the laboratory methods. The majority of points on the one-to-one plots fall within the 10x confidence interval for all stations.

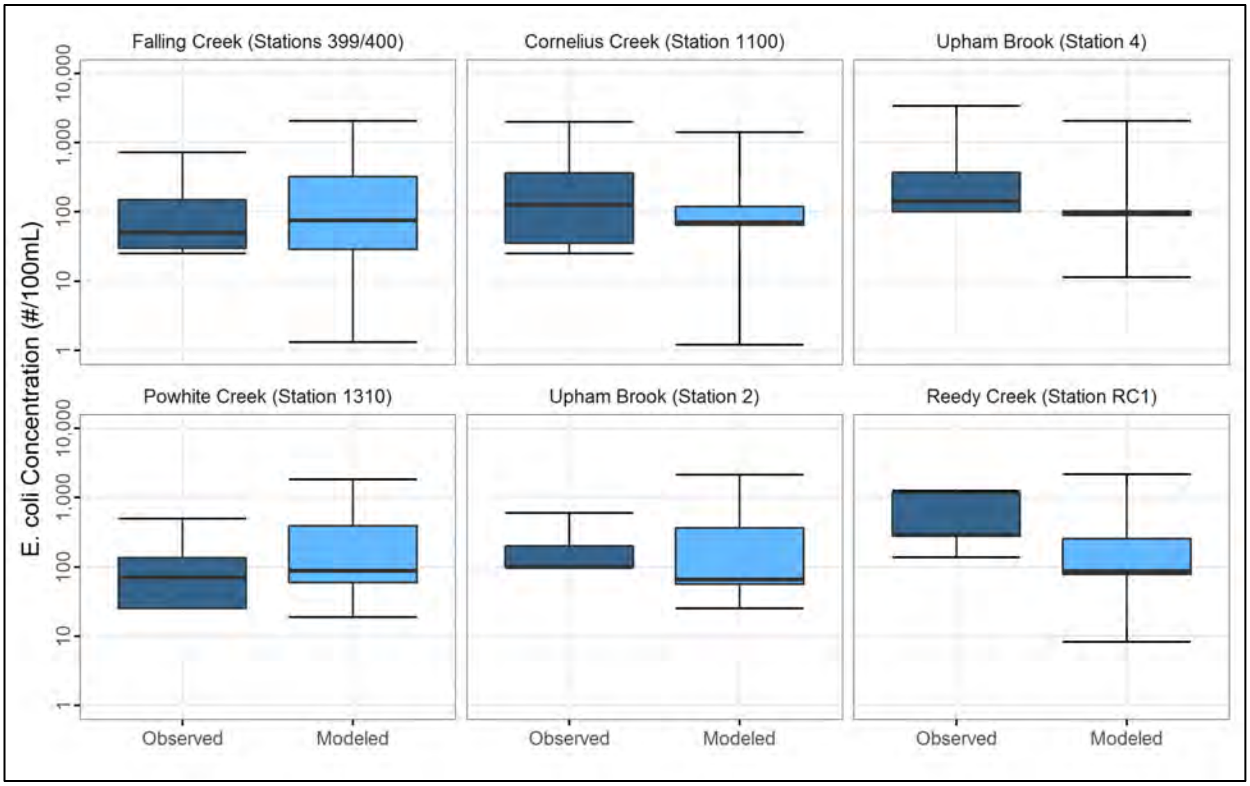


Figure 4-16: Boxplots of Modeled vs. Observed E.coli Concentrations in Select Richmond Tributaries

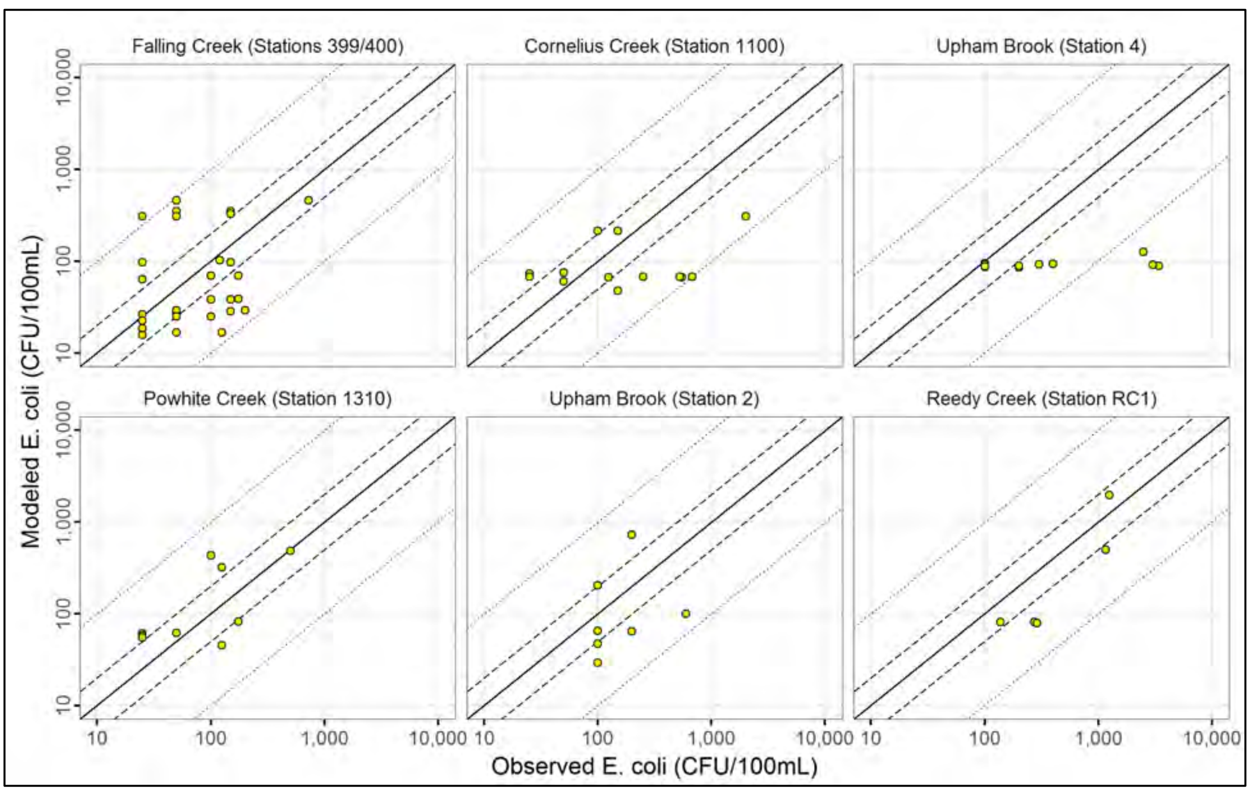


Figure 4-17: One-to-One Plots of Modeled vs Observed E.coli Concentrations in Select Richmond Tributaries

Calibration of the watershed model to better represent the *E.coli* concentrations was achieved by adjusting the values of four main parameters: pollutant build-up rate, pollutant wash-off rate, baseflow *E.coli* concentration, and in-stream decay rate. Pollutant build-up and wash-off had the greatest influence on wet weather in-stream concentrations, while baseflow *E.coli* concentration had the greatest influence on dry weather concentrations. Of the six stations evaluated, *E.coli* decay rate was found to have the greatest influence on Falling Creek, the largest tributary in the model extent. The impact of in-stream decay rate for the other five stations was nominal because travel times in these tributaries was generally shorter.

4.4.2 CSS Model

Explicit water quality calibration of the CSS model was not conducted. Rather, the CSO discharges were assigned bacteria concentrations based on monitoring results conducted for the development of the original LTCP. Additionally, the WWTP discharges were assigned bacteria concentrations based on the current bacteria water quality standards. Section 3.3 and 5.2 discusses the pollutant concentrations assigned to the various CSS outfalls and the WWTP discharge streams in more detail.

4.4.3 Receiving Water Quality Model

The primary objectives of the James River water quality model calibration were to: 1) evaluate the reasonableness of modeled *E.coli* loadings by source type and 2) evaluate the completeness of modeled *E.coli* sources. These objectives were achieved by evaluating consistency between modeled and observed *E.coli* concentrations and identifying and resolving any significant biases. The water quality model calibration is controlled in large part by estimates of *E.coli* concentrations from upstream of the study area and by estimates of *E.coli* loads from the watershed model and CSO model. Because of this, the water quality model calibration is a consistency check between the load estimates and sampling data in the James River.

The model was run for calendar years 2011 through 2013 and modeled *E.coli* concentrations were compared to observed concentrations at six stations. Figure 4-18 and Figure 4-19 illustrate the James River water quality model calibration. Median modeled *E.coli* concentrations are within 15% of median observed *E.coli* concentrations except at Station 641 where, as described in Section 4.1.3, the sampling data are anomalously high and not suitable for model calibration. Maximum modeled *E.coli* concentrations are all higher than observed *E.coli* concentrations. This is because model results are computed for every hour of the three year period, while samples were only taken occasionally, making it unlikely that the samples would capture the highest *E.coli* concentrations that actually occur in the river.

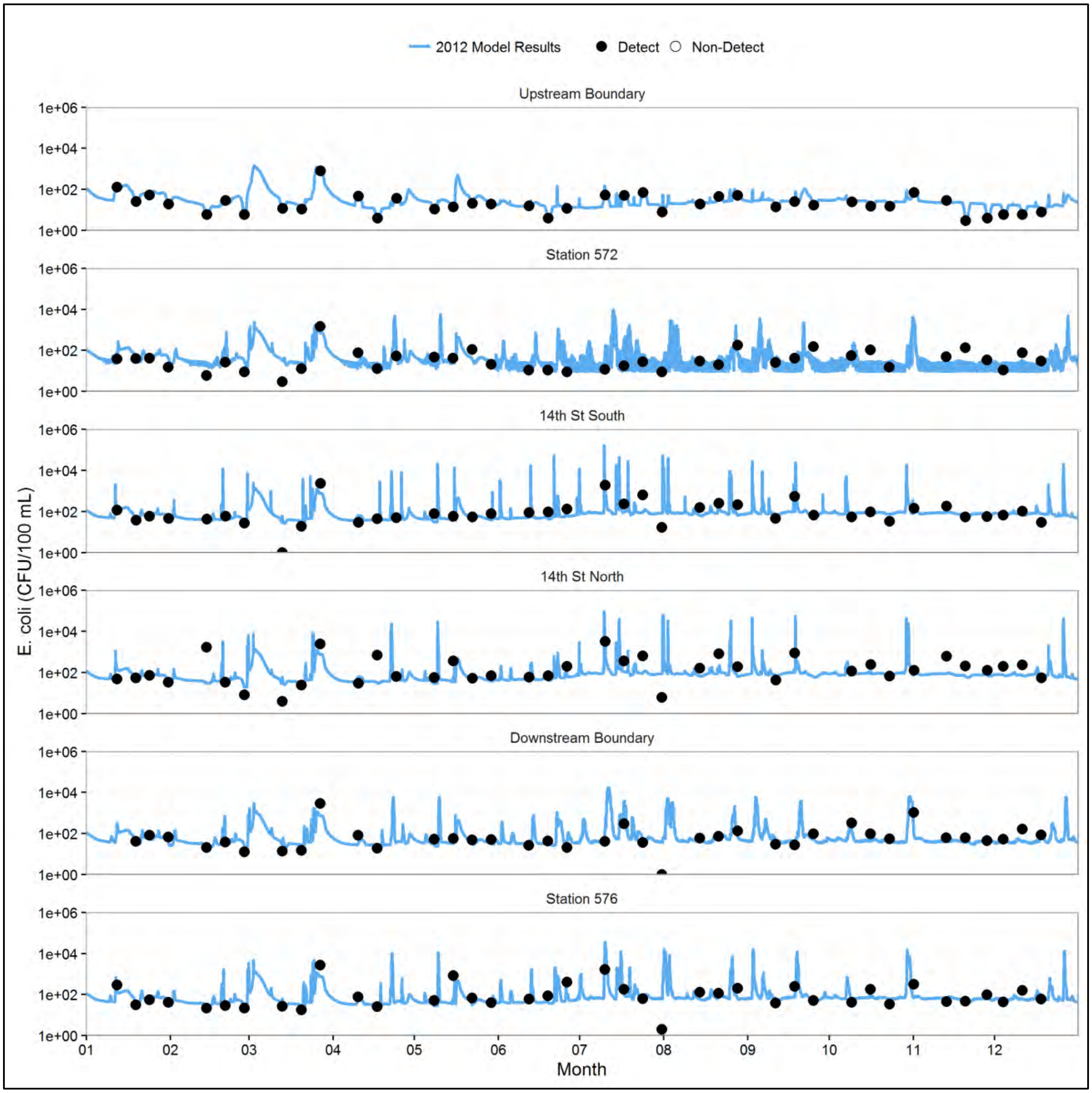


Figure 4-18: Time Series Comparison of Modeled and Observed *E.coli*

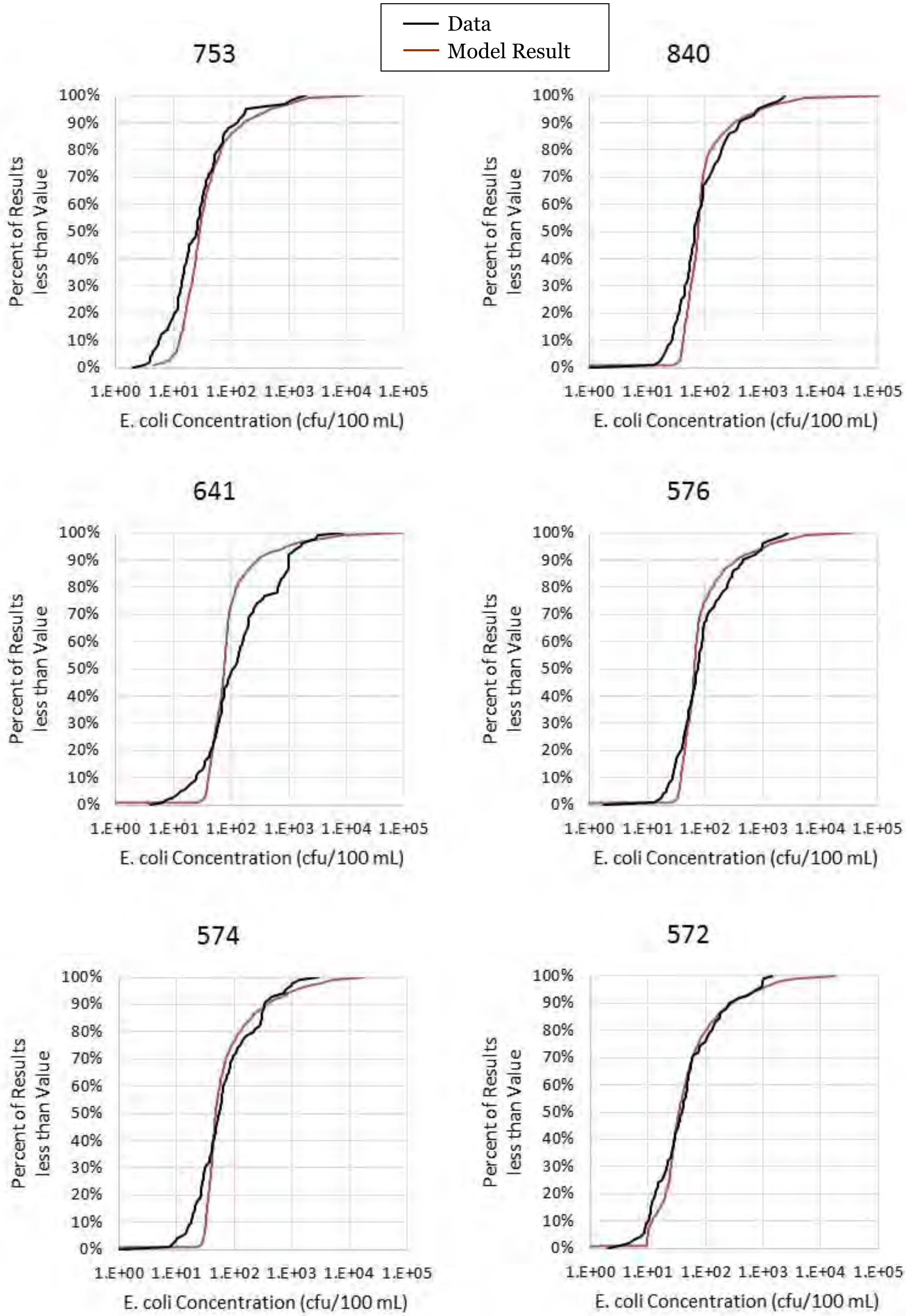


Figure 4-19: Cumulative Frequency Distribution Comparisons of Modeled and Observed *E.coli*

Calibration of the water quality model required the introduction of a significant unknown source between the Huguenot Bridge and the 14th Street Bridge (Figure 4-20). It is assumed that this source represents bacteria contributions from common background sources such as wildlife and failing septic systems. This source was introduced to the model at a constant rate of 3.2E+12 CFU/day just downstream of the Poney Pasture Park. This assumed loading rate is of the same order of magnitude as the loading rate estimated for failing septic systems and wildlife in the James River Richmond Bacteria TMDL (MapTech, 2010). Increases to instream *E.coli* concentrations due to the background source are generally between 30 and 40 CFU/100 mL. The decision to input this load near the park is not meant to indicate that the source(s) necessarily originates there. Additional sampling data would be required to identify the spatial distribution of this source(s) between the Huguenot Bridge and the 14th Street Bridge.

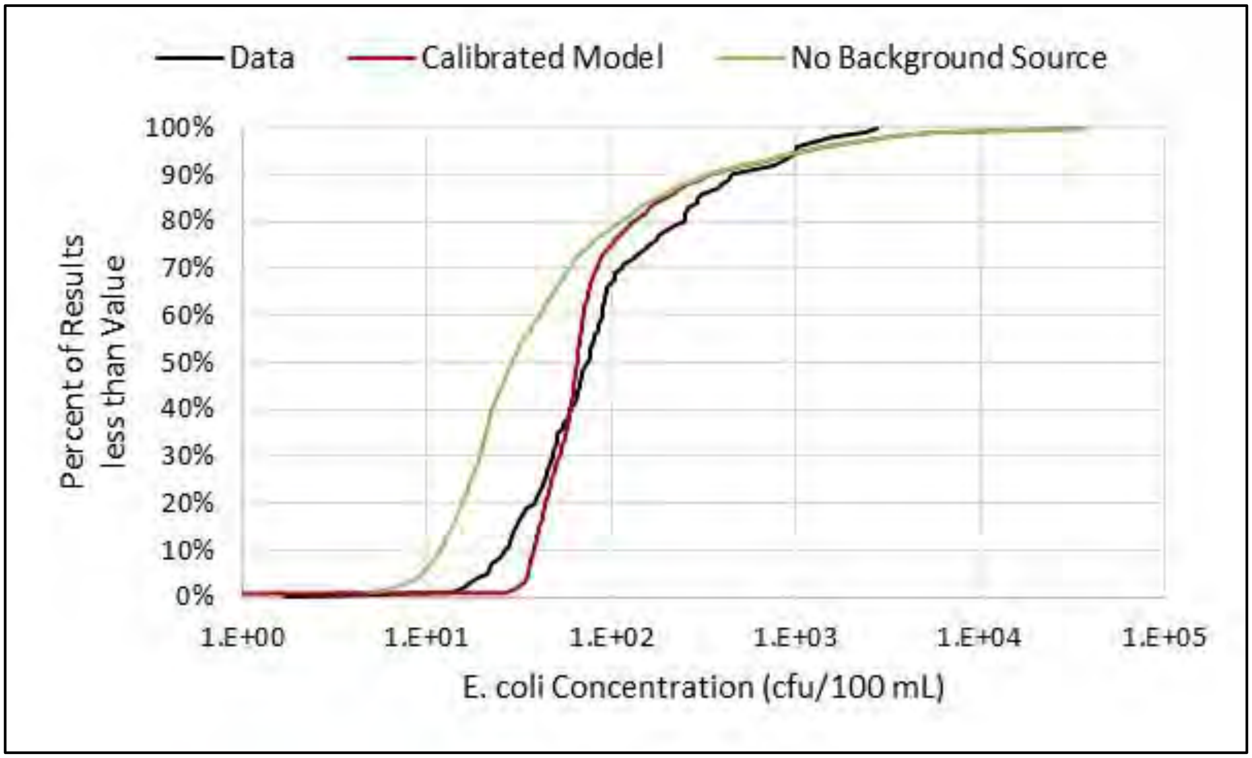
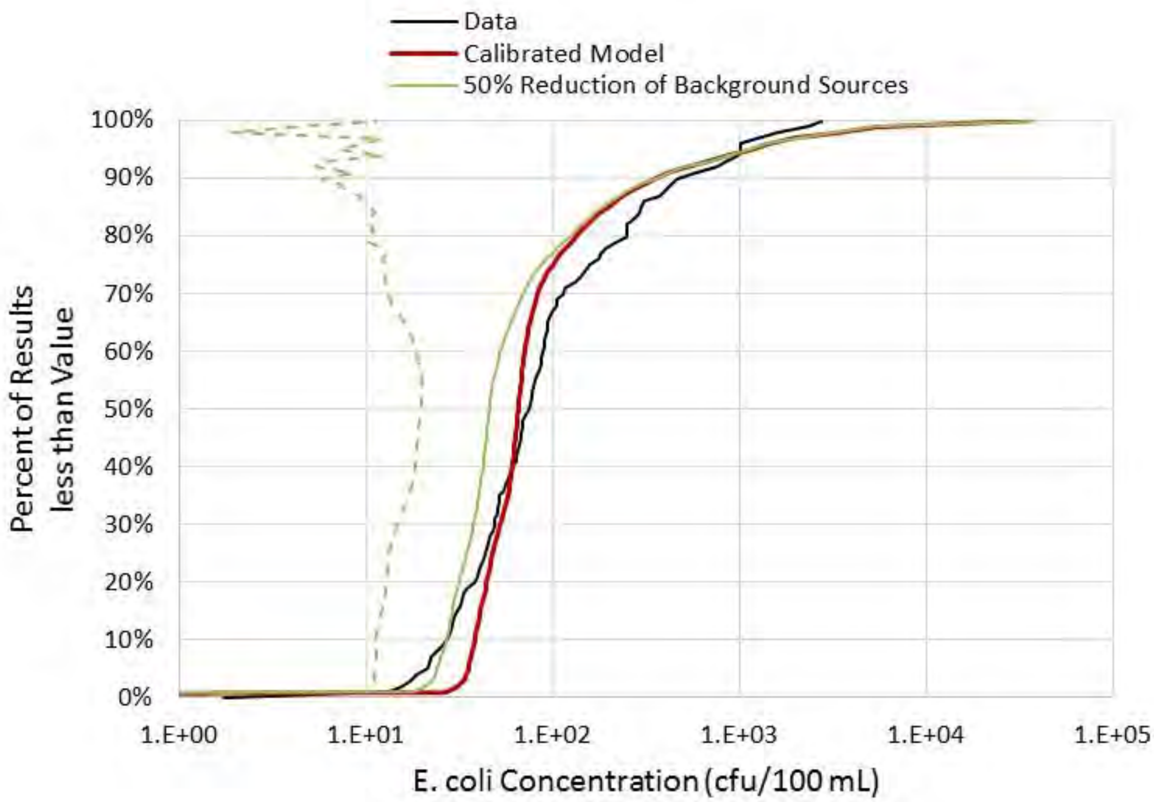


Figure 4-20: Sensitivity of Model Calibration to the Background Source

Figure 4-21 and Figure 4-22 illustrate sensitivity of the model results to adjustments of all major *E.coli* loading assumptions. In each plot, the source type of interest was reduced by 50% to evaluate its influence on modeled *E.coli* concentrations. Model results at the downstream city limit are shown. In these figures, the green dashed line represents the difference between the calibrated model result and the source reduction sensitivity test result. Reductions in persistent sources such as the James River upstream of Richmond and the background source always have some influence on *E.coli* concentrations. However, wet weather sources only reduce *E.coli* concentrations when precipitation has occurred. As a result, CSOs, for instance, only reduce concentrations thirty-five percent of the time (i.e. for the 65th to 100th percentile on the plots).



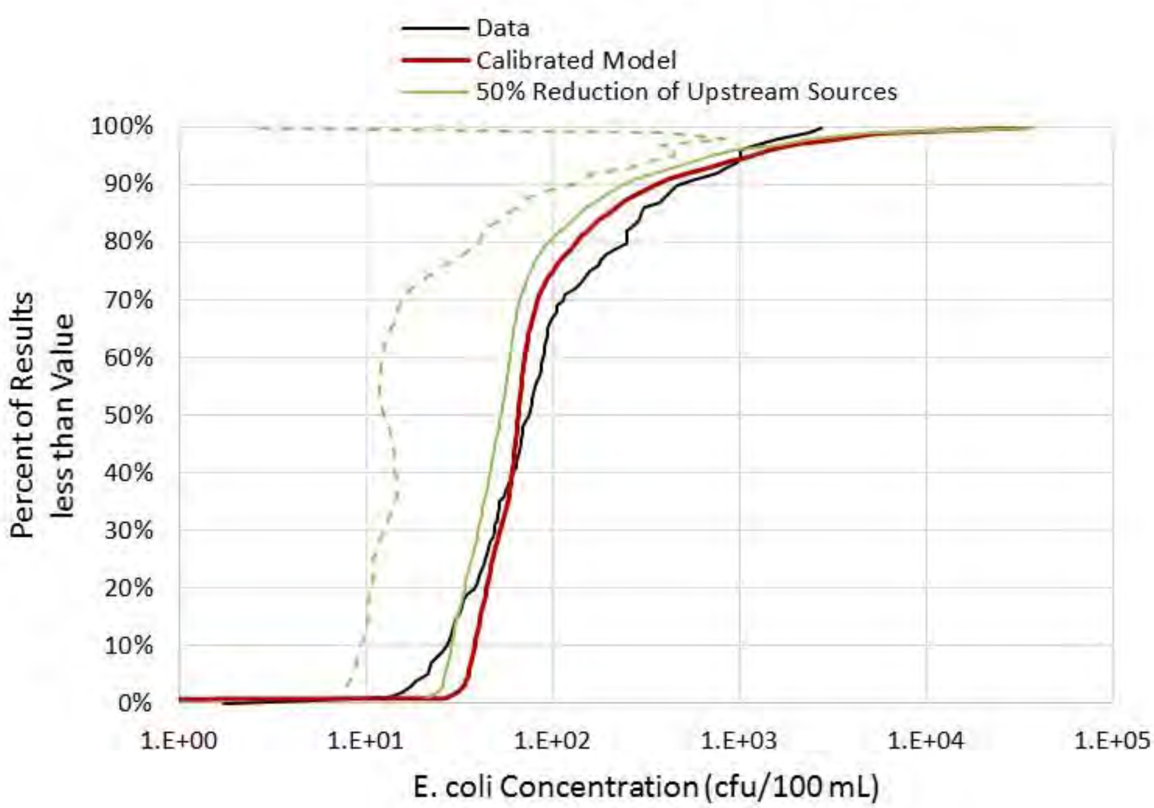
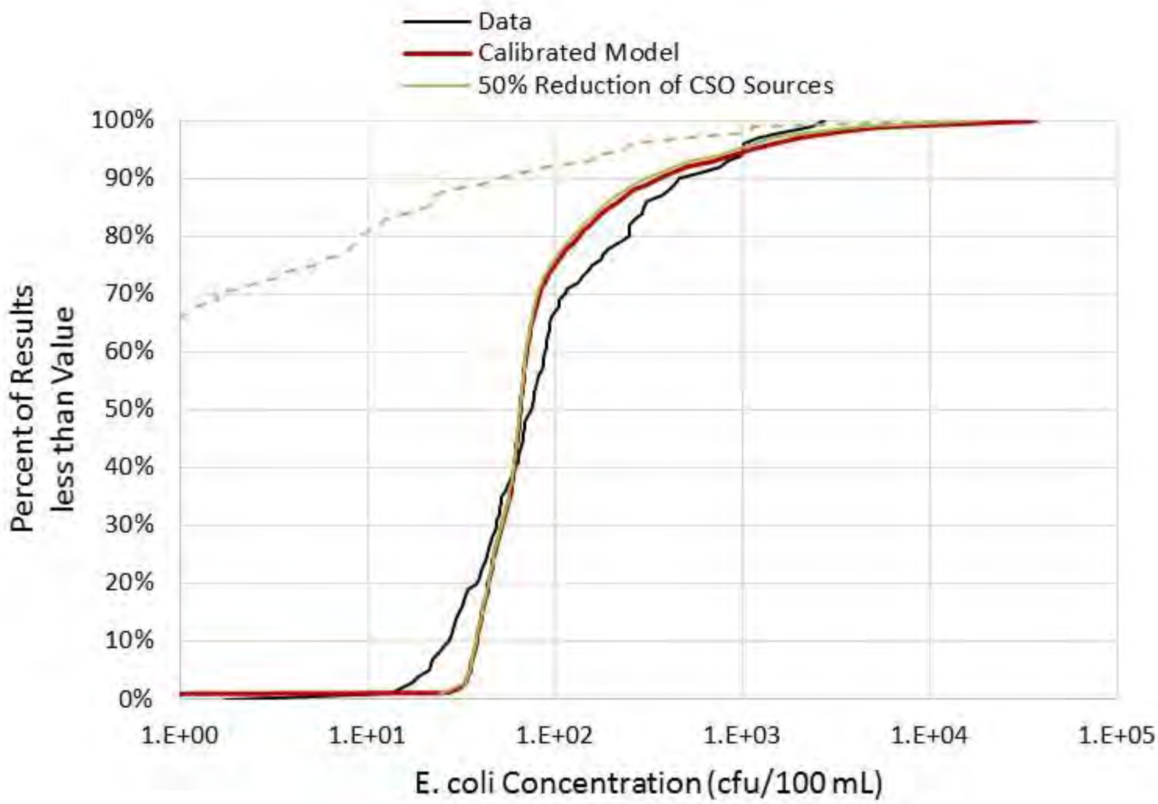


Figure 4-21: Sensitivity of Model Results to 50% Reduction of Persistent Sources



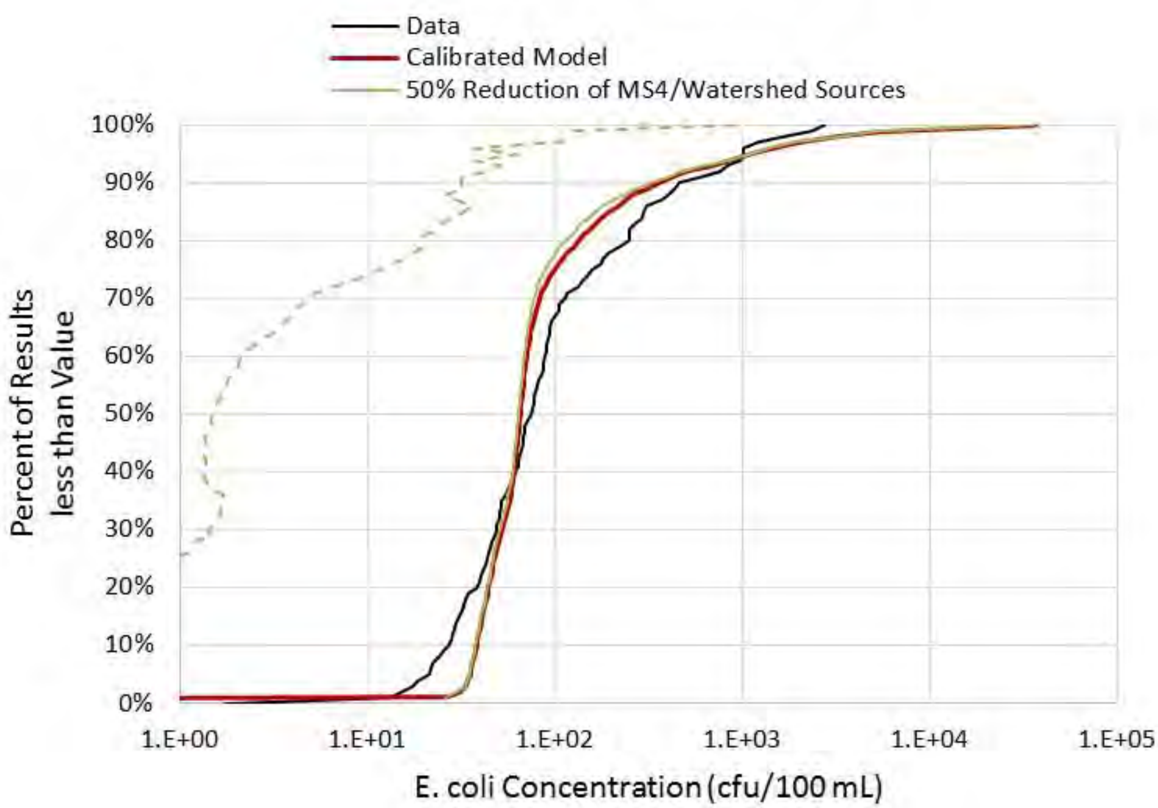


Figure 4-22: Sensitivity of Model Results to 50% Reduction of Wet Weather Sources

5 Model Application and Results

5.1 Overview

To date, the model has been applied to evaluate the following:

- Current conditions: Best representation of current conditions, and includes all the Phase I and Phase II CSO improvements from the LTCP.
- Baseline Conditions: represents the current condition, plus all the currently funded Phase III collection system improvement projects from the LTCP.
- Green Infrastructure in the MS4 Area Strategy: represents the baseline conditions, plus the implementation of 104 acres of green infrastructure on city-owned area in the MS4.
- Green Infrastructure in CSO Area Strategy: represents the baseline conditions, plus the implementation of 18 acres of green infrastructure on city-owned area in the CSS area.
- CSS Infrastructure Improvements Strategy: represents the baseline conditions, plus all the remaining unfunded Phase III collection system improvement projects from the LTCP.

The sequencing of the modeling applications is shown in the figure below.

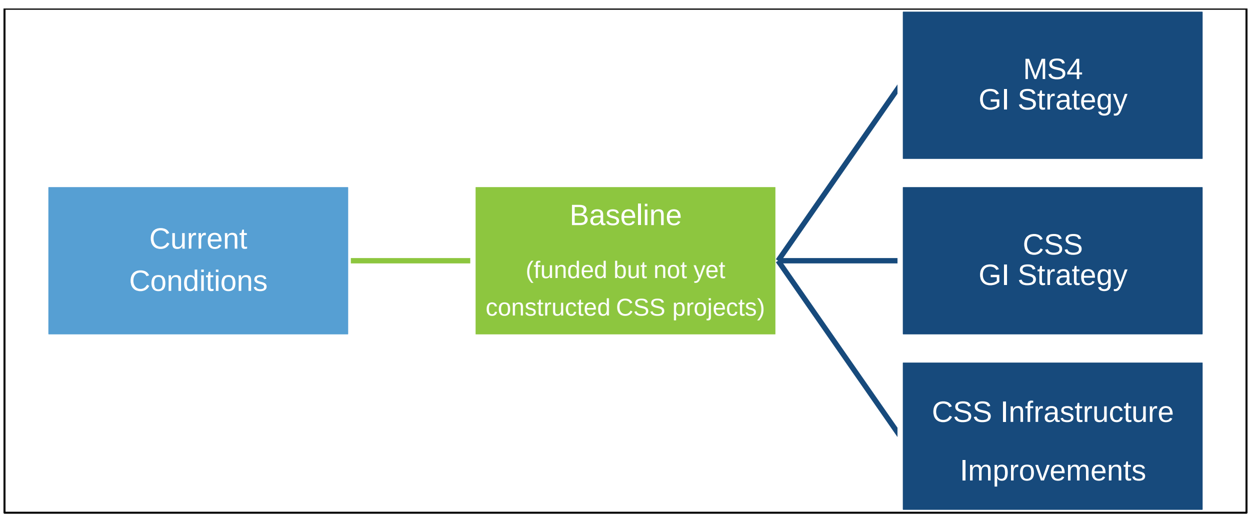


Figure 5-1: Sequencing of Model Applications

These conditions and strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges, expressed as Billion CFU
- Overall average percent improvement in monthly geomean water quality standard compliance at the downstream city limit
- Reduction in number of CSO events

- Reduction in CSO volume (Million gallons)

These four metrics are used in the Strategy Calculator, a spreadsheet tool that is used to evaluate and score the different management strategies across a wide range of goals and objectives (LimnoTech, 2017).

The model is further used to evaluate water quality benefits relative to the monthly geometric mean standard and the statistical threshold value (STV) standard, on a monthly basis. The geometric mean standard states that the monthly geometric mean *E.coli* concentration must fall below 126 cfu/100 mL to be in compliance. The VDEQ statistical threshold value standard states that no more than 10% of *E.coli* concentrations in a month may exceed 235 cfu/100 mL to be in compliance.

5.2 Methodology for Model Application and for Evaluating Model Results

The three-year period of 2011 through 2013 was selected as the application period because it represents a continuous time period that includes typical wet, dry, and average precipitation conditions, with corresponding responses in James River flow conditions. This is shown in Figure 5-2.

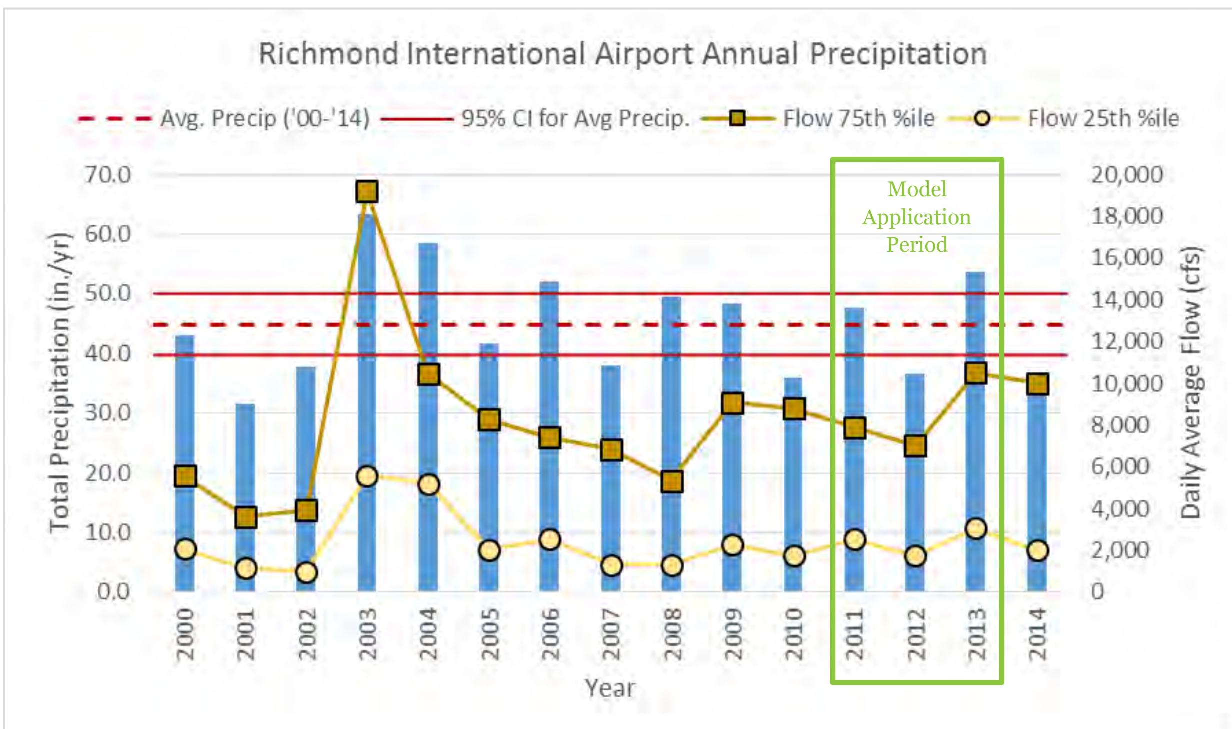


Figure 5-2: Precipitation and Daily Average Flow at Richmond International Airport

The following process was followed when applying the water quality model components to evaluate the various strategies:

1. Simulate any improvements to the combined sewer system or treatment plan with the CSS model;
2. Relay model results from potential CSS improvements in the Gillies or Almond Creek tributaries to the watershed model;
3. Simulate any MS4 strategies or CSS improvements in the Gillies or Almond Creek improvements with the watershed model;

4. Simulate the impact of improvements in the James River by relaying CSS model results (i.e. time series of overflow discharge and bacteria load) and watershed model results (i.e. time series of tributary flows and bacteria loads) to the James River Receiving Water Quality Model.
5. Summarize the results of the model runs using the metrics described in the previous section.

After running the water quality modeling framework through the process described above, water quality compliance was evaluated at the downstream boundary of the city, Richmond's National Pollutant Discharge Elimination System (NPDES) compliance point. *E.coli* concentrations at this point were compared to the monthly geometric mean of 126 CFU/100 mL and the STV of <10% of all samples exceeding 235 CFU/100mL. For each month that violated the water quality standard, a detailed component analysis was completed. The component analysis tracks the relative contribution of each *E.coli* source (upstream, CSOs, watershed/MS4, background, and WWTP) to the modeled concentration in the James River. This type of analysis is useful to evaluate which sources of bacteria have the greatest impact on water quality conditions in the James River for a given point in time or location in the river.

Additionally, model results were summarized to determine the overall bacteria load reduction, CSO volume reduction, reduction in number of CSO overflow events, and to evaluate the percent improvement towards monthly geomean water quality standard compliance at the downstream city limit. The "percent improvement towards monthly geometric mean compliance", also dubbed "percent improvement" for convenience, ranges from 0% to 100%, with 0% corresponding to the existing state of compliance and 100% corresponding to full compliance with the monthly geomean water quality standard. The "percent improvement" is computed as follows:

$$I_p = \frac{\sum_1^n V_{n,scenario} - \sum_1^n V_{n,current}}{\sum_1^n V_{n,current}}$$

Where:

- "I_p" is Percent Improvement,
- "V" is the compliance metric value for a given month, (e.g. the geometric mean value for December 2011),
- "n" is an index for the month, and
- the subscripts "scenario" and "current" correspond to a scenario of interest and the current condition, respectively.

Graphically, each summation term in this equation is the total bar height above the water quality standard as shown in Figure 5-3. If, under a particular scenario, the total bar height above the standard is small compared to the current conditions, then the "percent improvement" will be nearly 100% and the system will be near full compliance. If the total bar height under a particular scenario is similar to that of the current condition, then the "percent improvement" will be nearly 0%.

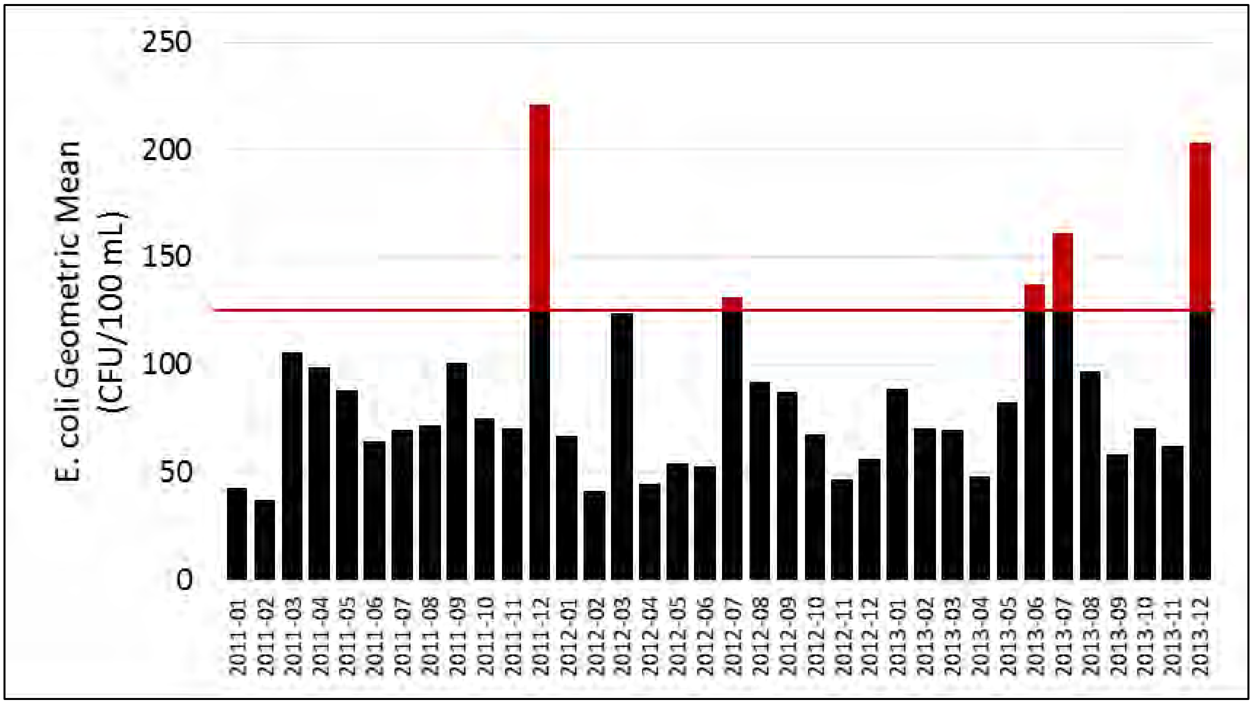


Figure 5-3: Graphical Depiction of the "Percent Improvement" Metric

5.3 Overview of Model Scenarios

Each strategy that was evaluated by the water quality model required unique changes to the model inputs, as further described in the sections below.

5.3.1 Current Conditions

Because the model calibration period and model application period are the same, no further changes were implemented to assess the current conditions.

5.3.2 Baseline Conditions

The baseline conditions represents the current conditions plus the addition of all the currently funded Phase III collection system improvement projects from the LTCP. These projects include the sewer separation of CSO 028A and CSO 028E, replacement of the CSO 04 regulator, and increasing the wet weather treatment capacity of the treatment plant to 140 MGD. These three projects were modeled in the CSS model, and results were passed down to the watershed model and the receiving water quality model. Because these projects are already funded and included in the City's planning documents, this condition was considered to be the baseline condition against which other additional strategies would be compared for the purpose of evaluating the metrics used in the Strategy Calculator.

Additional discussion of the projects included in the baseline conditions is presented in Section 5.3.5

5.3.3 Green Infrastructure in the MS4 Area Strategy

The "green infrastructure in the MS4 area" strategy proposed to implement green infrastructure to treat 104 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation (DPR), in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. The acreage of green infrastructure was determined by identifying the total area of land that is owned by either DPU or DPR, using ArcGIS. Additional information such as topography and soil type was then superimposed over the DPU and DPR properties. Through this visual analysis, it was determined that roughly 50% of the DPU/DPR land would likely not be conducive to the implementation of green infrastructure without significant engineered modifications such as land leveling or soil amendments. Therefore the total available land for this strategy was reduced by half. The remaining area was summarized by subwatershed so that it could be simulated in the watershed model.

All area available for green infrastructure implementation within a subwatershed was modeled as one representative green infrastructure practice since the specific types of green infrastructure are unknown at this planning stage. The generic practices were modeled using SWMM storage nodes with an assumed effective depth of 1.5 feet and sized in area to capture a 1.2 inch storm (90th percentile storm on an average annual basis). The modeled generic green infrastructure practices account for evaporation and bottom infiltration into the native soil. It was assumed that all green infrastructure is being drained within 48 hours to provide storage volume for back-to-back rainfall events. This was simulated by using an appropriately sized orifice to simulate practice underdrains. Potential flows exceeding the green-infrastructure capacity in the model were handled by a weir simulating practice overflow or flow rejection. Water quality routines were applied to the water volumes stored in the practices.

5.3.4 Green Infrastructure in the CSS Area Strategy

The "green infrastructure in the CSS area" strategy proposed to implement green infrastructure to treat 18 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation, in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. The acreage of green infrastructure included in this strategy was determined through the same process as described in the previous section. Additionally, green infrastructure in the CSS model was simulated in the same way as is done in the MS4 area, as described in the previous section.

5.3.5 CSS Infrastructure Improvements Strategy

The "*CSS Infrastructure Improvements*" strategy[2] includes ten projects that are included in the Phase III collection system upgrades described in the LTCP (Greeley and Hansen, 2002):

1. CSO 14 regulator upgrade
2. CSO 028A & 028E sewer separation
3. CSO 04 & CSO 05 regulator replacement
4. Lower Gillies sewer conveyance
5. WWTP wet weather treatment to 140 MGD
6. WWTP wet weather treatment to 300 MGD
7. CSO 21 replacement
8. CSO 21 additional 2 MG storage
9. Shockoe Retention Basin (SRB) expansion
10. SRB disinfection

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[2] Alternative LTCP projects are currently being evaluated by Brown and Caldwell but results are not yet available to be included as of March 2017.

Of those ten projects, #1-#3 and #5 are included in the Baseline Conditions, since these projects are currently funded by the City of Richmond. Implementation of all ten projects represents the obligations under the LTCP, and is commonly referred to as the "*full LTCP*" scenario.

The unfunded projects were modeled in isolation to determine individual impact on CSO volume discharge, bacteria load reduction, and impact on the receiving water quality. These CSS "scenarios" are summarized in Table 5-1 and Table 5-2.

Table 5-1: Description of CSS Projects Evaluated by the Water Quality Model

CSS Scenario	CSS Project Name	CSS Project Description
Current	Current Conditions	Current sewer conditions, including all LTCP Phase I and Phase II projects.
14-3	Baseline Conditions	Includes the currently funded projects: -- CSO 04, 014, and 05 regulator upgrades -- CSO 028A & 028E disconnection -- WWTP wet weather treatment up to 140 MGD
14-2	Gillies Conveyance	Lower Gillies Wet Weather Conveyance Interceptor to convey more flow to the WWTP
15-4	300 MGD Wet Weather Treatment	WWTP wet weather treatment up to 300 MGD
15-5	CSO 21 Replacement	Replacement of the CSO 21 regulator and additional 2MG storage
18-4	SRB Expansion	Shockoe retention basin (SRB) expansion to 15MG
18-5	SRB Expansion and Disinfection	SRB Expansion to 15MG and chlorine disinfection of the SRB discharge at CSO 06
19-3A	Full LTCP	All 10 Phase III projects, Full Long-term Control Plan (LTCP) achieved.

Table 5-2: CSS Water Quality Model Matrix

CSS Project	CSS Scenario					
	Baseline (14-3)	**14-2**	**15-4**	**15-5**	**18-4**	**18-5**	**Full LTCP (19-3A)**
CSO 14 regulator upgrade	X	X	X	X	X	X	X
CSO 028A & 028E separation	X	X	X	X	X	X	X
CSO 04 & CSO 05 replacement	X	X	X	X	X	X	X
Lower Gillies Conveyance		X					X
WWTP wet weather treatment to 140 MGD	X	X		X	X	X	
WWTP wet weather treatment to 300 MGD			X				X
CSO 21 replacement and additional 2MG storage				X			X
SRB expansion					X	X	X
SRB disinfection						X	X

In addition to making changes to the CSS model elements and configuration to represent the individual CSS improvements, the E.coli concentrations associated with the WWTP were also modified depending on the CSS project. Under current conditions, the WWTP treats inflows up to 75 MGD, with no supplemental treatment during wet weather flows. Several CSS scenarios simulate wet weather treatment up to 140 MGD, and yet others simulate wet weather treatment up to 300 MGD. The WWTP treatment scheme for each scenario is summarized in Table 5-3.

Table 5-3: WWTP Treatment for Each CSS Scenario				
CSS Scenario	**Full Treatment (MGD)**	**Primary Treatment (MGD)**	**Preliminary Treatment (MGD)**	**Total Treatment (MGD)**
Current	75	--	--	75
14-3	75	65	--	140
14-2	75	65	--	140
15-4	85	55	160	300
15-5	75	65	--	140
18-4	85	55	--	140
18-5	85	55	160	140
19-3A	85	55	160	300

E.coli concentrations associated with each treatment pathway were estimated based on previous modeling, and a flow-weighted average *E.coli* concentration was calculated to estimate the total *E.coli* contribution from the WWTP. All influent to the WWTP was assumed to have an *E.coli* concentration of 235,000 CFU/100mL. It was assumed that influent receiving full treatment would result in an effluent concentration of 126 CFU/100 mL, consistent with the effluent concentration guidelines in the VAPDES permit (#VA0063177). Effluent concentrations from primary and preliminary treatment facilities were calculated according to the following formula:

$$Effluent\ E.coli\ concentration = \frac{influent\ concentration}{reduction\ factor}$$

The effluent reduction factors for primary and preliminary treatment were calculated using formulas that were developed as part of ongoing modeling efforts by Greeley and Hansen (Greeley and Hansen, personal communication, 11/15/2016).). The primary treatment reduction factor is governed by the following equation:

$$Log\ reduction\ factor = 0.76 * \ 10^{2.57904-1.2563*\log(Q)}$$

Where: Q is the inflow in MGD

The preliminary treatment reduction is governed by the following equation:

$$Log\ reduction\ factor = 0.76 * \ 10^{2.77053-1.2563*\log(Q)}$$

Where: Q is the inflow in MGD

For both treatment pathways, the reduction factor is large when flows are small due to increased contact time with the UV disinfection system. Therefore, a treatment floor of 126 cfu/100 mL was set because it was assumed that the treatment capacity of the primary and preliminary pathways could not exceed full treatment.

Post-processing was also required to simulate disinfection at SRB. All influent to SRB was assumed to have an *E.coli* concentration of 111,000 CFU/100 mL, consistent with *E.coli* EMC for CSO 06. The effluent reduction factor for SRB was calculated using a formula that was developed as part of ongoing modeling efforts by Greeley and Hansen (Greeley and Hansen, personal communication, 11/15/2016.)

$$Log\ reduction\ factor = 11.8102 - 3.1211 * \log(Q)$$

Where: Q is the flow rate in MGD

Similar to the WWTP alternative treatment pathways, the SRB reduction factor is large when flows are small due to increased contact time with the chlorine disinfection system. Therefore, a treatment floor of 126 cfu/100 mL was set because it was assumed that the SRB treatment capacity could not exceed full treatment at the WWTP.

5.4 Results

The James River water quality model was configured to compute *E.coli* concentrations at an hourly interval for the three year typical period. These results were compared against the monthly water quality standards and summarized at key locations of interest along the river. Additionally, results were also summarized to show the overall bacteria load reduction, CSO volume reduction, and reduction in number of CSO events.

5.4.1 Current Conditions

Figure 5-4 show the modeled monthly geomean concentrations and the percent exceedance of the STV standards at the downstream boundary of the city. For each month that violated the water quality standard, a detailed component analysis was completed. The component analysis tracks the relative contribution of each *E.coli* source (upstream, CSOs, watershed/MS4, background, and WWTP) to the modeled concentration in the James River. This type of analysis is useful to evaluate which sources of bacteria have the greatest impact on water quality conditions in the James River for a given point in time or location in the river.

Under current conditions, the geometric mean water quality standard is violated at the downstream city limit (the compliance evaluation point) for 4 months of the 36 month typical period. Significant contributors to non-compliance are upstream sources, the background sources, and CSOs. Non-compliance tends to occur when James River flows and upstream James River concentrations are high or when James River flows are low and significant precipitation events cause combined sewer discharges.

The statistical threshold value standard is more frequently violated, with 16 of 36 months exceeding the standard at the downstream City limit. Significant contributors to non-compliance of the STV standards are mainly CSOs and upstream sources, and to a lesser extent, the MS4/Watershed source. The CSOs are a more frequent and greater contributor to water quality violations using the STV standard than using the monthly geometric mean standard.

These results illustrate that:

- The James River is in violation of both the geometric mean and the statistical threshold value water quality standards for some months out of the three year simulation period.
- The primary cause of a water quality standard violation can sometimes be linked to Richmond combined sewer overflows, while at other times it is due to upstream sources. Background and MS4/Watershed sources play a smaller overall role in the bacteria water quality violations. The WWTP does not contribute significantly to bacteria water quality violations.

Figure 5-5 illustrates the E.coli monthly geometric mean in the James River, from a few miles upstream of the city limits to a few miles past the downstream city limits. During some months, for example in April 2012 (orange line), the James River is compliant upstream of the city and local *E.coli* sources are small enough that the James River is also compliant downstream of the city. During other months, like in June of 2013 (blue line), the James River is compliant upstream of the city but because of the contributions from background, watershed, and CSO sources, the James River exceeds the water quality standards at the downstream city limit. Finally during some months, like December 2011 (dark green line), the river is non-compliant with the water quality standards upstream of the city and remains non-compliant downstream of the city.

Table 5-4 shows the E.coli load, CSO volume, and number of CSO events under the existing conditions.

Table 5-4: Existing Condition: E.coli Load, CSO Volume, and Number CSO Events

Metric	Value
Average yearly E.coli load (billion cfu)	9,651,987
Average annual number of CSO events	53
Average yearly CSO volume discharged (million gallons)	1,670

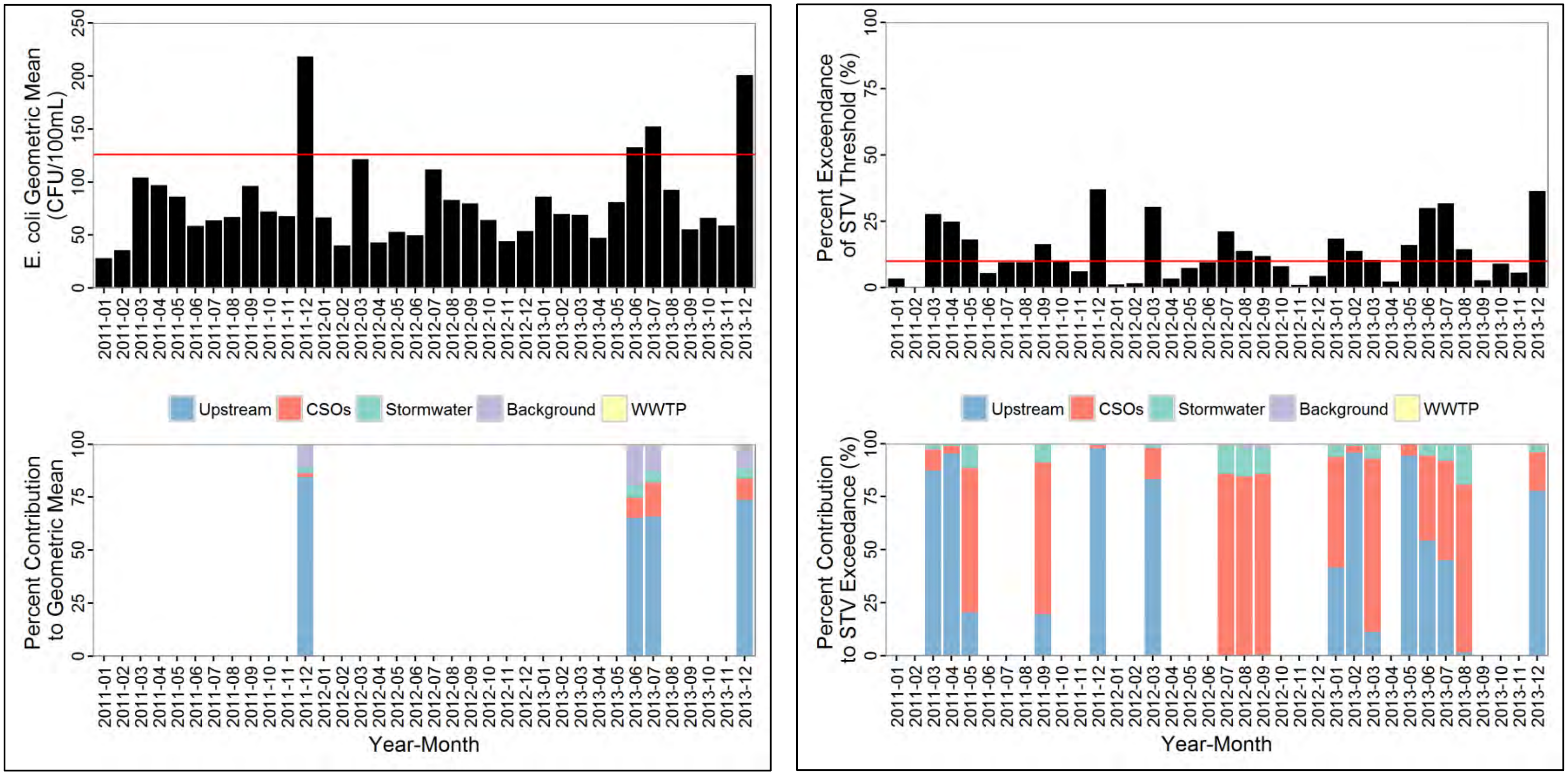


Figure 5-4: Existing Condition: Monthly Geometric Mean and STV Standard Model Results

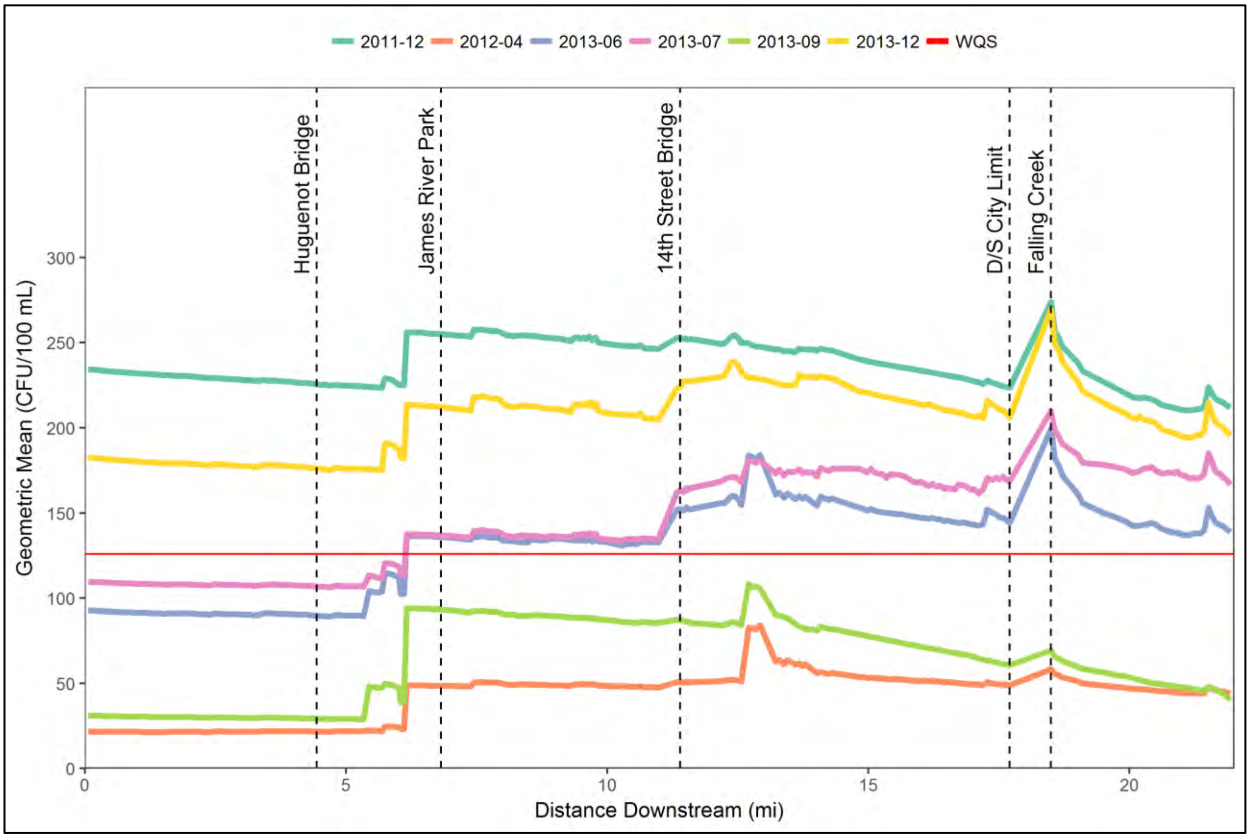


Figure 5-5: Lateral and temporal variability in E.coli concentration in the James River

5.4.2 Baseline Conditions

Figure 5-6 shows the modeled monthly geomean concentrations and the percent exceedance of the STV standards at the downstream boundary of the city for the baseline condition. For each month that violated the water quality standard, a detailed component analysis was completed. Similar to current conditions, under baseline conditions, the geometric mean water quality standard is violated at the downstream city limit (the compliance evaluation point) for 4 months of the 36 month typical period. Significant contributors to non-compliance are upstream sources, the “background” or “unknown” source, and CSOs. Non-compliance tends to occur when James River flows and upstream James River concentrations are high or when James River flows are low and significant precipitation events cause combined sewer discharges.

The statistical threshold value standard is more frequently violated, with 16 of 36 months exceeding the standard at the downstream City limit. Significant contributors to non-compliance of the STV standards are mainly CSOs and upstream sources, and to a lesser extent, the MS4/Watershed source. Though the baseline projects significantly reduce CSOs, these projects alone are not sufficient to bring the James River into compliance with water quality standards.

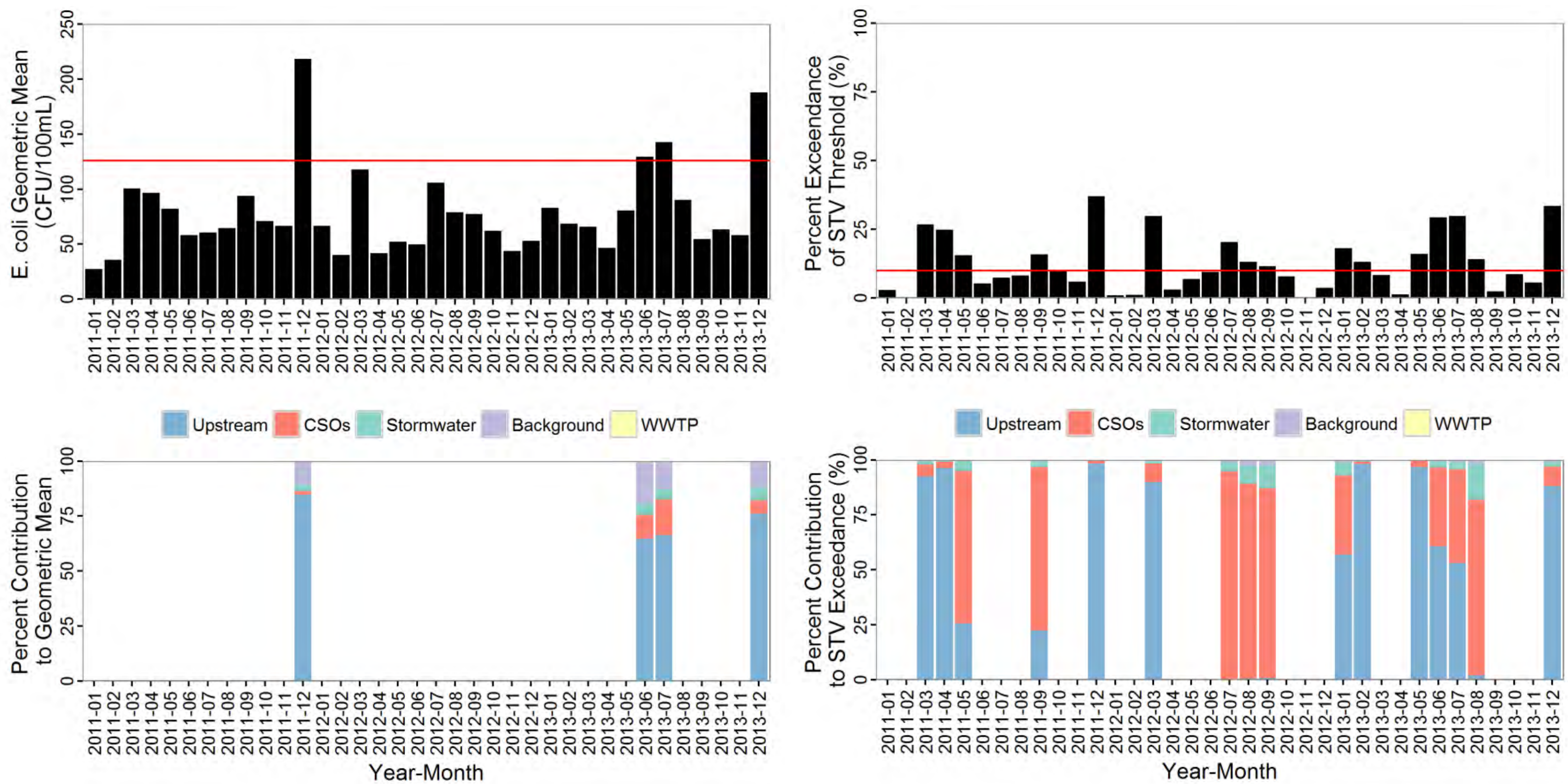


Figure 5-6: Baseline Condition: Monthly Geometric Mean and STV Standard Model Results

Table 5-5 shows the E.coli load, CSO volume, and number of CSO events under the existing conditions. The baseline conditions represent the improvements due to the implementation of several CSO improvement projects. Compared to the existing conditions, these projects collectively reduce the E.coli loads by approximately 18%, reduce the number of overflows by 2 events, and reduce the yearly CSO volume discharged by approximately 29%.

Table 5-5: Baseline Condition: E.coli Load, CSO Volume, and Number CSO Events	
Metric	**Value**
Average yearly E.coli load (billion cfu)	7,958,183
Average annual number of CSO events	51
Average yearly CSO volume discharged (million gallons)	1,190
Percent improvement compared to current conditions (%)	12.8

5.4.3 Green Infrastructure in the MS4 Area Strategy

The "*green infrastructure in the MS4 area*" strategy proposed to implement green infrastructure to treat 104 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation, in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. Table 5-6 shows the E.coli load, CSO volume, and number of CSO events under the "Green Infrastructure in the MS4 Area" strategy. This strategy reduces the E.coli load entering the James River only slightly compared to the baseline conditions (<0.6% reduction). This strategy only targets Richmond's MS4 area, so the number of CSO events and the yearly CSO volume are not affected compared to the baseline scenario.

Table 5-6: Green Infrastructure in MS4 Strategy: E.coli Load, CSO Volume, and Number CSO Events	
Metric	**Value**
Average yearly E.coli load (billion cfu)	7,954,132
Average annual number of CSO events	51
Average yearly CSO volume discharged (million gallons)	1,190
Percent improvement compared to current conditions (%)	13.0

5.4.4 Green Infrastructure in the CSS Area Strategy

The *"green infrastructure in the CSS area"* strategy proposed to implement green infrastructure to treat 18 acres of impervious area owned by the Department of Public Utilities (DPU) or Department of Parks & Recreation, in addition to all the currently funded phase III collection system improvement projects included in the baseline conditions. Table 5-7 shows the E.coli load, CSO volume, and number of CSO events under the "Green Infrastructure in the CSS Area" strategy. This strategy reduces the E.coli load entering the James River only slightly compared to the baseline conditions (<0.6% reduction). This strategy specifically targets the CSS area. The area of GI implementation (18 acres) is not significant enough to reduce the number of CSO events, but it does reduce the annual CSO volume discharged slightly compared to the baseline scenario.

Table 5-7: Green Infrastructure in CSS Strategy: E.coli Load, CSO Volume, and Number CSO Events	
Metric	**Value**
Average yearly E.coli load (billion cfu)	7,905,833
Average annual number of CSO events	51
Average yearly CSO volume discharged (million gallons)	1,180
Percent improvement compared to current conditions (%)	12.9

5.4.5 CSS Infrastructure Improvement Strategy

Table 5-6 shows the E.coli load, CSO volume, and number of CSO events under the "CSS Infrastructure Improvement" strategy. This strategy includes numerous projects intended to reduce the number of CSO events and CSO volume discharged.

Table 5-8: CSS Infrastructure Improvement Strategy: E.coli Load, CSO Volume, and Number CSO Events			
Metric	**Value**	**Reduction Compared to Baseline Conditions**	**Reduction Compared to Existing Conditions**
Average yearly E.coli load (billion cfu)	4,407,072	45%	54%
Average annual number of CSO events	50	2%	5%
Average yearly CSO volume discharged (million gallons)	228	81%	86%
Percent improvement compared to current conditions (%)	21.3%	-	-

Figure 5-7 illustrates water quality compliance at the downstream City limit for the CSS Infrastructure Improvement strategy. Under this strategy, the geometric mean water quality standard is violated at the downstream city limit (the compliance evaluation point) for 3 months of the 36 month typical period. Non-compliance occurs because the upstream sources contribute significant flow and high bacteria loads.

The statistical threshold value standard is more frequently violated, with 16 of 36 months exceeding the standard at the downstream City limit. Significant contributors to non-compliance of the STV standards are mainly CSOs and upstream sources, and to a much lesser extent, the MS4/Watershed source. The CSOs continue to contribute to non-compliance under the STV standards, especially during the summer months. The CSOs are a more frequent and greater contributor to water quality violations using the STV standard than using the monthly geometric mean standard.

These results illustrate that:

- Controlling City of Richmond bacteria sources alone would not achieve compliance with water quality standards.
- Reducing combined sewer overflows via the CSS Infrastructure Improvement strategies would significantly reduce the average yearly CSO volume discharged (81% reduction compared to the baseline conditions). It would also improve compliance with water quality standards, especially during times when upstream sources are not significantly contributing to water quality violations.

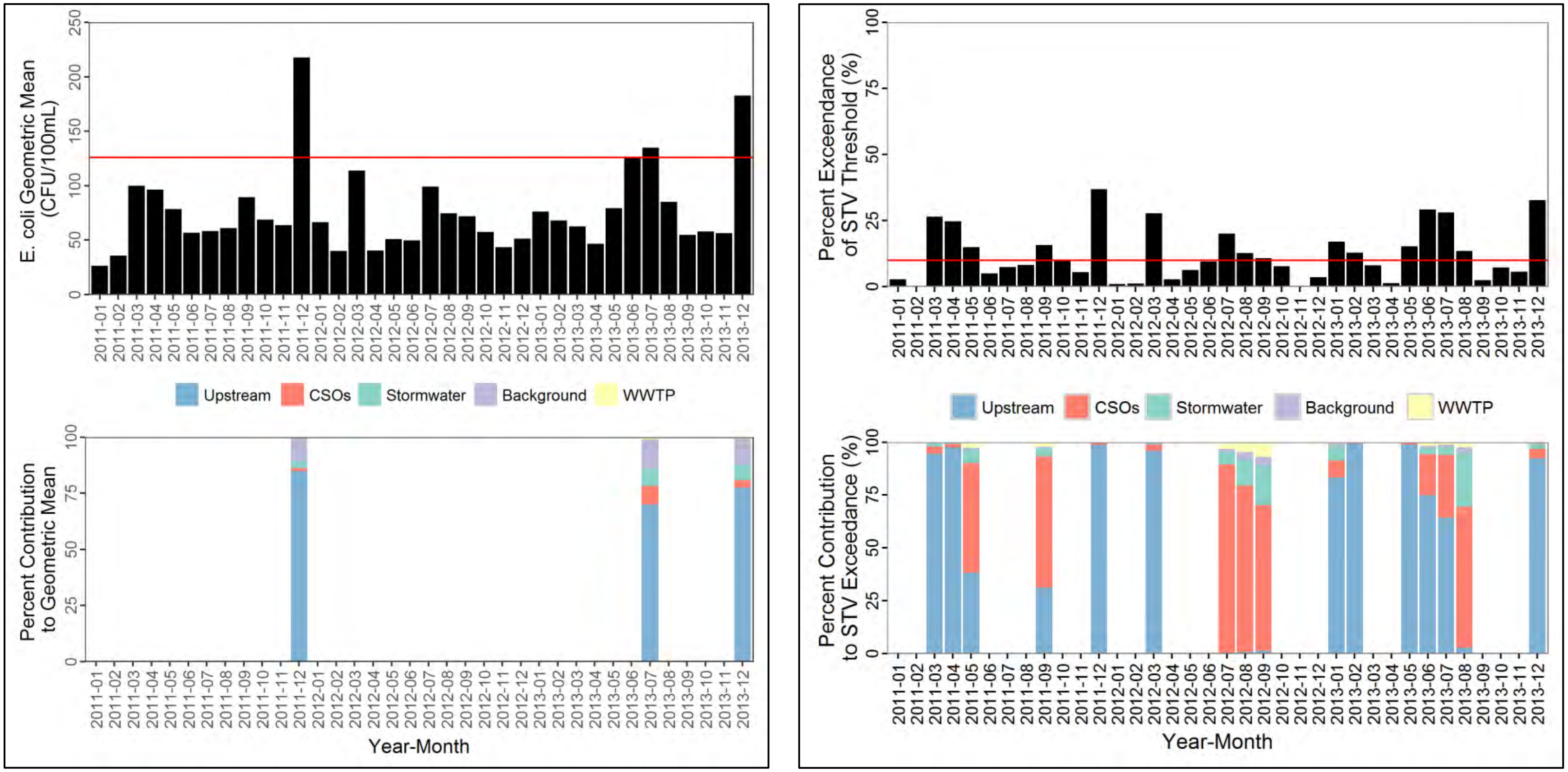


Figure 5-7: CSS Improvement Infrastructure Strategy: Monthly Geometric Mean and STV Standard Model Results

5.4.5.a CSS Infrastructure Improvement Strategy with Upstream Load Reductions

The James River Bacteria TMDL (MapTech, 2010) details the *E.coli* load reductions that would be necessary to achieve water quality compliance upstream of the City. These reductions, which were based on an independent analysis of water quality, were generally greater than 50%. Based on this information, the Water Quality model was applied for the CSS Infrastructure Strategy, whereby upstream load reductions were incrementally reduced until the downstream water quality criteria would be achieved under the monthly geomean standard. If all other sources remain the same, and with the CSS Infrastructure improvements in place, upstream sources would need to be reduced by 50% in order to meet the monthly geomean standard. These results are shown in

Figure 5-8.

5.4.5.b Evaluating Individual CSS Infrastructure Improvement Projects

The CSS Infrastructure Improvement Strategy consists of several different projects as outlined in the LTCP, and shown in Table 5-1 and Table 5-2. Each project was evaluated in isolation to determine individual project impact on bacteria load reduction and on the percent improvement towards meeting the monthly E.coli geometric mean water quality standard. Figure 5-9 summarizes the *E.coli* load reductions and Table 5-9 shows the "percent improvement" for each project scenario. Even though the individual scenarios can achieve significant E.coli load reductions (22%-67% reductions), the "percent improvement" shows smaller gains that vary between 13% and 21%. This is because E.coli loads from the CSS system make up only a fraction of the total *E.coli* load in the James River.

5.4.5.c Evaluating Alternative CSS Improvement Projects

It is anticipated that the modeling framework will be applied during the summer and fall of 2017 to evaluate alternative CSS reduction projects that may provide similar benefits to the LTCP projects, but at a reduced cost. These alternatives will be evaluated against the existing LTCP projects, and results will be presented as they become available.

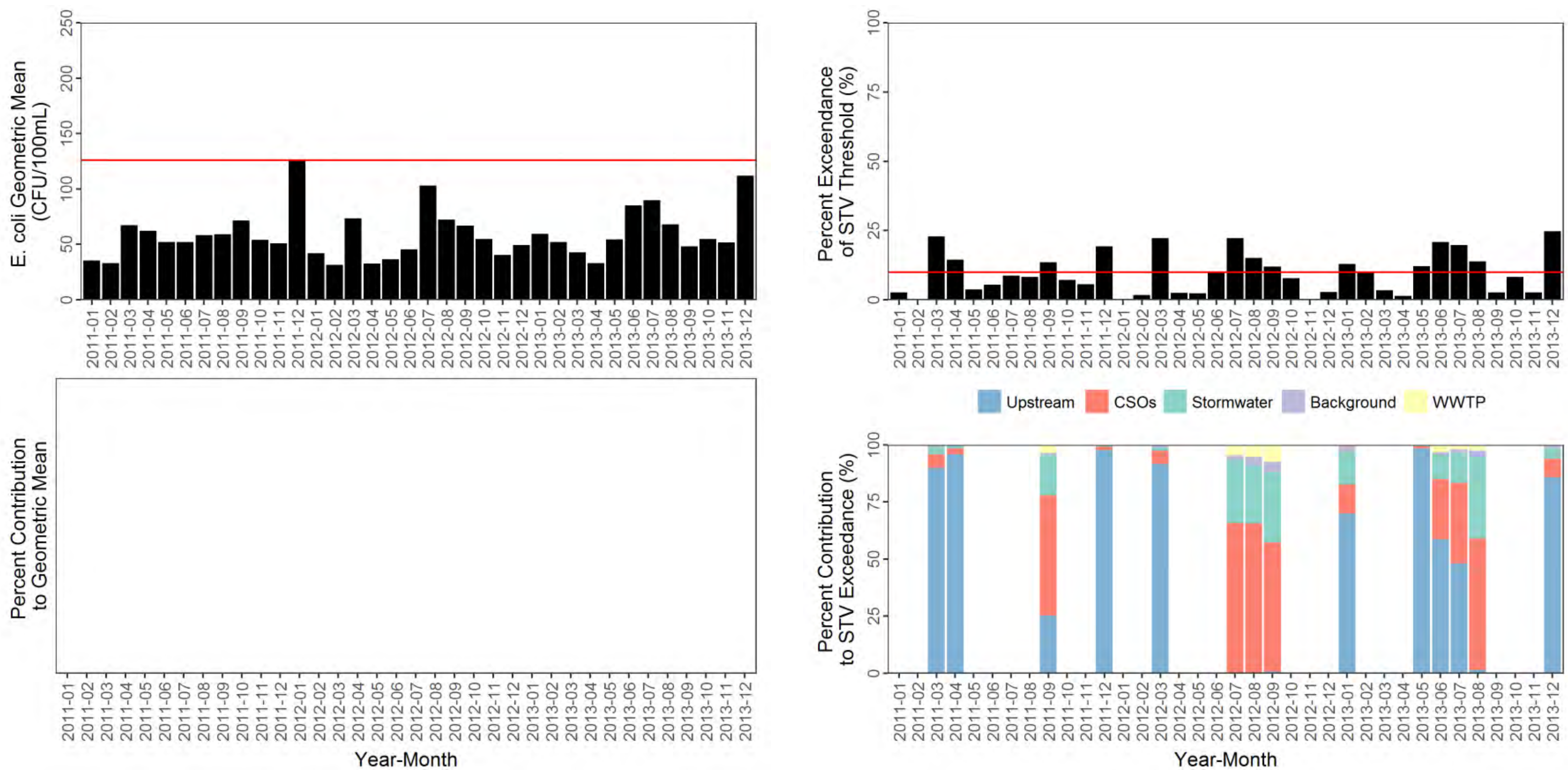


Figure 5-8: Modeled Water Quality Concentration with CSS Improvement Infrastructure Strategy and a 50 Percent Reduction in Upstream Loads

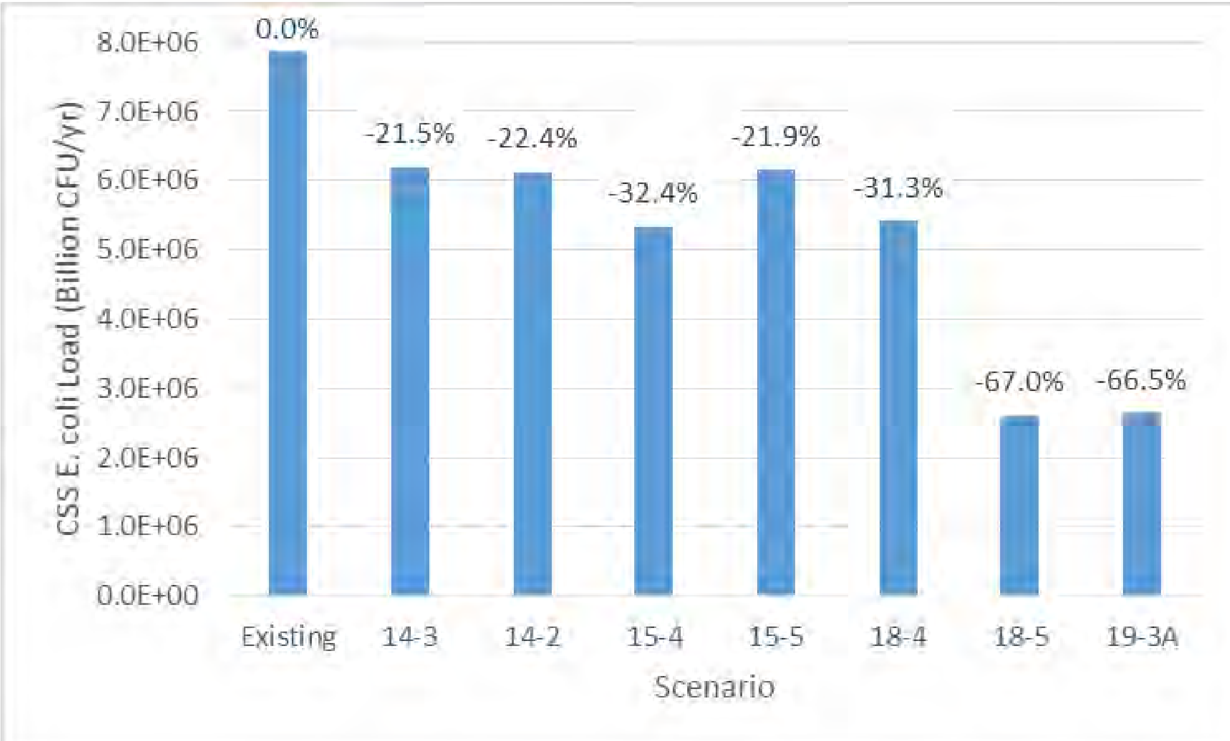


Figure 5-9: E.coli Load Reduction for Each CSS Infrastructure Improvement Project

Table 5-9: Percent Improvement Over Current Conditions for each CSS Infrastructure Improvement Project

CSS Scenario	Project	3-year Aggregate CSO Event Reduction (#)	3-year Aggregate CSO Volume Reduction (MG)	3-year Aggregate Exceedance of Geomean Standard (CFU/100ml)	Percent Improvement Over Current Conditions
Current	Current Conditions	--	--	200	--
14-3	Baseline Conditions	5	1,439	174	12.8%
14-2	Gillies Conveyance	5	1,468	174	13.2%
15-4	300 MGD Wet Weather Treatment	5	2,488	167	16.6%
15-5	CSO 21 Replacement	6	1,634	175	12.5%
18-4	SRB Expansion	1	1,950	168	16.1%
18-5	SRB Expansion and Disinfection	5	3,993	158	21.0%
19-3A	CSS Infrastructure Improvement Strategy (Full LTCP)	8	4,325	157	21.3%

5.4.6 Summary of Results for the Strategy Calculator

The strategies were evaluated using several metrics related to bacteria reduction, including:

- Bacteria load reduction from combined sewer and tributary discharges, expressed as Billion CFU
- Percent improvement in monthly geomean water quality standard compliance at the downstream city limit
- Reduction in number of CSO events
- Reduction in CSO volume (Million gallons)

These four metrics are used in the Strategy Calculator, a spreadsheet tool that is used to evaluate and score the different management strategies across a wide range of goals and objectives (LimnoTech, 2017). The results for the Strategy Calculator are summarized in Table 5-10.

Table 5-10: Strategy metric results used in the Strategy Calculator

Metric	GI in MS4	GI in CSS	CSS Infrastructure
Average yearly E.coli load reduction compared to the baseline (billion cfu)	4,051	52,350	3,551,112
Average reduction in annual number of CSO events compared to the baseline conditions	0	0	1
Average reduction in annual CSO volume discharged compared to the baseline conditions (million gallons)	0	9	962
Percent improvement compared to baseline conditions (%)	0.1	0.1	10

6 References

American Society of Civil Engineers (ASCE). 1992. Design & Construction of Urban Stormwater Management Systems, New York, NY.

Brown and Caldwell. 2016. Draft Technical Memorandum: CSO Model Review and Advancement Strategy: Model Review. May 10, 2016.

Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Federal Emergency Management Agency (FEMA). 2014. Flood Insurance Study: City of Richmond, Virginia. Revised July 16, 2014.

Gesch, D., Oimoen, M., Greenlee, S., Nelson, C., Steuck, M., & Tyler, D. 2002. The National Elevation Dataset. Photogrammetric engineering and remote sensing, 68(1), 5-32.

Greeley and Hansen. 2002. Combined Sewer Overflow (CSO) Study; Long-Term CSO Control Plan Re-Evaluation. January, 2002.

Greeley and Hansen. 2012-2014:

- Broad Rock Creek Watershed Plan. Final Report. November 2012.
- Cherokee Lake Watershed Plan. Final Report, November 2012.
- Falling Creek Watershed Plan. Final Report, February 2014.
- Gillies Creek Watershed Plan. Final Report, November 2012.
- Goodes Creek Watershed Plan. Final Report, November 2012.
- Grindall Creek Watershed Plan. Final Report, November 2012.
- Jordan’s Branch Watershed Plan. Final Report, November 2012.
- Manchester Watershed Plan. Final Report, November 2012.
- Pocosham Creek Watershed Plan. Final Report, February 2014.
- Reedy Creek Watershed Plan. Final Report, November 2012.
- Riverfront Watershed Plan. Final Report, January 2014.
- Willow Oaks Watershed Plan. Final Report, January 2014.

Greeley and Hansen. 2015. Wastewater Collection System Master Plan: Collection System Hydraulic Model. November 2015.

James, W., Rossman, L. A., & James, W. R. C. 2010. User's guide to SWMM 5: [based on original USEPA SWMM documentation]. CHI.

Lawson, 2003. HSPF Model Calibration and Verification for Bacteria TMDLS: Guidance Memo No. 03-2012. Commonwealth of Virginia. Department of Environmental Quality. Water Division.

LimnoTech. 2008. Richmond CSO and James River receiving water model – Model description & Modeling procedure.

LimnoTech, 2017. Calculator Webinar, January 2017. Accessible through: http://www.rvah2o.org/file-upload-form/ or through https://player.vimeo.com/video/199872947

MapTech, 2010. Bacterial Total Maximum Daily Load Development for the James River and Tributaries – City of Richmond. November 2010. McCuen, R. et al. 1996. Hydrology, FHWA-SA-96-067, Federal Highway Administration, Washington, DC

Risley, J. C., Stonewall, A., & Haluska, T. L. 2008. Estimating flow-duration and low-flow frequency statistics for unregulated streams in Oregon (No. FHWA-OR-RD-09-03). US Department of the Interior, US Geological Survey.

USACE, 2013. Richmond Deepwater Terminal to Hopewell After Dredging. Survey of September 2011 to January 2012. James River, Virginia. 1/23/2013.

USACE, 1979-1980. National Dam Safety Program. Norfolk District Corps of Engineers. Reports available through the Defense Technical Information Center: http://www.dtic.mil/dtic/

USEPA, 2010. Sampling and Consideration of Variability (Temporal and Spatial) For Monitoring of Recreational Waters (EPA Publication No. EPA-823-R-10-005).

USGS, 2017. Load Estimator (LOADEST): A Program for Estimating Constituent Loads in Streams and River. Website accessed 2/13/2017. Page last modified: 12/12/2016.

7 Glossary

CSO: Combined sewer overflow

CSS: Combined sewer system

CWA: Clean Water Act

DCIA: Directly connected impervious area

DEM: Digital elevation model

EFDC: Environmental Fluid Dynamic Code

EMC: Event mean concentration

HSG: Hydrologic soil group

LiDAR: Light detection and ranging

MRLC: Multi-Resolution Land Characteristics

MS4: Municipal separate storm sewer system

NCDC: National Climatic Data Center

NLCD: National Land Cover Database

NRCS: National Resources Conservation Service

NOAA: National Oceanic and Atmospheric Administration

NRCS: National Resources Conservation Service

RIA: Richmond International Airport

SSO: Sanitary sewer overflow

SSURGO: Soil Survey Geographic database

SWMM: Storm Water Management Model

USGS: United States Geological Survey

Appendix 2. Strategy Fact Sheets

STRATEGY: RIPARIAN AREAS

Replace or restore 10 acres of riparian buffers according to state guidance. This may include:

- Implementing in the MS4 and / or the CSS areas of the City
- Replacing grassed buffers and impervious surfaces with a forested buffer
- Evaluating opportunities for inclusion of access points to waterbody for recreational activities

Riparian areas within urban environments often face numerous pressures from encroachment to increased pollutant impacts. The Riparian Area strategy includes the identification of areas within a 100 foot riparian buffer that have been compromised by insufficient vegetation to perform its function. This can stem from factors such as the removal of trees, lack of an understory, or presence of impervious surfaces.

A GIS analysis of the City's streams and the land cover surrounding these streams identified locations where these stream buffer deficiencies exist. The intent of the Riparian Area strategy is to replace or restore these deficient buffers. Several assumptions were made in association with this strategy including:

- Removal of two acres of impervious surfaces
- Restoration of eight acres of grassed areas to forest buffer
- Planting 125 trees per acre

Additionally, because one objective is to facilitate recreational access to the streams, this strategy will also incorporate four access points within these 10 acres of restored riparian area (1 access point per 1,000 feet of buffers replaced/restored).

This strategy also makes the assumption that there will be an investigation of the possibility to increase the width of riparian buffers within the City to 200 feet. If determined feasible, riparian buffers will be expanded upon where possible.

While this strategy is not traditionally considered "green infrastructure," it was characterized as such for the scoring of the strategies due to elements of the strategy, such as removal of impervious surfaces and tree planting.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Riparian Area strategy was included in **TIER 1** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC		METRIC		METRIC
√	TN reduction	√	Riparian buffers restored/increased	√	Area treated by GI
√	TP reduction	√	Habitat protected or restored		Streams restored
√	TSS reduction	√	Habitat connected by green corridor	√	Stormwater volume reduction
√	Bacteria reduction	√	Impervious surface reduced or treated	√	Stream access points added
	Reduction in no. of CSO events	√	Trees planted	√	Streams buffers added
	Reduction in CSO volume		Potable water consumption reduced		Conservation easements added
√	PCB, metals, and toxics reduction		Rain or storm water used for irrigation		Trash reduction
	Amount of water conserved		Percent increase in WQS compliance at James River compliance point		

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	19
Average yearly TP load reduction (lbs/yr)	4
Average yearly TSS load reduction (lbs/yr)	1,081
Average yearly E.coli load reduction (billion cfu/yr)	83

Cost Effectiveness	
Cost per pound TN removed	$58,902
Cost per pound TP removed	$292,553
Cost per pound TSS removed	$1,017
Cost per billion cfu E.coli removed	$13,190

STRATEGY: GREEN INFRASTRUCTURE IN THE MS4

Install or retrofit green infrastructure (GI) draining 104 acres of city-owned impervious surfaces (50% of all city-owned impervious area) through efforts such as:

- Installing GI on DPU property, specifically targeting city-owned vacant properties for stormwater management
- Installing a mix of GI, including bioengineered tree boxes (like Filtera-type practices)
- Installing GI on Parks department property (e.g.: playgrounds, parks, cemetery roadways, vacant properties, etc.)
- Retrofitting four DPU stormwater BMPs (e.g., dry ponds to more efficient BMPs); draining at least 6 acres of impervious surface

This green infrastructure (GI) strategy is intended to represent a general mix of practices typically included in GI implementation efforts. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the GI types included, area treated, and load reductions efficiencies, and other benefits provided by the GI practices. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

The Mix of GI and Associated Acres Assumed for GI in the MS4

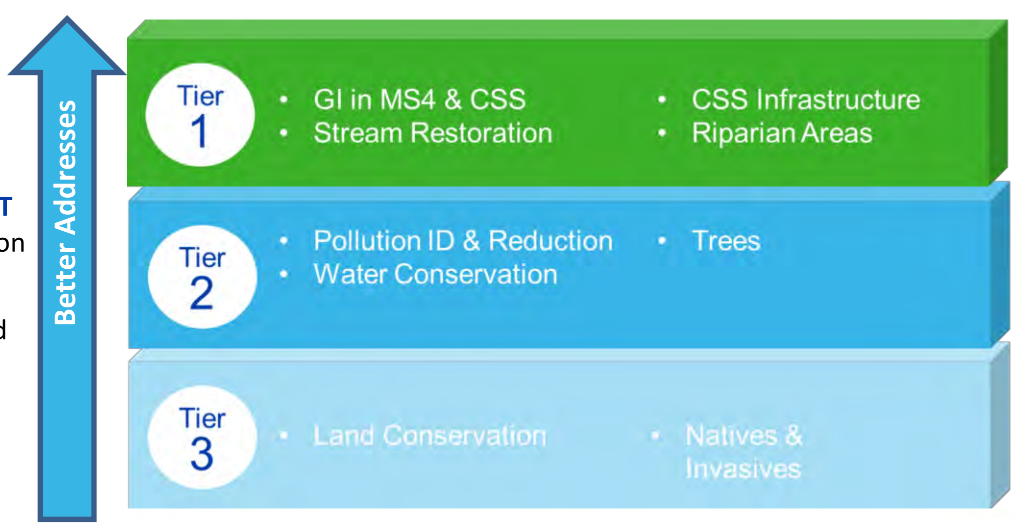
Green Infrastructure Practice	Area Treated (acres)
Engineered tree boxes	17
Stormwater pond retrofit (dry pond to wet pond)	6
Green roofs	1
Rainbarrels	16
Permeable pavement - A/B soils, underdrain	10
Permeable pavement - C/D soils, underdrain	10
Bioretention/raingardens - A/B soils, underdrain	21
Bioretention/raingardens - C/D soils, underdrain	23
Total Area Treated by Green Infrastructure in the MS4 area	**104**

The mix of GI types included and shown below is based on some of the more common GI types that are routinely implemented in the region. The practices assumed for this strategy are not meant to be exclusive or all-encompassing; other practices such as constructed wetlands, impervious surface disconnection, or nutrient management, could also be included under this strategy. The “final” list of GI practices will be determined though the Framework Planning process, as the City and stakeholders move closer to evaluating projects for implementation (see Chapter 7 of the City’s Integrated Water Resources Management Plan for additional discussion on Framework Planning).

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, GI in the MS4 was included in **TIER 1** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC		METRIC		METRIC
√	TN reduction		Riparian buffers restored/increased	√	Area treated by GI
√	TP reduction	√	Habitat protected or restored		Streams restored
√	TSS reduction		Habitat connected by green corridor	√	Stormwater volume reduction
√	Bacteria reduction	√	Impervious surface reduced or treated		Stream access points added
	Reduction in no. of CSO events	√	Trees planted		Streams buffers added
	Reduction in CSO volume		Potable water consumption reduced		Conservation easements added
√	PCB, metals, and toxics reduction	√	Rain or storm water used for irrigation		Trash reduction
	Amount of water conserved	√	Percent increase in WQS compliance at James River compliance point		

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs)	414
Average yearly TP load reduction (lbs)	90
Average yearly TSS load reduction (lbs)	42,397
Average yearly E.coli load reduction (billion cfu)	3,531

Cost Effectiveness	
Cost per pound TN removed	$30,181
Cost per pound TP removed	$138,687
Cost per pound TSS removed	$295
Cost per billion cfu E.coli removed	$3,540

STRATEGY: GREEN INFRASTRUCTURE IN THE COMBINED SEWER SYSTEM (CSS)

Install or retrofit green infrastructure (GI) draining 18 acres of city-owned impervious surfaces through efforts such as:

- Installing GI on DPU property, specifically targeting city-owned vacant properties for stormwater management
- Installing a mix of GI, including bioengineered tree boxes (like Filtera-type practices)
- Installing GI on Parks department property (e.g.: playgrounds, parks, cemetery roadways, vacant properties, etc.)

This green infrastructure (GI) strategy is intended to represent a general mix of practices typically included in GI implementation efforts. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the GI types included, area treated, and load reductions efficiencies, and other benefits provided by the GI practices. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

The Mix of GI and Associated Acres Assumed for GI in the CSS

Green Infrastructure Practice	Area Treated (acres)
Engineered tree boxes	2.9
Green roofs	0.2
Rainbarrels	2.7
Permeable pavement - A/B soils, underdrain	1.8
Permeable pavement - C/D soils, underdrain	1.8
Bioretention/raingardens - A/B soils, underdrain	4.1
Bioretention/raingardens - C/D soils, underdrain	4.5
Total Area Treated by Green Infrastructure in the MS4 area	**18**

The mix of GI types included and shown here is based on some of the more common GI types that are routinely implemented in the region. The practices assumed for this strategy are not meant to be exclusive or all-encompassing; other practices such as constructed wetlands, impervious surface disconnection, or nutrient management, could also be included under this strategy. The "final" list of GI practices will be determined though the Framework Planning process, as the City and stakeholders move closer to evaluating projects for implementation (see Chapter 7 of the City's Integrated Water Resources Management Plan for additional discussion on Framework Planning).

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, GI in the CSS was included in **TIER 1** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
√	Bacteria reduction
	Reduction in no. of CSO events
√	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
√	Habitat protected or restored
	Habitat connected by green corridor
√	Impervious surface reduced or treated
√	Trees planted
	Potable water consumption reduced
√	Rain or storm water used for irrigation
√	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
√	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs)	74
Average yearly TP load reduction (lbs)	16
Average yearly TSS load reduction (lbs)	7,393
Average yearly E.coli load reduction (billion cfu)	40,642

Cost Effectiveness	
Cost per pound TN removed	$45,270
Cost per pound TP removed	$209,375
Cost per pound TSS removed	$453
Cost per billion cfu E.coli removed	$82

STRATEGY: STREAM RESTORATION

This strategy includes the rehabilitation of 2,500 linear feet of stream, including activities such as removal of concrete channels and repair of incised banks. These streams can be located within the MS4 or the CSS areas of the City. This strategy also includes the evaluation of opportunities for inclusion of access points to a waterbody for recreational activities.

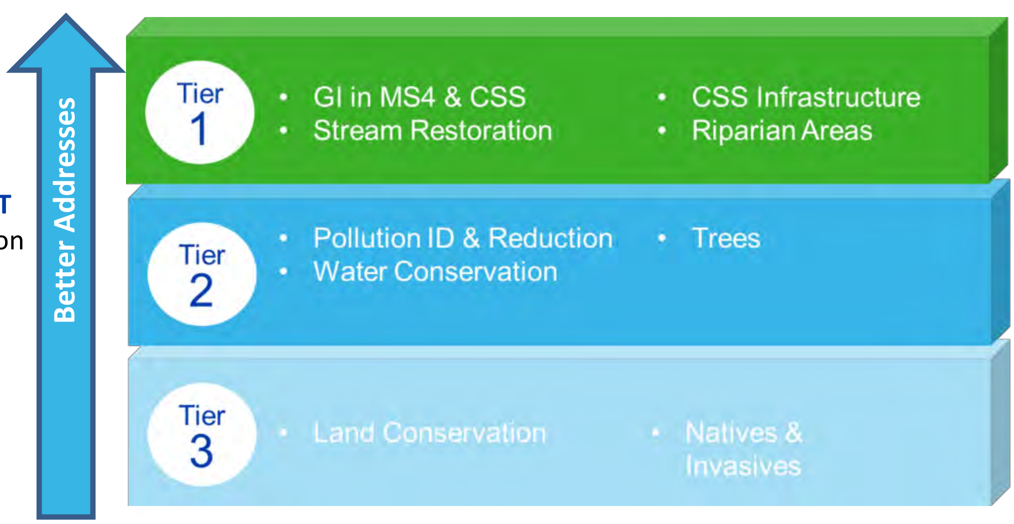
The 2,500 linear feet selected for this Stream Restoration Strategy was based upon a similar expanse included within the City's Chesapeake Bay TMDL Action Plan. Several assumptions were made in the development of this strategy including the following:

- The EPA CBP-approved pollutant reduction for this practice considers the ecoregion within which the stream restoration takes place. Because Richmond is split approximately in half between the Coastal Plain and the Piedmont ecoregions, it was assumed that 50% of the stream rehabilitation efforts would occur in each.
- Stream restoration projects will include a riparian buffer of 100 feet, but, where possible, the buffer will be increased to 200 feet.
- The average width of the streams restored was assumed to be 50 feet.
- This 100-foot buffer along the 2,500 linear feet of stream restoration results in almost 6 acres of riparian buffer restored or increased.
    - This is separate from what is included in the Riparian Area Strategy.
- Trees would be planted at a density of 125 trees per acre with over 700 trees planted.
    - This is separate from what is included in the Tree Strategy.
- Because improving waterfront access for recreation is an objective for the IWRM Plan, an access point for residents was assumed to be included for every 1,000 feet of stream restored. Two access points are therefore assumed for this 2,500 linear feet of stream restoration.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Stream Rehabilitation strategy was included in **TIER 1** of priorities for implementation.



METRICS

The table below shows the metrics that are addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC		METRIC		METRIC
√	TN reduction	√	Riparian buffers restored/increased	√	Area treated by GI
√	TP reduction	√	Habitat protected or restored	√	Streams restored
√	TSS reduction	√	Habitat connected by green corridor		Stormwater volume reduction
	Bacteria reduction		Impervious surface reduced or treated	√	Stream access points added
	Reduction in number of CSO events	√	Trees planted		Stream buffers added
	Reduction in CSO volume		Potable water consumption reduced		Conservation easements added
	PCB, metals, and toxics reduction		Rain or storm water used for irrigation		Trash reduction
	Amount of water conserved		Percent increase in WQS compliance at James River compliance point		

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	188
Average yearly TP load reduction (lbs/yr)	170
Average yearly TSS load reduction (lbs/yr)	75,013
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$15,467
Cost per pound TP removed	$17,059
Cost per pound TSS removed	$39
Cost per billion cfu E.coli removed	--

STRATEGY: TREE PLANTING

Increase natural land cover by focusing on tree planting, including:

- Increasing tree canopy on City property by 5%
- Protecting existing tree canopy by following maintenance addressed in the Tree Planting Master Plan

The tree planting strategy is intended to protect as well as increase the amount of tree canopy that covers Richmond. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the number and density of trees planted, area treated, load reduction efficiencies, and other benefits provided by tree planting. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM. For example, it was assumed that 2,000 trees per year would be planted at a density of 125 trees/acre and that a single tree could reduce up to 466 gallons of storm water per year.

In addition to reducing target pollutant loads and stormwater volume, increasing the tree canopy also provides additional benefits to the public and to wildlife. As part of the tree planting strategy, trees planted in 50% of targeted areas are intended to increase or protect existing habitat, and 25% of the areas targeted for tree planting will be part of green corridors.

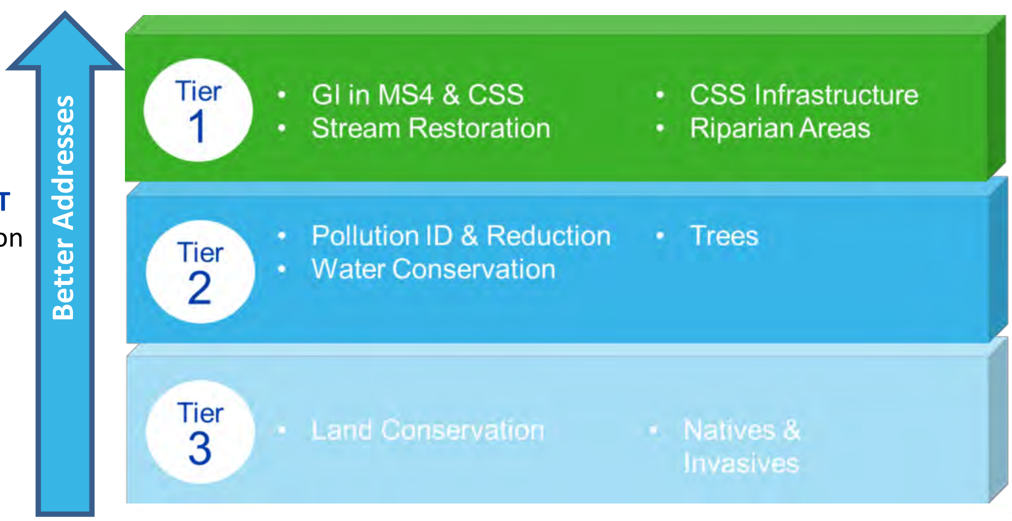
Acres Assumed for Tree Planting in the MS4

Tree Planting Practice	Area (acres)
Total area targeted for tree planting	80
Effective tree canopy area	33
Tree canopy area over impervious area	7
Tree canopy area over pervious areas	26
Habitat protected/restored	17
Habitat protected by green corridor	8

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Tree Planting strategy was included in **TIER 2** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
√	Habitat protected or restored
√	Habitat connected by green corridor
√	Impervious surface reduced or treated
√	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	30
Average yearly TP load reduction (lbs/yr)	4
Average yearly TSS load reduction (lbs/yr)	447
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$72,158
Cost per pound TP removed	$520,833
Cost per pound TSS removed	$4,925
Cost per billion cfu E.coli removed	--

STRATEGY: NATIVE PLANT RESTORATION/INVASIVE PLANT REMOVAL

Increase the number and variety of native plants in the City of Richmond by:

- Using 80% native plants in new landscaping at public facilities by 2023
- Removing 5% of invasive plant species on DPU and park properties and replace with native species

The native plant restoration/invasive plant removal strategy focuses on populating new landscaping projects with plant species native to Richmond, actively removing invasive plant species and replacing them with native, and promoting public awareness of invasive plants. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the area treated, load reductions efficiencies, and other benefits provided by the native plant restoration/invasive plant removal. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

There are two main components of the native restoration/invasive removal. The first component focuses on native plant restoration and invasive plant removal on City property. The native plant restoration/invasive plant removal strategy will also take several other factors into account such as biodiversity and the suitability of a species for a given location. Plantings of native species will focus on a wide variety of plants that are commonly found in the Coastal Plain/Piedmont region. In areas of the city that are not expected to receive supplemental watering, only drought-tolerant, native species will be considered. The second component of this strategy will be to develop a “do not plant” list of invasive species to raise awareness of problem species and to help guide local gardeners.

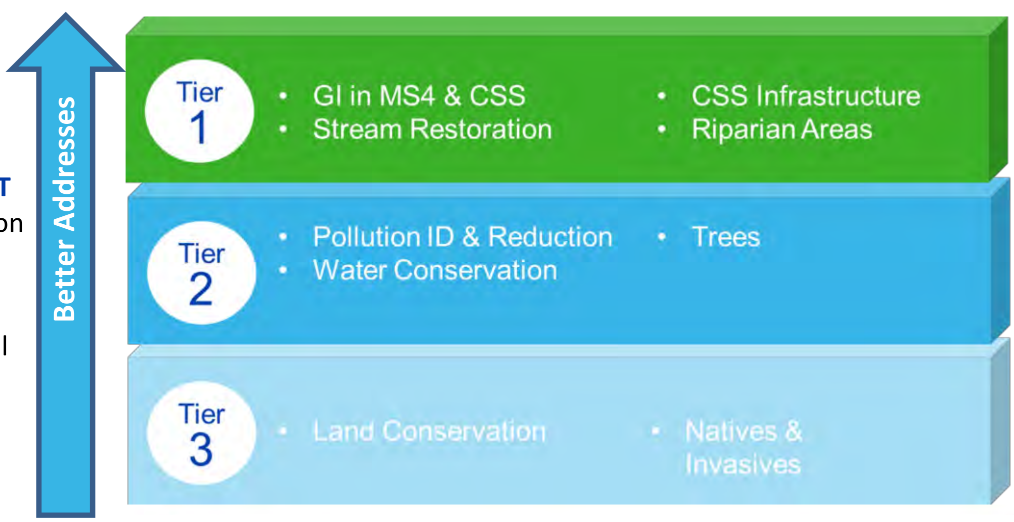
Strategy Elements	
20	Acres of native planting and/or invasive removal
2,000	Trees planted

While this Strategy does not offer significant reductions in target pollutants, they do provide a number of other benefits for the public, the city, and local wildlife, including: increased recreational space, plant biodiversity that will support a wider range of wildlife, and decreased watering costs associated with maintaining appropriately placed native plant species.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Native Plant Restoration/Invasive Plant Removal strategy was included in **TIER 3** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

METRIC		METRIC		METRIC
TN reduction		Riparian buffers restored/increased		Area treated by GI
TP reduction	√	Habitat protected or restored		Streams restored
TSS reduction	√	Habitat connected by green corridor		Stormwater volume reduction
Bacteria reduction		Impervious surface reduced or treated		Stream access points added
Reduction in no. of CSO events	√	Trees planted		Streams buffers added
Reduction in CSO volume		Potable water consumption reduced		Conservation easements added
PCB, metals, and toxics reduction		Rain or storm water used for irrigation		Trash reduction
Amount of water conserved		Percent increase in WQS compliance at James River compliance point		

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness for various strategies is evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) only. Because this strategy doesn't result in reduction of these pollutants, cost effectiveness could not be calculated.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	--
Average yearly TP load reduction (lbs/yr)	--
Average yearly TSS load reduction (lbs/yr)	--
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	--
Cost per pound TP removed	--
Cost per pound TSS removed	--
Cost per billion cfu E.coli removed	--

STRATEGY: WATER CONSERVATION

Reduce water consumption by 10% (from 2009-2014 baseline) through efforts such as:

- Installing water efficient fixtures as a policy by 2023 in all new public facility construction
- Implementing incentive programs that provide retrofits for low income households
- Encouraging water conservation on City properties
- Installing conservation landscaping on city-owned properties

This water conservation strategy is intended to represent a general mix of practices typically included in water conservation implementation efforts. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to the conservation measures included, gallons of water conserved, load reductions efficiencies, and other benefits provided by the conservation practices. These assumptions and decisions were necessary so that this strategy could be modeled at a high level in order to calculate expected load and stormwater volume reductions, and provide metric scores to assess how well the strategy meets the goals and objectives of the IWRM.

The Mix of Conservation Practices and Associated Gallons Conserved Assumed for Water Conservation

Water Conservation Practice	Water Conserved (million gallons)
1,000 New rain barrels	0.52
Conservation incentives	250
Improvements in the water distribution system	250
Total Water Conserved by Water Conservation Practices (over five years)	**500.52**

The mix of conservation activities included and shown here is based on incorporation of common water conservation practices, such as rain barrels and encouraging water conservation by City staff. An incentive program is also planned that will include retrofits of low flush toilets and other fixtures. The "final" list of water conservation practices will be determined though the Framework Planning process, as the City and stakeholders move closer to evaluating projects for implementation (see Chapter 7 of the City's Integrated Water Resources Management Plan for additional discussion on Framework Planning).

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Water Conservation strategy was included in **TIER 2** of priorities for implementation.

METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the Water Conservation strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
	PCB, metals, and toxics reduction
√	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
	Habitat protected or restored
	Habitat connected by green corridor
√	Impervious surface reduced or treated
	Trees planted
√	Potable water consumption reduced
√	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
√	Area treated by GI
	Streams restored
√	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	11
Average yearly TP load reduction (lbs/yr)	1
Average yearly TSS load reduction (lbs/yr)	422
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$24,092
Cost per pound TP removed	$195,744
Cost per pound TSS removed	$639
Cost per billion cfu E.coli removed	--

STRATEGY: LAND CONSERVATION

Place an additional 10 acres of city-owned land under conservation easement. When selecting acreage to include in the easement consideration will be given to the following factors:

- Prioritizing the conservation of land that creates connected green corridors
- Evaluating opportunities for inclusion of access points to waterbodies for recreational activities

The land conservation strategy focuses on placing an additional 10 acres of City-owned land under conservation easement. As part of the development of this high-level strategy, the IWRM Planning Team made a variety of assumptions and decisions with regard to implementation. It was assumed that 50% of the land included in the conservation easement would create connected green corridors. Green corridors are areas of open space that connect fragmented green spaces together allowing for the improved movement of people and wildlife.

Land Conservation Benefits
Conservation/restoration of habitat
Improved connectivity between habitats
Increased public open space
Increased mobility for wildlife
Increased access to recreational opportunities

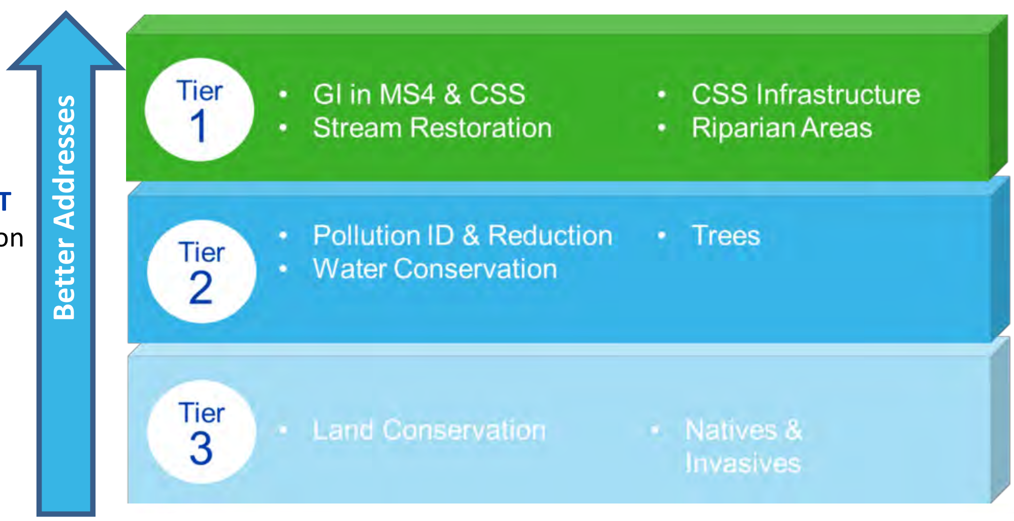
While the land conservation strategy does not offer significant reductions in target pollutants, they do provide a number of other benefits for both local wildlife and the public, including: habitat protection, habitat restoration, increased recreational space, and an increased number of access points to waterbodies within the City.

Because there are no regulatory requirements driving land conservation in the City, this strategy also helps the City address the IWRM Plan objective to exceed regulatory requirements, when possible.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Land Conservation strategy was included in **TIER 3** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC		METRIC		METRIC
	TN reduction		Riparian buffers restored/increased		Area treated by GI
	TP reduction	√	Habitat protected or restored		Streams restored
	TSS reduction	√	Habitat connected by green corridor		Stormwater volume reduction
	Bacteria reduction		Impervious surface reduced or treated	√	Stream access points added
	Reduction in no. of CSO events		Trees planted		Streams buffers added
	Reduction in CSO volume		Potable water consumption reduced	√	Conservation easements added
	PCB, metals, and toxics reduction		Rain or storm water used for irrigation		Trash reduction
	Amount of water conserved		Percent increase in WQS compliance at James River compliance point		

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness for various strategies is evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) only. Because this strategy doesn't result in reduction of these pollutants, cost effectiveness could not be calculated.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	--
Average yearly TP load reduction (lbs/yr)	--
Average yearly TSS load reduction (lbs/yr)	--
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	--
Cost per pound TP removed	--
Cost per pound TSS removed	--
Cost per billion cfu E.coli removed	--

STRATEGY: POLLUTANT IDENTIFICATION AND REDUCTION

Reduce the contribution of pollutants to the municipal separate stormwater sewer system (MS4) area by:

- Conducting at least one special study per year in hot spot areas to identify illicit discharges/connections
- Collecting data associated with non-structural BMPs to facilitate quantification of pollutant reduction

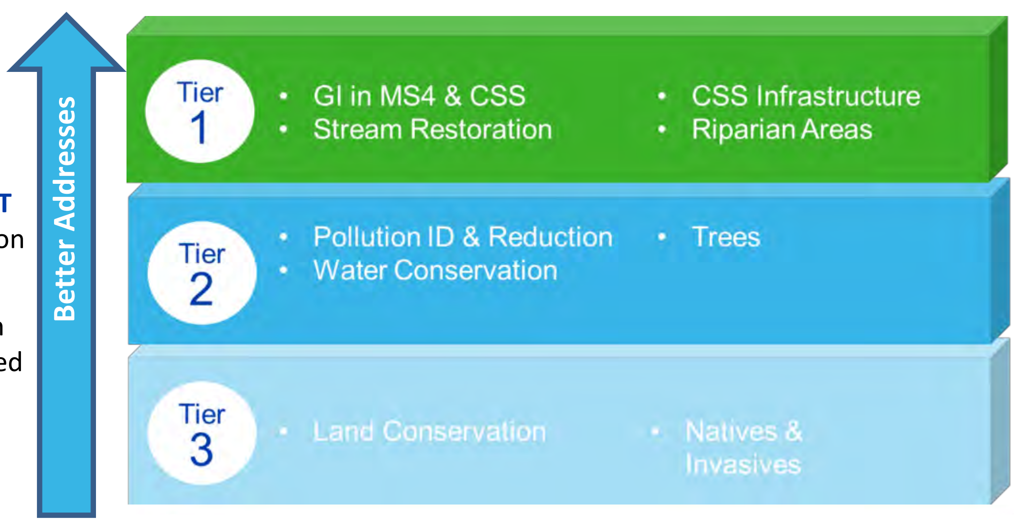
The first part of this strategy involves identifying and eliminating illicit discharges within the MS4 area. Illicit discharges are sources of pollutants collected to storm drains that contribute contaminants to the system during periods of dry weather. This strategy will find and eliminate illicit discharges by conducting at least one special study each year in an area that has been deemed a “hot spot” for pollutant loading. By targeting “hot spots” the city can effectively and efficiently target relatively large sources of pollutants by eliminating the source of the discharge or by implementing a best management practice (BMP) to reduce the pollutant loading. Over five years, at least 3 of these studies will be used to meet pollutant reductions required by the Chesapeake Bay TMDL.

The second part of this strategy involves data collection for non-structural best management practices (BMPs). Currently, the assumptions associated with implementing non-structural BMPs such as catch basin clean outs and street sweeping are based on region-specific literature reviews. Because there is not an approved or commonly used methodology in place to account for pollutant reductions associated with pet waste removoal, this practice was not accounted for quantitatively in the strategy calculator. By collecting site-specific data on pollution reduction practices, the City will be able to refine the pollutant removal rates associated with these projects and to better quantify their impact on the James River. As additional data and research substantiate the quantification of additional pollutant removal practices, these will also be taken into consideration.

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Pollutant Identification and Reduction strategy was included in **TIER 2** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
	Bacteria reduction
	Reduction in no. of CSO events
	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
	Habitat protected or restored
	Habitat connected by green corridor
	Impervious surface reduced or treated
	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
	Percent increase in WQS compliance at James River compliance point

	METRIC
	Area treated by GI
	Streams restored
	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
√	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	448
Average yearly TP load reduction (lbs/yr)	162
Average yearly TSS load reduction (lbs/yr)	57,893
Average yearly E.coli load reduction (billion cfu/yr)	--

Cost Effectiveness	
Cost per pound TN removed	$36,597
Cost per pound TP removed	$100,882
Cost per pound TSS removed	$284
Cost per billion cfu E.coli removed	--

STRATEGY: IMPLEMENT CSS INFRASTRUCTURE PROJECTS

Implement projects outlined in Richmond's combined sewer overflow long-term control plan (CSO LTCP), including:

- Installing wet weather interceptor in Lower Gillies Creek to convey more flow to the WWTP
- Increasing wet weather treatment to 300 MGD at the WWTP
- Expanding Shockoe Retention Basin by 15 MG to capture more combined sewer overflow
- Adding disinfection at the Shockoe outfall to reduce bacteria in combined sewer overflow
- Expanding secondary treatment at the WWTP to 85 MGD

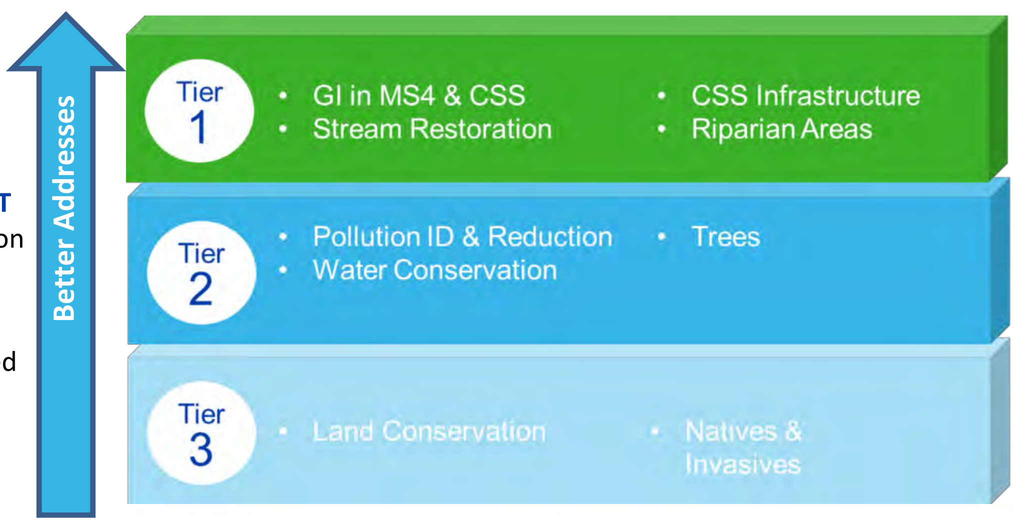
Implementation of Richmond's combined sewer overflow long-term control plan (CSO LTCP) is required under a consent order from the State Water Control Board. The consent order was issued in 2005 and includes an implementation schedule and a description of LTCP projects that will be implemented. Projects that are part of this strategy are aimed at decreasing the volume of CSOs by rerouting flows from the combined sewer outfalls to the Richmond waste water treatment plan (WWTP) and Shockoe retention basin (SRB), where those flows can then receive some level of treatment before being released into the James River. Increasing the treatment capacity of the WWTP and SRB, will result in smaller pollutant loads entering the James River, thereby improving water quality.

Strategy Elements
Expanding wet weather treatment at the waste water treatment plant
Improving wet weather conveyance in Lower Gillies Creek to the waste water treatment plant
Expanding the Shockoe Retention Basin and disinfecting combined sewer overflows at SRB
Expanding secondary treatment at the waste water treatment plant

STRATEGY TIERS

Priorities for implementation are based on how well the strategy addresses selected **METRICS, POLLUTANT REDUCTION**, and **COST EFFECTIVENESS**. Each is discussed on the following page.

Overall, the Implement CSS Infrastructure Strategy was included in **TIER 1** of priorities for implementation.



METRICS

The table below shows the metrics that were addressed by this strategy. Additional details regarding information and assumptions related to this strategy and the numeric metric results can be found in the IWRM Planning Spreadsheet Calculator Tool, located at RVAH2O.org.

Metrics evaluated for the GI in the MS4 strategy

	METRIC
√	TN reduction
√	TP reduction
√	TSS reduction
√	Bacteria reduction
√	Reduction in no. of CSO events
√	Reduction in CSO volume
√	PCB, metals, and toxics reduction
	Amount of water conserved

	METRIC
	Riparian buffers restored/increased
	Habitat protected or restored
	Habitat connected by green corridor
	Impervious surface reduced or treated
	Trees planted
	Potable water consumption reduced
	Rain or storm water used for irrigation
√	Percent increase in WQS compliance at James River compliance point

	METRIC
	Area treated by GI
	Streams restored
	Stormwater volume reduction
	Stream access points added
	Streams buffers added
	Conservation easements added
√	Trash reduction

√ = metric was addressed by the strategy

POLLUTANT REDUCTION & COST EFFECTIVENESS

Cost effectiveness was evaluated for the permit-driven metrics (TN, TP, TSS, bacteria) and expressed as cost per unit pollutant removed.

Pollutant Removal	
Average yearly TN load reduction (lbs/yr)	7,066
Average yearly TP load reduction (lbs/yr)	903
Average yearly TSS load reduction (lbs/yr)	116,843
Average yearly E.coli load reduction (billion cfu/yr)	3,551,112

Cost Effectiveness	
Cost per pound TN removed	$55,507
Cost per pound TP removed	$434,293
Cost per pound TSS removed	$3,357
Cost per billion cfu E.coli removed	$110

SUPPORTING ACTIONS TO MAIN STRATEGIES

While strategies have been defined as "activities, actions, or items that will help meet goals and objectives" of the Integrated Water Resources Management (IWRM) Plan, a number of additional actions have been identified to support or facilitate the implementation of these strategies. These supporting actions to the main strategies include efforts that may broaden the main strategy, additional specificity on how a strategy could be implemented, or identify additional resources and data needs to fully implement the main strategy. These supporting actions are not necessarily quantifiable in and of themselves and may be components of multiple main strategies. They may also involve efforts on non-City property and rely on resources that are outside the DPU's authority.

The development of strategies that meet the goals and objectives of the IWRM Plan resulted in a number of supporting actions related to:

- Partnerships
- Maintenance
- Monitoring, assessment & planning
- Incentives & credits
- Regulations, ordinances & codes
- Outreach

A summary of each of the supporting actions is discussed below and specific examples of these actions are included in the following tables.

The following table identifies which of these supporting actions are included in each strategy. For instance, the Riparian Area, Green Infrastructure (GI) in the municipal separate storm sewer system (MS4), and Tree Strategies address each of the six supporting actions. Alternatively the Pollution Identification (ID), Combined Sewer System (CSS) Infrastructure, and Land Conservation Strategies address only two supporting actions.

	Riparian Area	GI in MS4	GI in CSS	Stream Restor.	Natives/ Invasives	Trees	Land Cons.	Water Cons.	Pollution ID	CSS Infrast.
Partnerships	√	√	√	√	√	√	√	√		
Maintenance	√	√	√	√	√	√				
Monitoring	√	√	√	√	√	√			√	√
Incentives	√	√			√	√		√		
Regulations	√	√	√			√		√		
Outreach	√	√	√	√	√	√	√	√	√	√

Partnerships

The purpose of establishing partnerships is to facilitate a greater level of future implementation. This could be as the result of partnerships within the City, such as with Department of Planning or the Parks, Recreation, and Community Facilities. Partnerships may also include non-City agencies, such as watershed groups or neighborhood associations that can help facilitate implementation of strategies on private property. Non-DPU City departments, watershed groups, or neighborhood associations could work collectively with DPU to cost share implementation of strategies through shared staff and resources or through collaboration of actions. Additional specificity related to partnerships (along with other supporting actions) are expected to be refined over time as additional discussions and agreements are made with potential partners.

Maintenance
Many of the selected strategies require maintenance to ensure the strategy is performing as it should and will continue to meet its intended objectives. Part of this supporting action includes ensuring that sufficient funding is available and is part of each applicable strategy.

Monitoring, Assessment & Planning
The intent of this supporting action is to gather data and information and use these results to help inform and guide future implementation. This can include monitoring of specific practices, such as pre- and post-construction monitoring of a stream restoration project. It could also include the inventory and mapping of areas associated with the various strategies, such as riparian buffers or invasive species. Monitoring also includes the continuation of the James River and tributary sampling that is being used to evaluate the status and trends that are seen in the City's water quality and aquatic biological communities. As DPU is just one of the organizations that is conducting monitoring, another supporting action could include the initiation of a workgroup to improve coordination of data collection efforts.

Incentives & Credits
These supporting actions are intended to further evaluate, develop, and implement mechanisms to incentivize new initiatives or higher levels of future implementation. Specific actions can relate to expansion of the stormwater credit program to include reference to additional strategies, such as restoration of riparian buffers or removal of invasive and planting of native species on private land.

Regulations, Ordinances & Codes
This includes analyzing and modifying, if necessary, the framework within which implementation will occur. For instance, the Riparian Area Strategy is based on implementation within a 100 foot stream buffer. This supporting action could include evaluating expansion of this buffer to a 200 foot buffer. Additionally, City zoning and planning-related ordinances could be reevaluated to include language related to impervious area or to protect existing trees on developed property.

Outreach
Each of the 10 main strategies includes opportunities for education and outreach. This can include identifying ways to potentially expand upon future implementation by conveying information on resources available or ways for partners and the public support implementation of a strategy. As the implementation portion of the IWRM Plan is developed in more detail, specific activities will be identified and opportunities to implement these activities will be discussed with partner organizations.

COSTS
Costs were evaluated for each of the Supporting Actions. This information is summarized in the table below and detailed further in Appendix 5 (Strategy Cost Estimation) of the IWRM Plan.

Supporting Action	Estimated Cost
Partnerships	$655,000
Maintenance	Cost was included in association with the individual strategies
Monitoring	$1,208,000
Incentives/ Credits	$500,000
Regulations	Assumed to be part of City staff's normal job duties
Outreach	$500,000

	Riparian Areas	Green Infrastructure (in MS4)	Green Infrastructure (in CSS)	Stream Restoration	Native/ Invasives	Trees	Land Conservation	Water Conservation	Pollution Identification	CSS Infrastructure
Supporting Actions										
Partnerships	**20** acres of riparian buffers on private properties: * Through purchase of land * Partnerships with residents: Promote program for buffers on private properties (include tiers of level of involvement - (1) maintenance agreement with city, (2) conservation agreement/ easement.)] * Partner with Master Naturalists to enlist their support to assist with riparian restoration	* **5** acres on DPW property (rights of way, roadways, green alleys) Implement **10** acres of GI on private property: * Adopt a rain garden program - coordinate with residents, non-profits, commercial entities * Partner with City's community garden program to identify **3** acres of area for additional GI implementation * Partner with Public Works to ensure City greenways include GI (**5** acres of GI)	* **5** acres on DPW property (rights of way, roadways, green alleys) Implement **10** acres of GI on private property. : * Adopt a rain garden program - coordinate with residents, non-profits, commercial entities * Partner with City's community garden program to identify **1** acres of area for additional GI implementation * Partner with Public Works to ensure City greenways include GI (**2** acres of GI)	Promote requests for stream restoration by private landowners. Streamline the process by which these requests are addressed.	* Develop a program to encourage the use of native plants in private landscaping - sign up **20** private landscapers. * Initiate an adopt-a-lot program (**10** lots with invasive species removed, replanted, and maintained) * Partner with organizations, such as the James River Park System Invasive Plant Task Force, to better determine areas with significant invasive species issues and resources to deal with the problem.	* Partner with the public and other stakeholders, such as the Richmond Tree Stewards, to plant and maintain trees on public properties.	Partner with the public and other stakeholders to identify land to put in conservation easements. Include an additional **100** acres of non-City property in conservation easements.	* Partner with Richmond Redevelopment and Housing Authority to identify homes/properties that are eligible for upgrades to water efficient fixtures. * Partner with upstream localities and Virginia Department of Health to update/maintain Source Water Protection Plan		
	Hire DPU staff or assign 1 FTE to coordinate volunteers from corporate entities, watershed/environmental groups, and public with partnership opportunities associated with the IP effort. Staff to enlist/maintain **6** of partnerships per year									
	Hold **3** stakeholder meetings per year to continue communication with partners/stakeholders and add purpose to the IP effort.									
	Evaluate partnership network in 5 years (at the end of the permit cycle) to assess gaps and identify new public/private partners.									
Maintenance	Include funding to support maintenance of newly replanted / restored riparian buffers (to ensure success of plantings, prevention of establishment of invasive species, etc.)	Include funding to support maintenance of green infrastructure practices based on findings of the inspection program to ensure continued pollutant reduction credit.		Include funding to support maintenance of restored streams.	Include funding to support maintenance of newly planted native plants as well as to maintain newly established plantings where invasives have been removed from the landscape	Provide funding to support maintenance of trees on city property to ensure their survival and health.				
Monitoring, Assessments & Planning	Inventory and map riparian areas to better understand loss or growth of riparian buffers	Evaluate potential for conducting pre and post construction monitoring of key stormwater BMPs.		Conduct pre and post restoration monitoring per Chesapeake Bay Program requirements	Monitor growth/expansion of invasive species.	Inventory and map locations of trees and tree boxes to better understand loss or growth of tree coverage.			Implement IDDE-related monitoring to support this effort - supported by a desktop analysis of high risk dischargers	Continue monitoring effort associated with the CSO and WWTP discharge programs.
	Continue monitoring of 8 locations across the city for macroinvertebrate, habitat, and instream water quality. Continue monitoring at two locations for flow. Evaluate opportunities to expand the flow monitoring network across the City.									
	Evaluate the development of a monitoring data portal to facilitate sharing of data collected within the City with stakeholders and the public.									

	Riparian Areas	Green Infrastructure (in MS4)	Green Infrastructure (in CSS)	Stream Restoration	Native/ Invasives	Trees	Land Conservation	Water Conservation	Pollution Identification	CSS Infrastructure
	Initiate monitoring workgroup in year one made up of technical stakeholders and other key groups/individuals to evaluate current monitoring efforts and identify potential efficiencies and additional monitoring needs moving forward.									
	Conduct assessments of **4** stream segments across the four watershed groupings to support the development of watershed restoration plans to address pollutant sources and watershed stressors.									
Incentives/ Credits	Reevaluate the stormwater credit program to determine potential to include practices such as replacing or restoring riparian buffers.	* Reevaluate the stormwater credit program (through updates to the credit manual) to include additional practices including tree planting, green roofs, etc. Reevaluation of the credit program will also include increases of funding available for these credits to incentivize implementation on private property. * Provide credits for residential and non-residential properties to reduce stormwater fees based on implementation of "green practices".			Evaluate incentives/credits for purchasing / planting native species (such as Montgomery County, MD).	* Reevaluate the stormwater credit program to determine potential to include practices such as planting trees on private property. * Provide **500** trees for planting on private property or equivalent incentives to purchase native trees.		* Offer grants to replace **20** % of inefficient fixtures in moderate to low-income units. * Evaluate expansion of incentive program to cover washing machines and dishwashers		
Regs/ Ordinance/ Code	Evaluate expanding the regulatory buffer from 100ft to 200ft	Evaluate inclusion of language in City zoning and planning-related ordinances to limit impervious area on developed property.				Evaluate inclusion of language in City zoning and planning-related ordinances to protect existing trees and add new trees on developed property.		Adopt permitting standards for water efficient appliances/ fixtures in city code		
Outreach		Conduct outreach to advertise the resources, requirements, and services available through city related to green infrastructure for private property owners				Conduct outreach to advertise the resources, requirements, and services available through city related to tree planting and maintenance.		* Promote ability to use grey water for toilet flushing. Promote as way to achieve higher LEED standards. * Encourage and incentivize water capture and reuse for landscaping * Promote water conservation for commercial, industrial, and residential customers through efforts such as "Fix a Leak Week" and the City's Every Drop Counts initiative.	Conduct targeted outreach to high-risk industries, particularly in areas of the city identified as hot spots.	
	Conduct outreach to educate the general public about the goals and objectives of RVAH2O, and the resources and services available through the city.									

Appendix 3. RVA Clean Water Plan Goals, Objectives & Metrics

RVAH2O WATERSHED METRICS

GOAL	OBJECTIVES	METRICS
Manage wastewater and stormwater to improve the water quality and water quantity of ground water and surface water.	Develop one stormwater management plan to cover the City's four watershed groupings based on the City's watershed characterization report.	Plan produced (yes=1, no=0)
	Reduce nitrogen, phosphorus and sediment in discharges to achieve VPDES permit requirements (Chesapeake Bay TMDL).	• N reduction (lbs.) • P reduction (lbs.) • TSS reduction (lbs.)
	Reduce bacteria levels to achieve VPDES permit requirements (local TMDL and water quality standards).	• Percent increase in monthly geomean WQS compliance • Average yearly E. coli load reduction (billion cfu) • Average yearly reduction in CSO events (number) • Average yearly reduction in CSO volume discharged (million gallons)
	Reduce toxics (e.g., mercury, PAHs, PCBs), trash and other pollutants and address TMDLs for these pollutants.	• PCB, metals and toxics reduction (yes=1, no=0) • Trash reduction (lbs.)
	Develop green infrastructure, including riparian buffers and removal of impervious surfaces on development, existing development and redevelopment.	• Area treated by GI (acres) • Impervious surface reduced or treated (acres)
Protect and restore aquatic and terrestrial habitats to support balanced indigenous communities.	Restore streams to improve, restore and enhance native ecological communities.	• Streams restored (miles of streams) • Reduce stormwater volume discharging to streams (gallons) • Riparian buffers restored and/or increased (acres)
	Identify, protect and restore critical habitats.	Critical habitat protected or restored (acres)
	Enhance aquatic and terrestrial habitat connectivity.	Habitat connected by green corridor (acres)
	Investigate and, where feasible, promote actions that might surpass regulatory requirements.	Exceeds regulatory requirements (yes=1, no=0)
Engage and educate the public to share responsibility and take action on achieving healthy watersheds.	Engage and efficiently educate the public about standards, processes and actions associated with watershed health and public health.	Residents reached by effort (# of people)
	Assist in the education of citizens about overall water quality issues and benefits of improved water quality.	Residents reached by effort (# of people)
	Support and encourage local action to improve water quality.	• NGOs/community groups provided support by City (# of groups) • Money available for incentives (dollars)
	Provide quicker public notifications of spills or pollution from regulators or other "river watchers."	Time to notify (days)
Implement land conservation and restoration and incorporate these into planning practices to improve water quality.	Protect, restore and increase riparian buffers.	Riparian buffers restored and/or increased (acres)
	Reduce impervious surfaces.	Impervious surface reduced or treated (acres)
	Increase natural land cover with a focus on preserving, maintaining and increasing tree canopy.	Trees planted (acres)
	Incorporate green infrastructure in new development and redevelopment.	Area treated by GI (acres)
	Conserve lands where possible and consistent with Richmond's Comprehensive Plan.	Conservation easements added (acres)
Create partnerships across the watersheds internal and external to the City of Richmond to maximize benefits and minimize impacts to all stakeholders.	Develop and implement a source water prevention plan/strategy.	Plan produced (yes=1, no=0)
	Establish public-private partnerships to secure funding, implement strategies and projects, and achieve plan goals.	Partnerships implemented (# of)
	Maintain and expand the RVAH20 group.	Meetings held (# of)
Maximize water availability through efficient management of potable water, stormwater and wastewater.	Reduce use of potable water for industry and irrigation.	• Potable water consumption reduced (gallons) • Rainwater and stormwater used for irrigation (gallons)
	Achieve water conservation by improving the existing water conveyance system.	Amount of water conserved (gallons)
	Achieve water conservation by incentivizing upgrades to end-user water fixtures where appropriate.	Money available for incentives (dollars)
Provide safe, accessible, ecologically sustainable water-related recreational opportunities for all.	Improve water quality to promote safe recreation consistent with the City's Riverfront Plan.	• Percent increase in monthly geomean WQS compliance • Average yearly E. coli load reduction (billion cfu) • Average yearly reduction in CSO events (number) • Average yearly reduction in CSO volume discharged (million gallons)
	Promote ecologically sustainable management of riverfront and riparian areas.	Streams with buffers (length of streams with 100-foot buffer added)
	Improve river and waterfront access for recreation.	Access points (yes=1, no=0)
Work collaboratively to gather consistent high-quality data to characterize the status and trends of water resources and to gauge the effectiveness of restoration efforts.	Conduct water quality and biological monitoring.	Stations monitored (# of stations)
	Provide timely water quality information.	Time necessary for monitoring results (days)
	Collaborate with citizens and local/state agencies for coordinated monitoring.	Citizen groups/agencies coordinated with (# of)
	Utilize results to target restoration efforts and convey progress.	Project with monitoring component (yes=1, no=0)

RVA H2O
EVERY DROP COUNTS

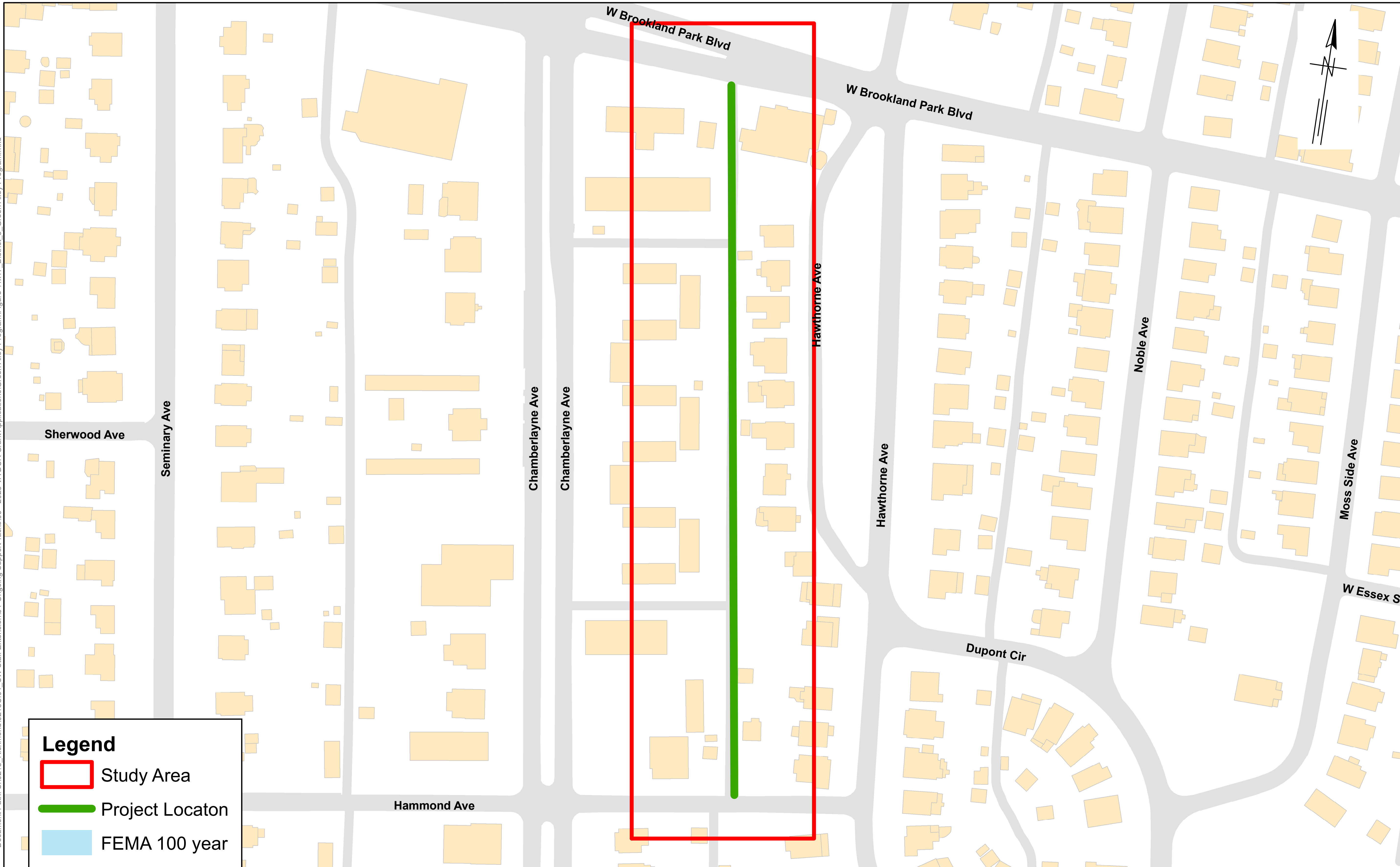
CITY OF RICHMOND
DEPARTMENT OF PUBLIC UTILITIES

Appendix 4. Calculator Spreadsheet Tool

See attached Excel document.

Appendix 5. Strategy Cost Estimation

See attached Excel document.

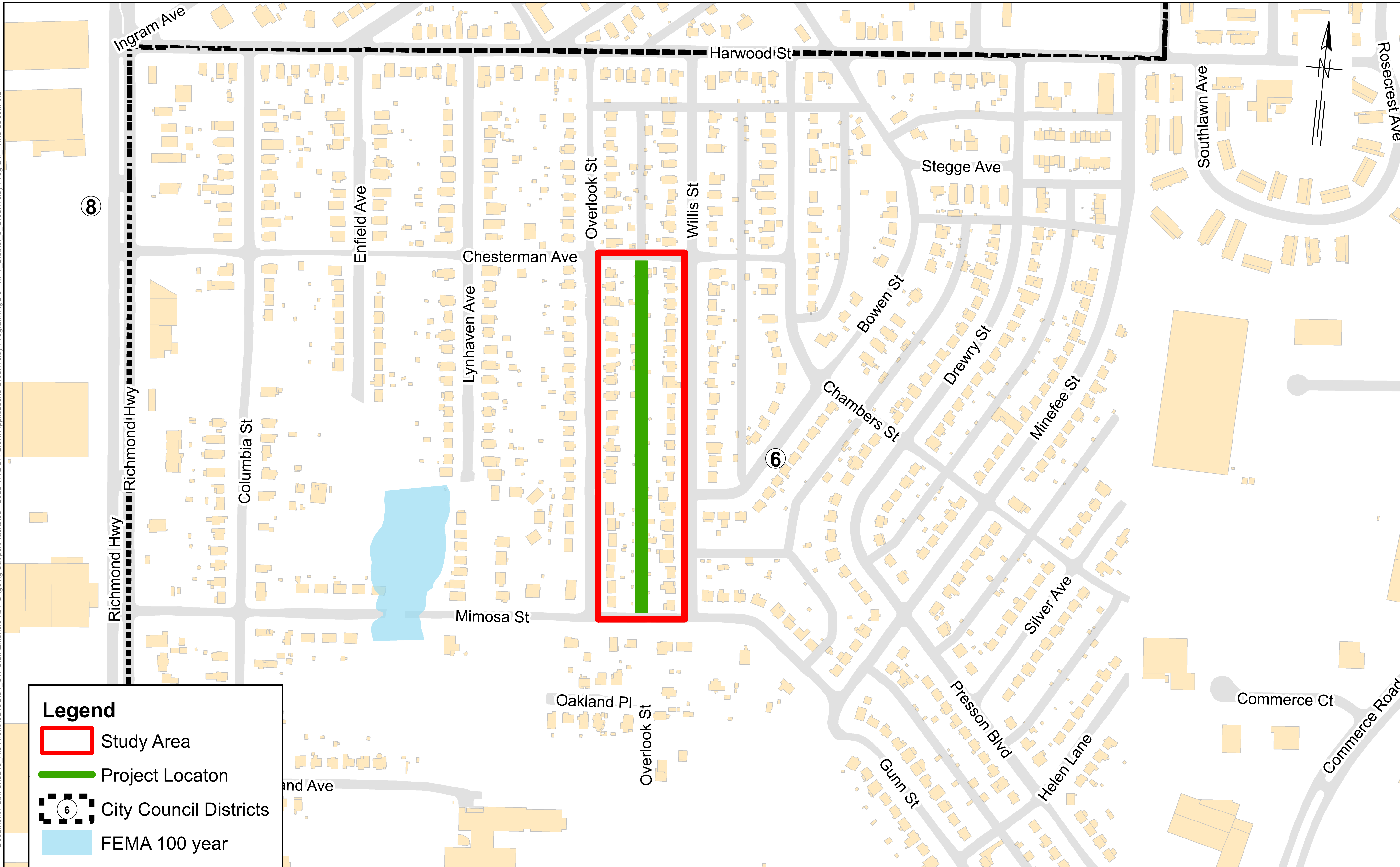


Green Alley Corridor, Council District 3, Chamberlyan Ave and Brookland Park Blvd

GREELEY AND HANSEN
A TYLin Company

0 65 130 260 390 Feet 1 in = 135 ft

CITY OF RICHMOND
2023 VA DCR GRANT APPLICATIONS
GREEN ALLEY PROGRAM
NOVEMBER 2023

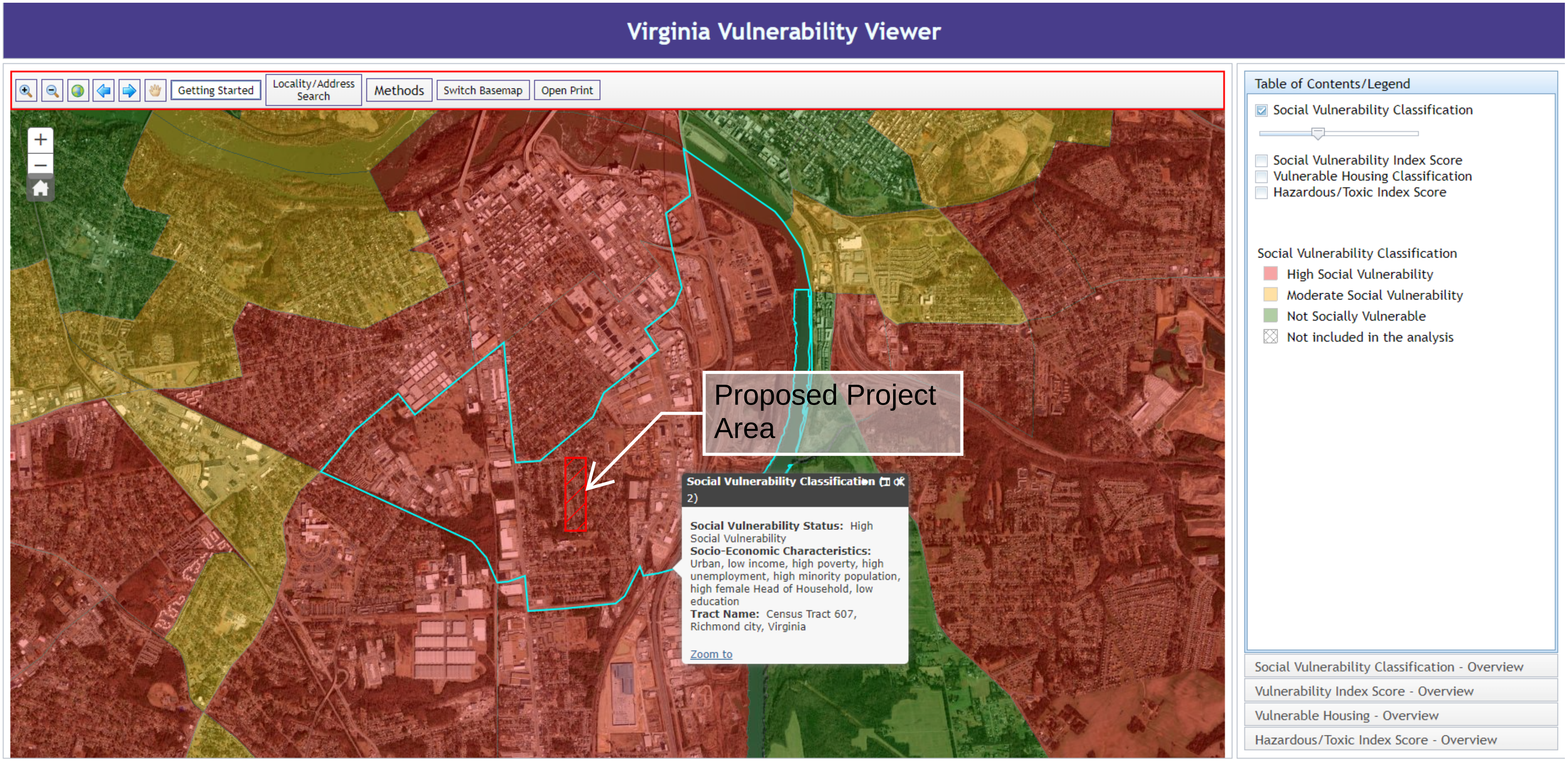


Green Alley Corridor, Council District 6, Willis Street and Overlook Street

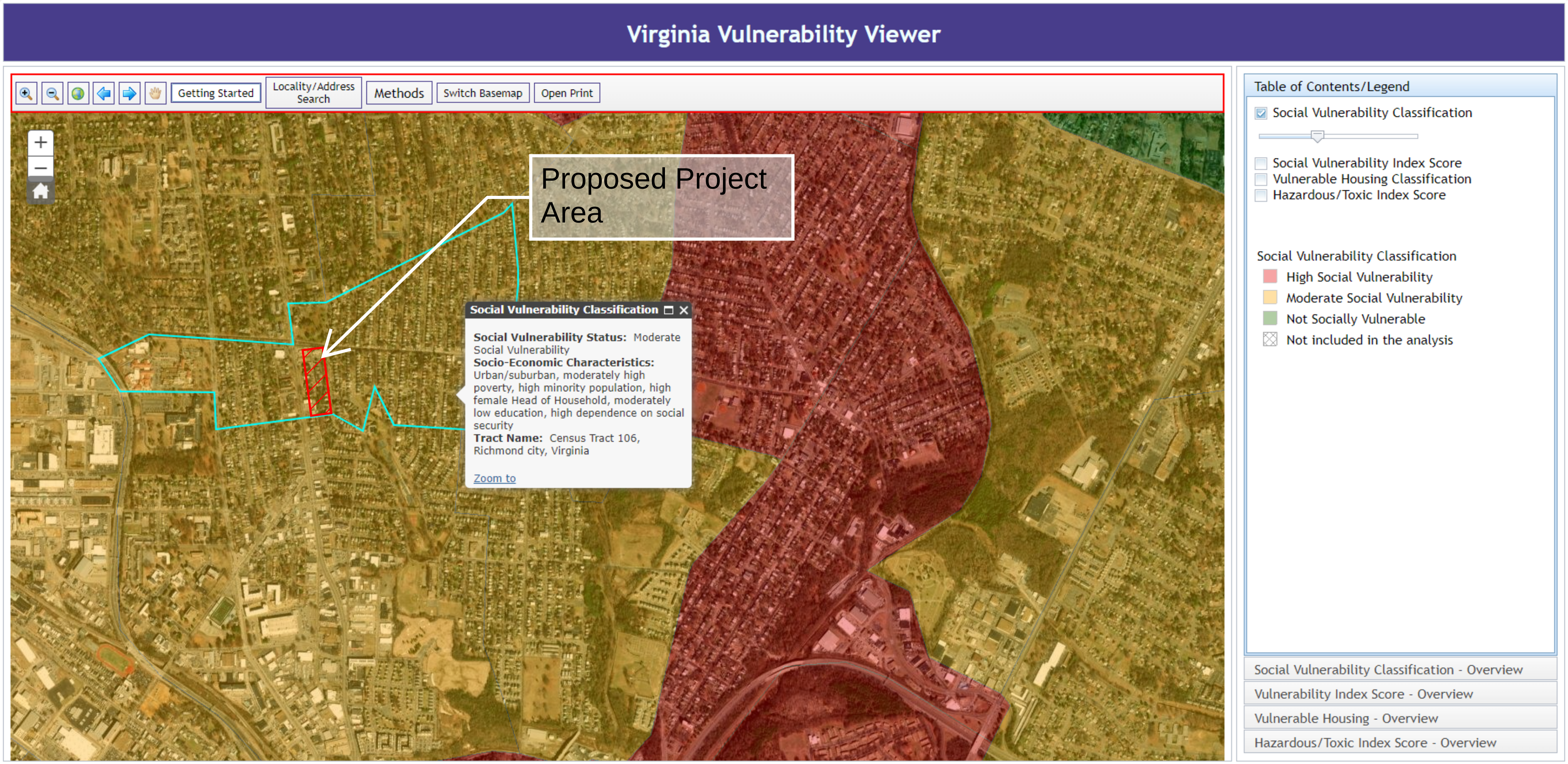
GREELEY AND HANSEN
A TYLin Company

0 150 300 600 900
Feet 1 in = 300 ft

CITY OF RICHMOND
2023 VA DCR GRANT APPLICATIONS
GREEN ALLEY PROGRAM
NOVEMBER 2023



Virginia Vulnerability Viewer
Getting Started
Locality/Address Search
Methods
Switch Basemap
Open Print
Proposed Project Area
Social Vulnerability Classification
2)
Social Vulnerability Status: High Social Vulnerability
Socio-Economic Characteristics: Urban, low income, high poverty, high unemployment, high minority population, high female Head of Household, low education
Tract Name: Census Tract 607, Richmond city, Virginia
Zoom to
Table of Contents/Legend
Social Vulnerability Classification
Social Vulnerability Index Score
Vulnerable Housing Classification
Hazardous/Toxic Index Score
Social Vulnerability Classification
High Social Vulnerability
Moderate Social Vulnerability
Not Socially Vulnerable
Not included in the analysis
Social Vulnerability Classification - Overview
Vulnerability Index Score - Overview
Vulnerable Housing - Overview
Hazardous/Toxic Index Score - Overview



Virginia Vulnerability Viewer
Getting Started
Locality/Address Search
Methods
Switch Basemap
Open Print
Proposed Project Area
Social Vulnerability Classification
Social Vulnerability Status: Moderate Social Vulnerability
Socio-Economic Characteristics: Urban/suburban, moderately high poverty, high minority population, high female Head of Household, moderately low education, high dependence on social security
Tract Name: Census Tract 106, Richmond city, Virginia
Zoom to
Table of Contents/Legend
Social Vulnerability Classification
Social Vulnerability Index Score
Vulnerable Housing Classification
Hazardous/Toxic Index Score
Social Vulnerability Classification
High Social Vulnerability
Moderate Social Vulnerability
Not Socially Vulnerable
Not included in the analysis
Social Vulnerability Classification - Overview
Vulnerability Index Score - Overview
Vulnerable Housing - Overview
Hazardous/Toxic Index Score - Overview

Maintenance Plan – Green Alleys

City of Richmond

The City of Richmond has no detailed maintenance plan for existing green alleys. Existing green alleys are currently maintained with a combination of sidewalk maintenance, street maintenance, and green infrastructure maintenance practices as required by each site. All alleys receive maintenance by the City of Richmond Department of Public Utilities – Stormwater Division maintenance crew twice annually.

Attached are posts from the rvah2o Instagram account with Richmond Green Alley maintenance information as well as the City of Richmond sidewalk and street maintenance information.

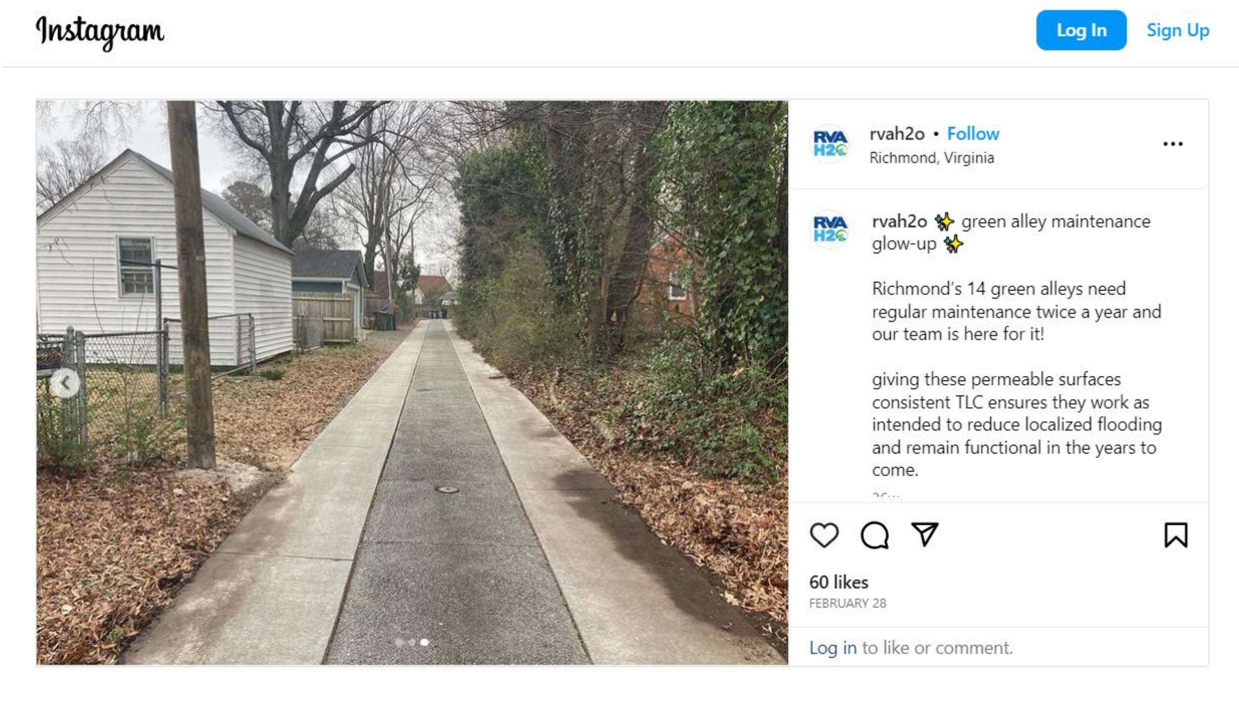


Figure 1: @rvah2o Instagram post regarding Richmond green alley maintenance.

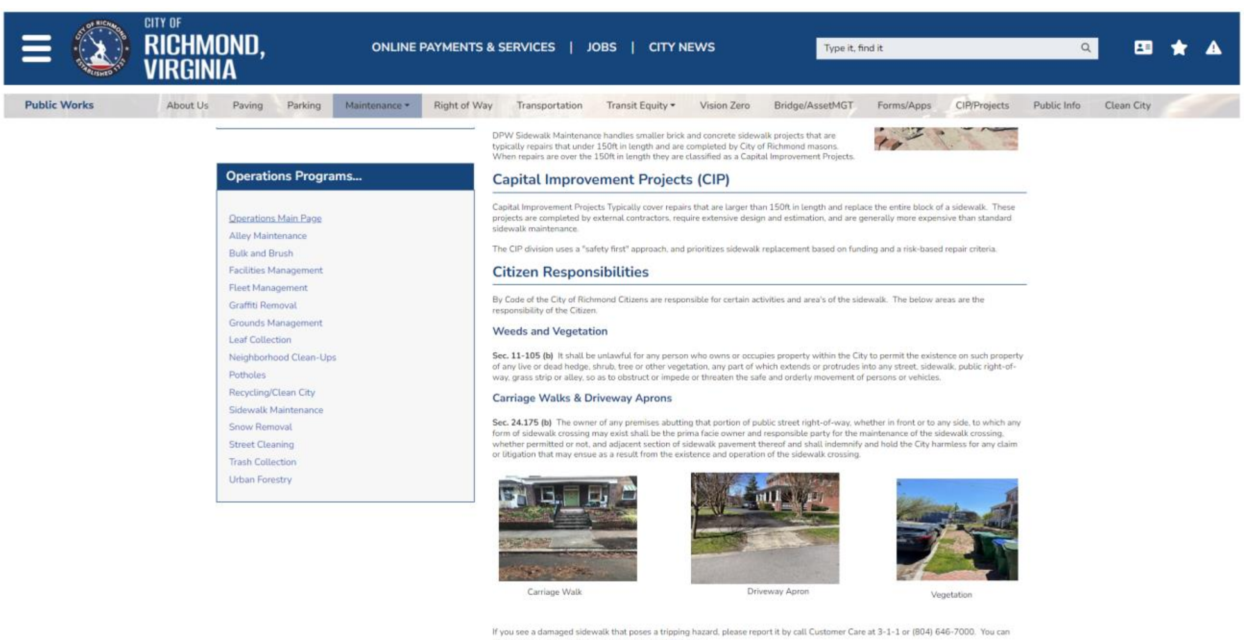
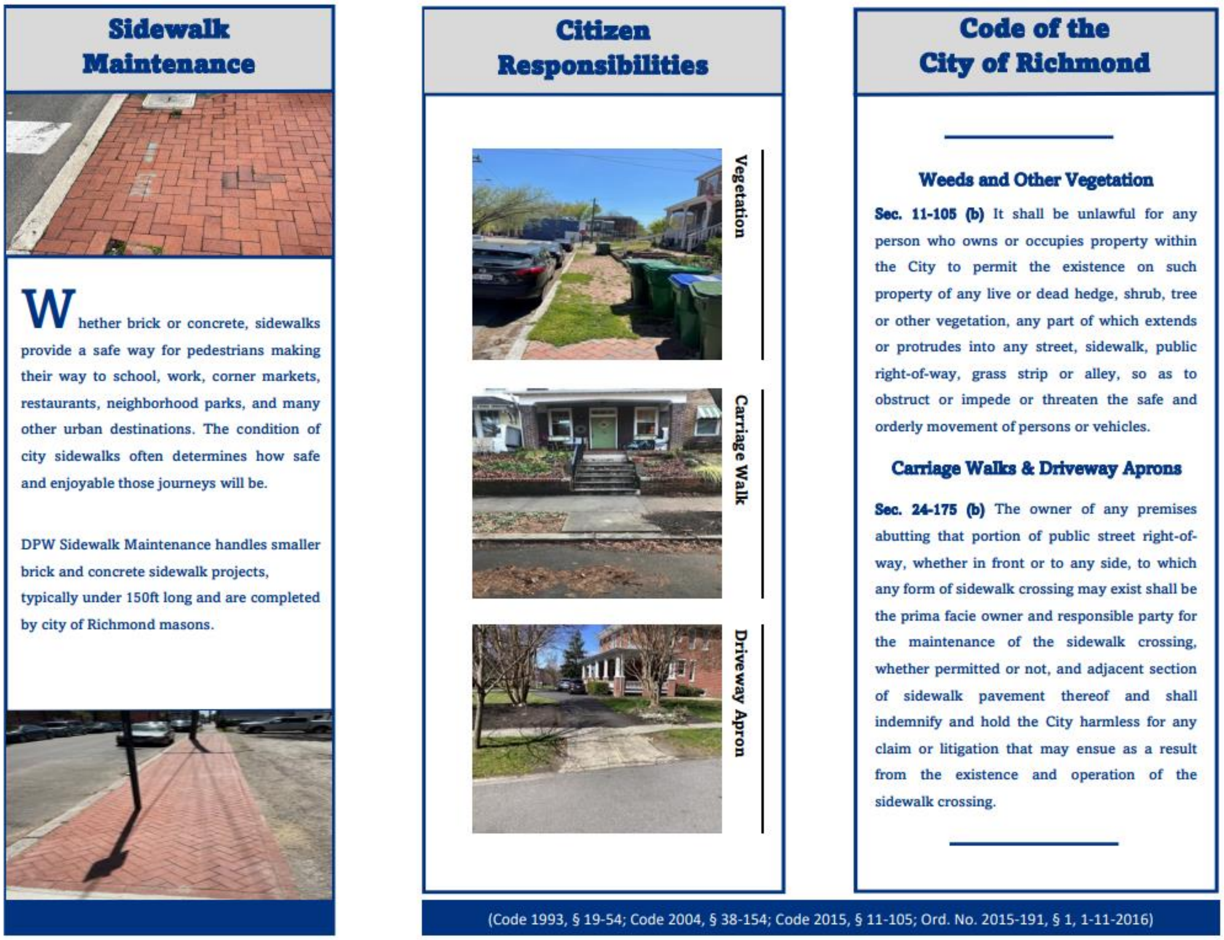


Figure 2: City of Richmond, Virginia sidewalk maintenance & capital improvement projects (CIP) information page.



Sidewalk Maintenance

Whether brick or concrete, sidewalks provide a safe way for pedestrians making their way to school, work, corner markets, restaurants, neighborhood parks, and many other urban destinations. The condition of city sidewalks often determines how safe and enjoyable those journeys will be.

DPW Sidewalk Maintenance handles smaller brick and concrete sidewalk projects, typically under 150ft long and are completed by city of Richmond masons.

Citizen Responsibilities

Vegetation

Carriage Walk

Driveway Apron

Code of the City of Richmond

Weeds and Other Vegetation

Sec. 11-105 (b) It shall be unlawful for any person who owns or occupies property within the City to permit the existence on such property of any live or dead hedge, shrub, tree or other vegetation, any part of which extends or protrudes into any street, sidewalk, public right-of-way, grass strip or alley, so as to obstruct or impede or threaten the safe and orderly movement of persons or vehicles.

Carriage Walks & Driveway Aprons

Sec. 24-175 (b) The owner of any premises abutting that portion of public street right-of-way, whether in front or to any side, to which any form of sidewalk crossing may exist shall be the prima facie owner and responsible party for the maintenance of the sidewalk crossing, whether permitted or not, and adjacent section of sidewalk pavement thereof and shall indemnify and hold the City harmless for any claim or litigation that may ensue as a result from the existence and operation of the sidewalk crossing.

(Code 1993, § 19-54; Code 2004, § 38-154; Code 2015, § 11-105; Ord. No. 2015-191, § 1, 1-11-2016)

Figure 3: City of Richmond, Virginia sidewalk maintenance brochure.

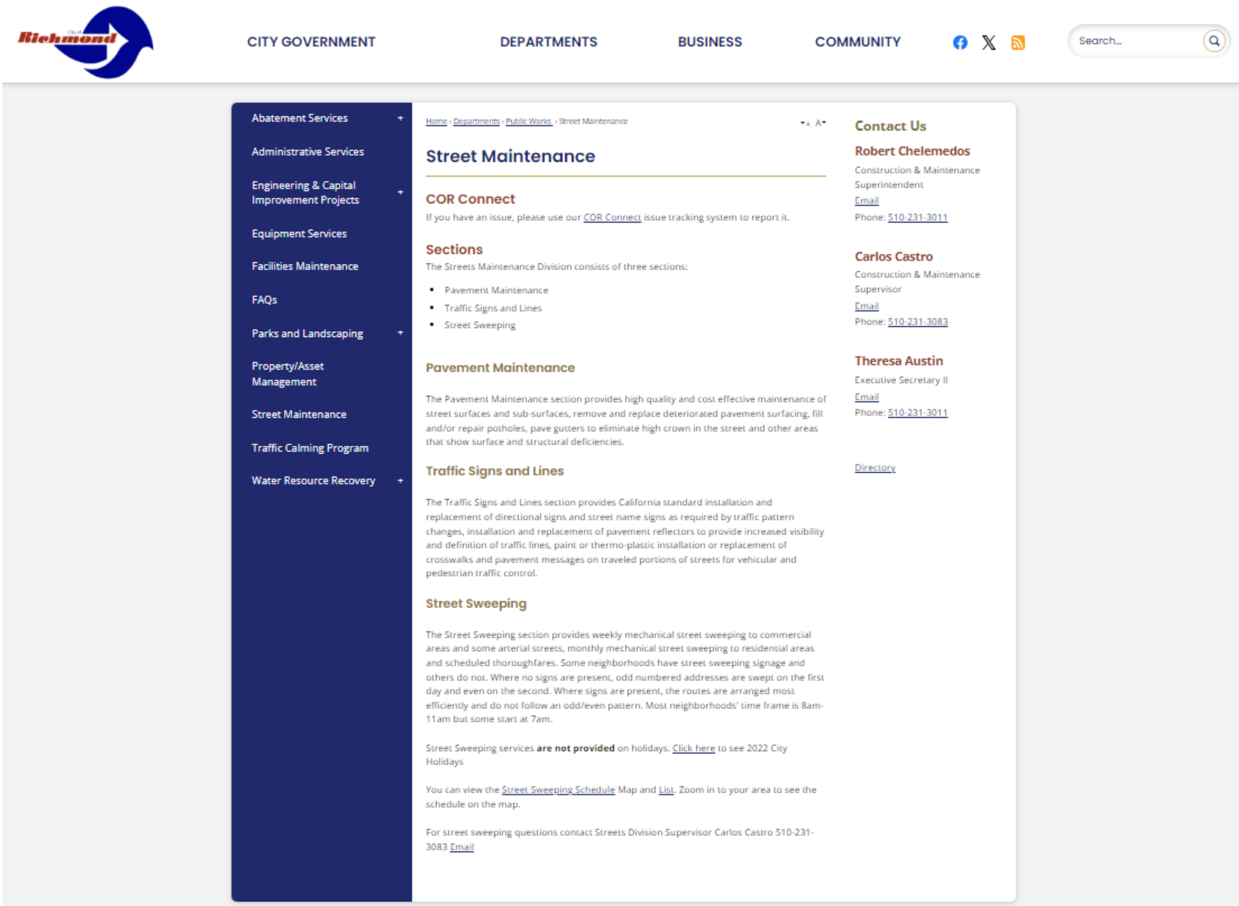


Figure 4: City of Richmond, Virginia street maintenance information page.

Budget Narrative

City of Richmond
Green Alley Projects

Provided below is the City of Richmond Green Alley Projects budget narrative in Table 1.

Table 1: Budget Summary for City of Richmond Green Alley Grant Proposal for Virginia Community Flood Preparedness Fund Grant

Applicant Name: City of Richmond
Community Flood Preparedness Fund &
Resilient Virginia Revolving Loan Fund
Detailed Budget Narrative
Period of Performance: Q1 2024 through Q1 2027
Submission Date: November 12th, 2023

Grand Total State Funding Request	$ 1,078,615
Grand Total Local Share of Project	$ 719,077
Federal Funding (if applicable)	N/A
Project Grand Total	$ 1,797,692
Locality Cost Match	40%

Breakout By Cost Type	Personnel	Fringe	Travel	Equipement	Supplies	Contracts	Construction	Maintenance	Indirect Costs	Other Costs	Total
Federal Share (if applicable)											
Local Share						$ 77,675	$ 621,402		$ 20,000		$ 719,077
State Share						$ 116,513	$ 932,102		$ 30,000		$ 1,078,615
Pre-Award/Startup											
Total						$ 194,188	$ 1,553,504		$ 50,000		$ 1,797,692

The green alley budget narrative (Table 1) is informed by the previous City of Richmond Green Alley Project costs. The two proposed project costs were estimated on a linear footage cost scale. A 10% design fee and 2.5% construction management fee were added within the contracts section and an estimated $25,000 for permitting was estimate for both sites. This is a hybrid solution and therefore this project is requesting 60% funding from the Virginia Community Flood Preparedness Fund Grant and the City of Richmond Department of Public Utilities will match the remain 40% of project costs. The total project costs is $1,797,692 with a grant request of $1,078,615 (60% of total cost) and a match by the City of Richmond Department of Public Utilities of $719,077 (40% of total cost)

November 12, 2023

Virginia Department of Conservation and Recreation

Attn: Virginia Community Flood Preparedness Fund

Division of Dam Safety and Floodplain Management

600 East Main Street, 24th Floor

Richmond, Virginia 23219

RE: CID510129- City of Richmond Department of Public Utilities- Stormwater Division City of Richmond Green Alley Projects -2023 Grant Round 4- Community Flood Preparedness Fund Grant Application

Greeley and Hansen is pleased to submit on behalf of the City of Richmond Department of Public Utilities Stormwater Division (DPU/SW) this Virginia Community Flood Preparedness Fund Grant application for the City of Richmond Green Alley Projects scope of work.

Scope of Work

Project Overview:

The City of Richmond Green Alley Projects is a continuation of the previous City of Richmond Green Alley Program. This application proposes the conversion of two City of Richmond (City) priority listed alleys into green alleys to reduce localized flooding of the alleys and adjacent properties, increase infiltration and stormwater storage, increase usability and accessibility by the surrounding community, and increase community engagement and support of green infrastructure. Major items of work will include removal of existing pavement, gravel, and subgrade, regrading of alleys to create local depressions to prevent flooding of adjacent properties, and installation of green infrastructure.

This scope proposes the following two alleys (also shown in Figure 1) for green alley conversion that were listed as priority alleys by the City of Richmond Department of Public Utilities – Stormwater Division:

- Location 1 is in North Richmond in District 3. The proposed alley is within the Northern Barton Heights neighborhood parallel and east of Chamberlayne Avenue between West Brookland Park Boulevard and Hammond Avenue. Location 1 alley is 1030 feet long.
- Location 2 is in South Richmond in District 6. The proposed alley is within the Bellemeade neighborhood parallel and west of Willis Street between Chesterman Avenue and Mimosa Street. Location 2 is 1140 feet long.

These alleys have been prioritized by the City due to residential flooding complaints and flooding damage. The alleys regularly flood preventing a safe pathway to foot traffic and vehicles due to reduced ground visibility. Adjacent properties also experience increased flooding due redirected stormwater by the alley grading. Beyond flooding, the two proposed alleys are heavily degraded with potholes, poor surfacing, and inadequate design.

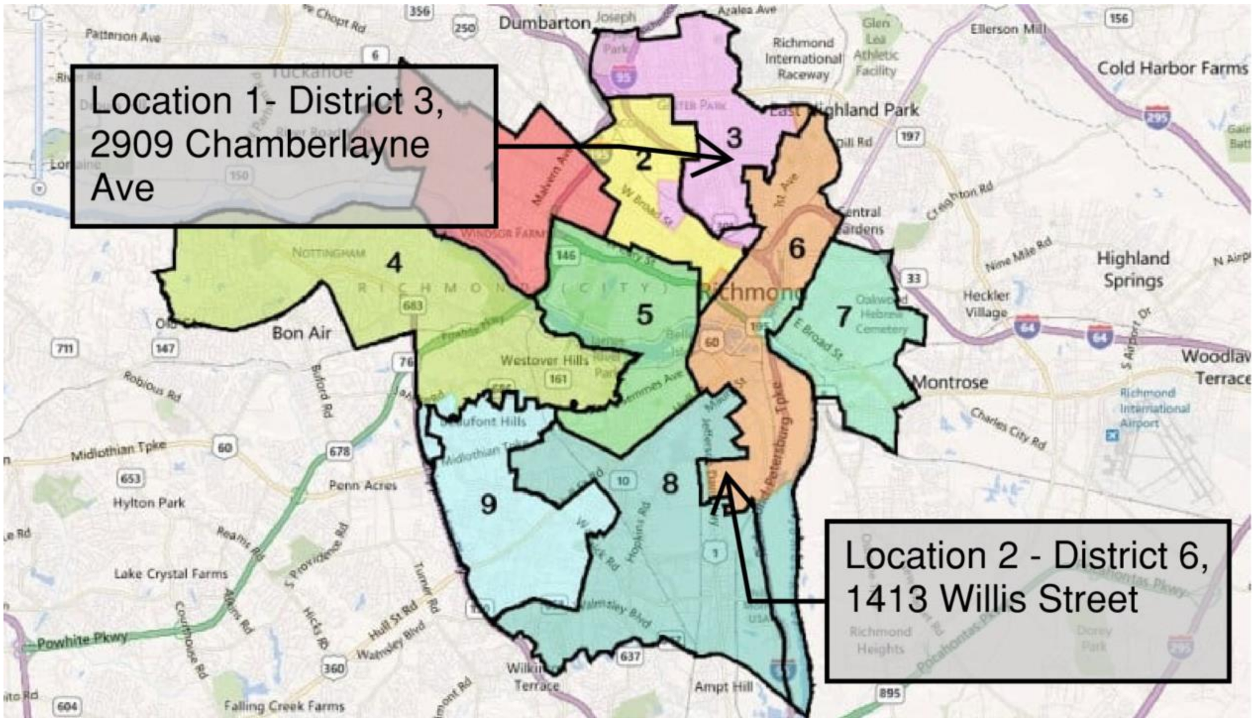


Figure 1: City of Richmond green alley projects vicinity map.

Background:

The City of Richmond is serviced by a separate stormwater conveyance system which conveys only stormwater, and the Combined Sewer System (CSS) which conveys both sewage and stormwater. The separate stormwater system outfalls stormwater into nearby waterways and waterbodies with most stormwater ultimately discharging to the James River. The CSS conveys mixed flows to the Richmond Water Treatment Plant during dry weather and regular wet weather events, and overflows directly to the James River through 31 overflow outfalls during high wet weather events. This means that raw sewage is discharged into the James River during high wet weather events when the overflow system is utilized.

The City of Richmond identifies the installation of green infrastructure as a strategy for decreasing combined sewer overflows as every gallon of stormwater that is infiltrated into green infrastructure elements is a gallon of combine sewer overflow that does not enter the James River during peak flows. Location 1 is in the CSS system watershed meaning that implemented green infrastructure would reduce sewage flows into the James River. Location 2 is serviced by the separate stormwater system and will reduce the amount of stormwater runoff into the James River through stormwater infiltration and storage.

Existing alleys converted to green alleys are a viable option for stormwater management. Alleys are comprehensive networks of low speed, low volume streets that often have little to no storm water infrastructure when compared to main streets and highways. An 85% reduction of stormwater runoff in alleys can be achieved by converting existing urban alleys to green alleys through the implementation of permeable pavers or pavement, edge vegetation, and other green stormwater infrastructure elements.

Reducing runoff and preventing flooding in these streets will reduce storm event runoff flows through existing storm drain systems and allow for safe access to alleys during storm events. Flooded alleys are a flooding risk for adjacent buildings and homes and are a proven safety risk to pedestrians and bikers as people are unable to see the ground terrain when flooded. Reducing and eliminating flooding in these alleys and preventing alley stormwater from being redirected into adjacent private properties will reduce damage to homes and businesses and benefit all residents within the project areas. By beautifying green alleys and utilizing native vegetation elements, stormwater resources will be conserved on site through methods of storage and infiltration and increase alley usability by the public.

An added benefit of green alleys is that the green infrastructure can partially alleviate the urban heat island phenomenon by eliminating impervious pavement and creating additional shaded areas. This will help decrease ambient temperatures in the surrounding neighborhood during hot days.

The City of Richmond has an existing green alley program, and 13 alleys were converted to green alleys between 2010-2021 (Table 1). While there is no formal definition of green alleys, the National Association of City Transportation Officials (NACTO) identified green alleys as alleyways that "uses sustainable materials, pervious pavement, and effective drainage to create inviting public space for people to walk, play, and interact." Past projects have experienced success in stormwater management and creating new community spaces, and a continuation of this project can expect to meet similar success.

Table 1: City of Richmond Prior Green Alley Projects

Green Alley	Location	Year Built
12th Street	12th – Main – 13th – Cary	2010
5th Street	5th – Main – 4th – Cary	2010
Monument Avenue	Monument – Cleveland – Tilden – Franklin	2012
Grace Street	Grace – Laurel – Franklin – Shafer	2012
St. Christopher's Road	St. Christopher's – Wesley – Henri – Bay	2012
N 23rd Street	N. 23rd – Clay – 24th – Marshall	2013
Meridian Avenue	Meridian – Bells – Lynhaven	2016
Fendall Avenue	Fendall – Garland – Culpepper	2016
Cheatwood Avenue	Cheatwood – Akron – Moss Side	2016
Grove Avenue	Grove – Meadow – Hanover – Granby	2016
Lorraine Avenue	Avenue Lorraine – Crestwood – Westbrook – Stratford	2018
T Street	T – 27th – S – 26th	2018
Forest View	Forest View – Bassett – Hill Top – Clarence	2021

All previous green alley projects were successfully completed and well received by the surrounding communities. The latest green alley project on Forest View was inaugurated by Mayor Levar M. Stoney (Figure 2). @rvah2o Instagram and Twitter have posted about these new green alleys to spread awareness of green infrastructure and stormwater management. Posts about green alleys have received hundreds of likes and tens of thousands of views.

Figure 2: New Forest View green alley opened and celebrated by Mayor Levar M. Stoney and council members. (Justin Doyle [@JustinDoyleRVA]. Photo of Forest View green alley opening. Instagram, June 10, 2023)

Alternatives:

Alternative solutions are available to address the flooding issues noted at the two project locations. Gray-infrastructure design and construction could reduce costs for rehabilitating the Locations 1 and 2 alleys by approximately 10% by installing subsurface storm drain systems, regrading the alley surfaces, and paving the alleys with impermeable pavement. This alternative solution would eliminate flooding in the alleys and on adjacent properties, but would lack the green infrastructure benefits of infiltrating stormwater and removing pollutants.

As the City of Richmond and DPU/SW have regulatory requirements to meet the needs to reduce bacteria, nitrogen, phosphorus, and total suspended solids, and are actively and continually looking for opportunities for projects that employ green infrastructure and nature based solutions, the green alley approach was chosen for this proposal as it incorporates green infrastructure and improves water quality.

Goals and Objectives:

The purpose of the proposed Green Alley Projects is to mitigate impacts of flooding by reducing stormwater runoff from Richmond alleys. These projects will also act as community beautification and increase aesthetics, comfort, and mobility.

Goal 1. Eliminate flooding in alleys and on adjacent properties while also reducing stormwater runoff

- Objective 1.1. Eliminate flooding in alleys and on adjacent properties and ensure that new designs effectively redirect stormwater.
- Objective 1.2. Decrease stormwater runoff to existing CSS system and separate stormwater system during peak flows.
- Objective 1.3. Increase stormwater infiltration and storage through green infrastructure elements and set goal of capturing 85% of stormwater runoff during a 2-year storm with new green alley construction.
- Objective 1.4. Increase stormwater quality through native vegetation filtration and treatment by planting native grasses and plants where appropriate.

Goal 2. Increase beautification and mobility of alley spaces

- Objective 2.1. Increase native biodiversity in alleys with vegetation areas by prioritizing the planting of native grasses and plants where appropriate. Set up maintenance program to maintain these areas.
- Objective 2.2. Implement design elements that limit visible waste containers but will not impact waste collection practices.
- Objective 2.3. Create a branded alley wayfinding system to allow for increased public access and usability during construction.

Goal 3. Engage in public outreach and awareness of green alleys and green stormwater infrastructure

- Objective 3.1. Host at least one in person community event every year about green alleys to provide education and visibility on the implementation of crucial green infrastructure elements in residents' neighborhoods.
- Objective 3.2. Create a webpage dedicated to green alley information, contacts, tools, and reporting system by the completion of this project.

Work Plan:

This grant proposal aims to convert existing Locations 1 and 2 alleys into green alleys.

The reconstruction of existing alleys to green alleys requires the removal of existing pavement/gravel surfacing and subgrade and the addition of permeable pavers or pavement and other additional green stormwater elements where appropriate. The two alleys identified in this work plan have been prioritized by the City of Richmond DPU – Stormwater Department, as these alleys have received consistent flooding complaints and do not serve the local residents as needed.

The City of Richmond Department of Public Utilities and Department of Public Works/Transportation and Stormwater Division will be responsible for bidding out design and construction work. These departments will also be responsible for all major operations and maintenance of the green alleys. The City of Richmond DPU requires regular maintenance twice a year for the 13 existing green alleys. This regular maintenance ensures that that the green alley surfaces remain permeable and functional to reduce flooding as designed. The new green alleys would be added to the existing regular maintenance program.

Successful green alley programs regularly rely on involvement and support from residents. This support may come in the form of community involvement programs or incentivized alley care programs.

The two proposed green alley projects will require site evaluation, developed design, and construction. Once both projects receive Notice to Proceed, design will be bid out and awarded to the preferred consultants within 6 months. The consultants will complete and submit alternatives analysis, as well as 50%, 90%, and 100% design packages within 6 months of contract awarding. Construction will then be bid out, awarded, and completed within 2 years. Each project will be completed within a 3-year time period after the grant is awarded and accepted by the City of Richmond.

Evaluation:

Successful completion of this work will result in decreased flooding in alleys during regular storm events, a highly utilized public space for walking and biking, and continuous positive relationship building between communities and public works as both work together to maintain and appreciate these new spaces

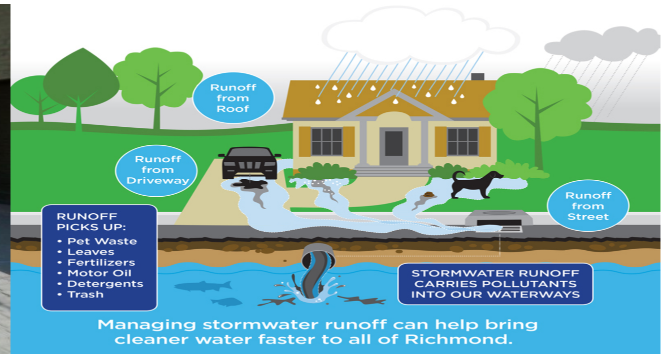
Goal 1 Expected Results – Stormwater storage capacity and infiltration increased within green alleys achieving an 85% reduction in stormwater runoff during 2-year storm events. No new flooding complaints from alley adjacent residents.

Goal 2 Expected Results – Residents and visitors regularly use green alleys as a place of walking, biking, and community gathering.

Goal 3 Expected Results – Increased community engagement and education sessions for green alleys and green stormwater infrastructure regularly held and advertised to the public.

The City of Richmond Department of Public Utilities will be responsible for monitoring these projects to ensure that the projects meet the requirements of this agreement and are delivered on time. The City of Richmond Department of Public Utilities will conduct outreach events and provide green alley information to the public in line with existing outreach events and information distribution done for the existing green alley program. Success will be measured in the decrease of flooding complaints within the project area and periodic monitoring and surveying of how often the green alley is utilized by the public and how it affects the residents within the project area. Cost effectiveness will be evaluated by the decrease in flooding complaints by residents and increased safety for residents and businesses associated with decreased flooding.

STORMWATER FACILITIES IMPROVEMENTS



Category:	Utilities	**Priority Area:**	Efficient & High-Quality Service Delivery
Department:	Public Utilities	**Award #:**	500084/500085/500086/5000658
Location:	Citywide	**Project #:**	Various

Description & Scope: Provide funding for citywide rehabilitation and upgrade of stormwater sewers and associated facilities, inspection and replacement programs, miscellaneous stormwater extensions, and emergency replacements. This project also allows for the purchase of replacement vehicles and equipment used to provide services throughout the Department of Public Utilities' Stormwater Utility service territory.

History & Key Milestones: This project has been funded to rehabilitate and/or replace drainage structures, ditches and culverts throughout the city. Development and use of "Green" technology has proven to be a positive step toward the reduction of untreated urban runoff into the City's rivers and streams. A proactive approach is being taken to meet federal, state and local regulations.

Funding Source(s): User Fees, Revenue Bonds

FINANCIAL SUMMARY

	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	TOTAL FY 2024 - 2028
FY 2024 Proposed	—	27,555,000	35,890,000	27,885,000	3,680,000	180,000	95,190,000
FY 2023 Adopted	23,900,000	15,555,000	12,005,000	9,885,000	4,180,000	—	41,625,000
CHANGE	—	12,000,000	23,885,000	18,000,000	(500,000)	180,000	53,565,000

OPERATING IMPACT (AMOUNT & EXPLANATION)

	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027	FY 2028	TOTAL FY 2024 - 2028
AMOUNT	—	—	—	—	—	—	—

EXPLANATION: N/A

Total Project Cost	237,513,945
Prior Year Appropriation	142,323,945
Prior Year Available	68,488,363
FY 2024 Proposed	27,555,000
FY 2025 - 2028 Planned	67,635,000
Remaining Need	—

FY 2024 BUDGET DISTRIBUTION	AMOUNT
PLANNING/DESIGN	—
ACQUISITION	—
SITE IMPROVEMENT	—
CONSTRUCTION	27,555,000
FURNITURE/FIXTURES/EQUIPMENT	—
OTHER	—
TOTAL	27,555,000

Note: The distribution amounts shown are estimated and are subject to change.

2021

Green Alley Network Plan

Dan Motta
Virginia Commonwealth University

GREEN ALLEY NETWORK PLAN

PREPARED BY DAN MOTTA
Master of Urban and Regional Planning
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VCU

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DEDICATED TO THE PEOPLE OF RICHMOND

Acknowledgements

A special thank you to everyone who made this plan possible, including panel members, survey respondents, and members of the community who lent their time and insights to help shape the final product. Additional thanks to my colleagues at PlanRVA, in the Wilder Fellowship, and in the Master of Urban and Regional Planning Program at Virginia Commonwealth University. And to the people who care for alleys and other public spaces.

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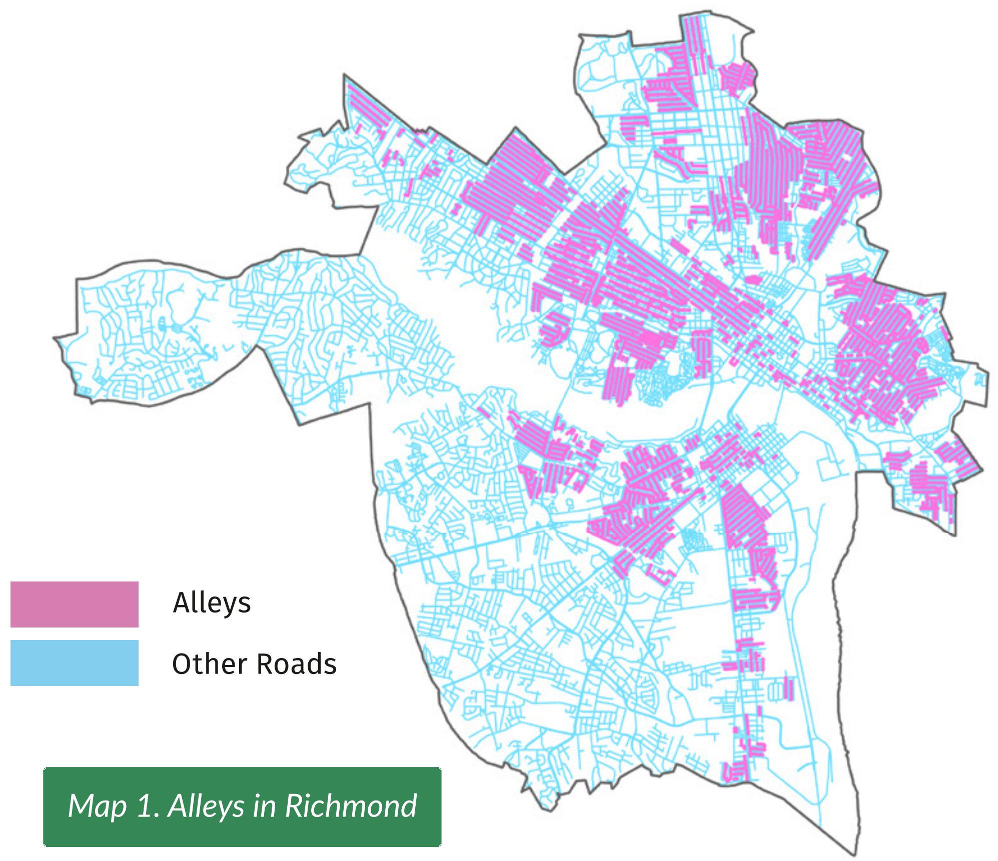
Purpose

The Green Alley Network Plan seeks to realize the potential of Richmond's public alleyways as opportunities for biodiverse shared streets acting as active transportation corridors, stormwater management systems, and public spaces that support high quality of life and community health. Richmond alleys have an impressive reach into many diverse neighborhoods across the city (Map 1)— often in areas with a high proportion of Environmental Justice populations (communities that bear a disproportionate burden of negative environmental impacts) and one/zero-car households. For this reason, and in an effort to embed the majority of research in a particular space, an urban study area was chosen as a hypothetical demonstration area. The tools and strategies covered in this plan are applicable to many parts of the Richmond Region and including in the most neglected communities that need equitable pedestrian and bikeway investments. Where alleys do not exist, related green stormwater infrastructure can be used in place of treatments discussed in this document. The notion is to utilize natural processes in our stormwater and transportation infrastructure to support a healthy urban ecosystem.



Map 1. Alleys in Richmond

PLAN VISION:

Richmond's public alleys are utilized to their full potential as biodiverse shared streets acting as active transportation corridors, stormwater management systems, and public spaces that support high quality of life and community health.

This plan was developed from August 2020– April 2021, in the shadow of the COVID-19 Pandemic and ever-expanding calls for racial justice. This past year has proved the value of resiliency in our communities. And while we are connected at a global level, our immediate environments still have a critical place for our individual well-being and neighborhood health.

The context of this plan rests in two general assessments of our immediate needs. The first is that we are living in a climate emergency. The second is that we face a related crisis of automobile supremacy that has spawned entirely unsustainable communities, which in turn exacerbates the existing climate crisis and establishes a vicious cycle of social harm based on the basic design of our built environment. We also know that negative aspects of transportation—including pollution, noise, stress, and associated health effects— are disproportionately felt by children, the elderly, people with disabilities, and people of color. This makes transportation a matter of social, environmental, and racial equity and we must be willing to invest in swift and comprehensive changes.

This plan is specifically about green alleys, but the strategies discussed broadly apply to all transportation networks. Alleys are the focus because this plan was born out of that specific context; throughout the plan one can easily substitute street, road, lane, path, parkway, or any number of terms. This topic was chosen in part because of the unique opportunity alleys provide for urban areas, as neglected public space not thought of as "community" space.

While this plan doesn't pretend to hold the solutions for climate change or racial inequity, it was developed with the belief that streets are both ecosystems and places for community life. Transportation planning therefore has a unique responsibility to consider how the design of the public right-of-way contributes to environmental and racial justice.

A primary belief behind this plan is that streets are for people, a philosophy summarized in Bernard Rudofsky's book *Streets for People*. As our urban space fills in, alleys provide a space for municipalities to integrate sustainability into transportation corridors and provide simple and opportunistic greening.

This project set out to create a Green Alley Network Plan that would be an expansion on Richmond's Green Alley program, detailing tools, examples, recommendations, and steps to implementation. It is guided by the city's visions of High-Quality Places, Equitable Transportation, a Diverse Economy, Inclusive Housing, and a Thriving Environment as expressed in the Richmond 300: A Guide for Growth Master Plan. Additionally, the region's long-range transportation plan being developed by PlanRVA, ConnectRVA 2045, as well as the companion bicycle and pedestrian plan, is taken to account in this project and final document.

WHY ALLEYS?

Why focus on alleys when our streets already need extensive maintenance?

Often a forgotten part of our transportation system, alleys are comprehensive networks of existing low speed, low volume streets that can provide multiple benefits to accessibility, stormwater capture, public health, and placemaking. We can maintain our main streets and invest in alleys as community space concurrently, with both part of an accessible and comfortable transportation network.

> *"Urban alleys, though often ignored or considered dirty or unsafe, can be designed to play an integral role in street networks, providing service access and recapturing space for the public realm."*
>
> – NACTO Stormwater Guide

Aren't alleys reserved for trash, utilities, and services?

Where alleys are accessible to refuse collection trucks, service is restricted to certain days, leaving alleys underutilized for the majority of a given week. This plan considers the needs of public utilities and services and a series of recommendations are designed to encourage interventions that are utility-friendly and even optimize refuse collection.

Why would we want more people traveling in alleys?

The common image of a dark and crime-filled alley survives in part because it is a self-fulfilling prophesy. People may be hesitant to walk down a public alley because of their seedy reputations– and visual cues such as loose trash and broken bottles can reinforce this image to someone in search of a shortcut. Inviting more people into these public spaces to walk or bike through on their way to work, while walking their dog, to use to access a restaurant, or to take an afternoon stroll, makes a well-travelled and safer alley.

Will more people in alleys lead to more crime?

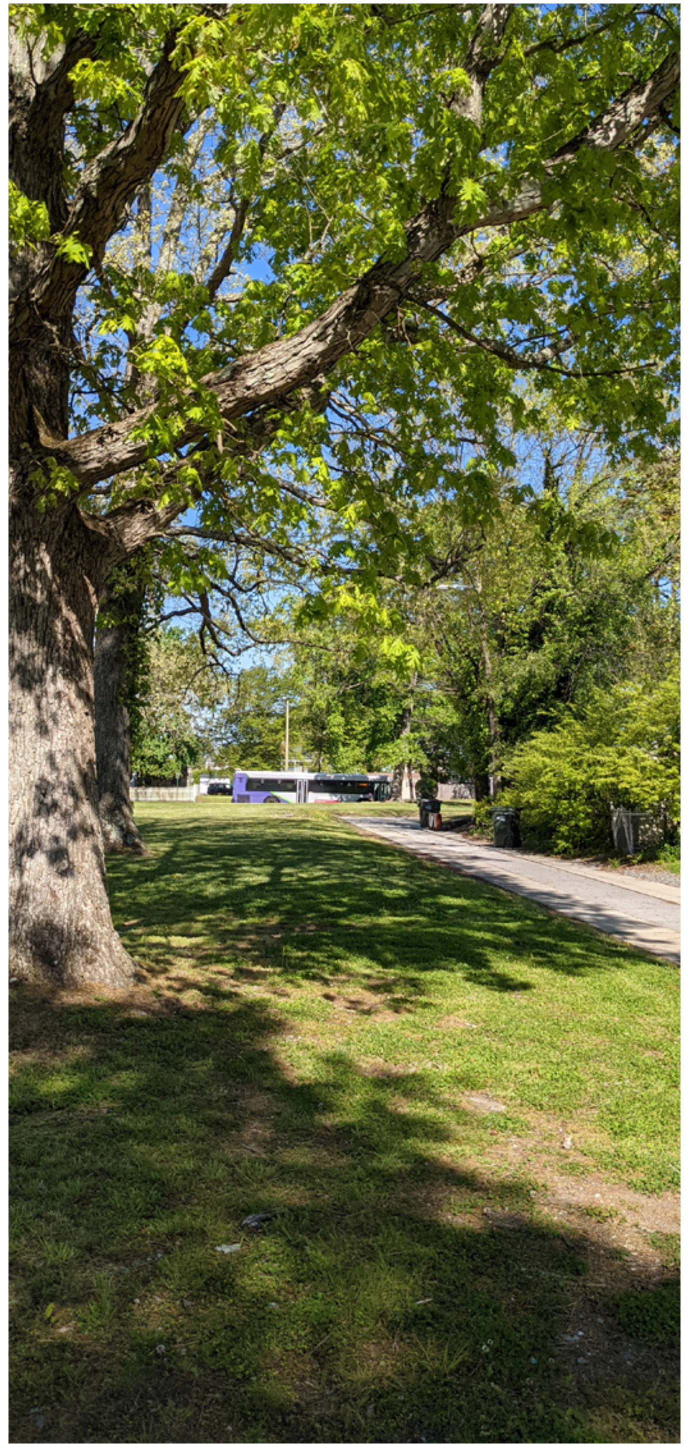
On the contrary, more activity on any street serves as a good deterrent to illicit activity. Residents and businesses who have an interest in the health of an alley are more likely to maintain a certain level of upkeep and provide more eyes on the alley.

We have a shared use path/bike lane nearby, so wouldn't it be redundant for alleys to serve as active transportation routes?

An effective transportation network takes people where they need to go and provides route options, walking and biking being no exception. In certain areas, bicycle route alignments could use alleys where there is insufficient space for fully-protected facilities on the main street. Alleys also have the added benefit of providing alternate residential and commercial access.

Who will be responsible for upkeep?

Because of the unique nature of alleys, maintenance is expected to be shared in a sense. Successful green alley programs in other cities rely on involvement from residents, department of public utilities, and departments of public works/transportation to carry out and sustain improvements. See the implementation section for more details.



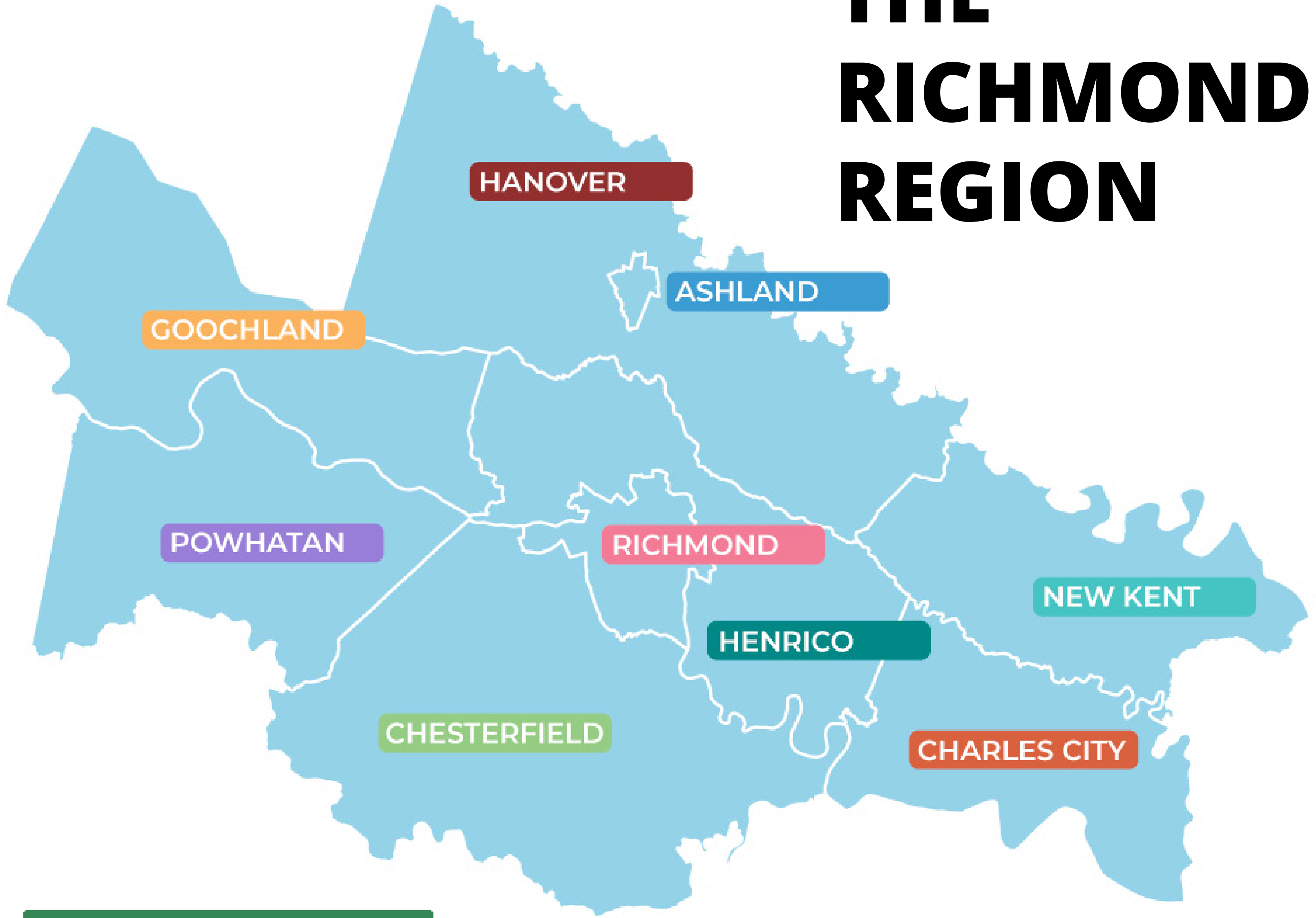
INTRODUCTION

Client

PlanRVA, previously known as the Richmond Regional Planning District Commission (RRPDC), is a regional planning organization made up of the City of Richmond, the Town of Ashland, and the Counties of Charles City, Chesterfield, Goochland, Hanover, Henrico, New Kent, and Powhatan (Map 2). PlanRVA focuses on collaboration to solve regional issues such as transportation, environment and air quality, and disaster management. PlanRVA also staffs and oversees the Richmond Regional Transportation Planning Organization (RRTPO), the region's Metropolitan Planning Organization (MPO), a federally mandated regional transportation body. The RRTPO is tasked with urban transportation planning and is involved in allocating federal and state funds toward transportation projects of regional significance. Additionally, PlanRVA is involved in rural transportation planning, along with environmental, resiliency, and emergency management planning. As a regional body, PlanRVA holds a unique position in advancing transportation and environmental priorities for the region while also working with individual member governments on studies and planning pilot projects of significance.

As part of its federal mandate, PlanRVA is currently developing an update to the long-range transportation plan, ConnectRVA 2045, which presents a forward-thinking strategy for regional transportation priorities and serves as a guide for allocating regional transportation funding from various sources. Currently in the visioning and planning phase, the plan has a proposed adoption date of October 2021. A companion plan, the regional Bicycle and Pedestrian Plan, is also undergoing an update on roughly the same timeline.

THE RICHMOND REGION



Map 2. PlanRVA member localities

Outline

This plan analyzes a certain network of alleys and presents a list of recommendations based on embedded research and consultation with resident. It provides a more robust custom toolbox for green alleys and lays out the beginning of a city-wide green alley network of shared streets—some more pedestrian-oriented and some more bicycle-oriented. Because green alleys are a relatively new concept and green infrastructure practices are ever-evolving, the plan presents essential definitions and concepts and a review of subsequent benefits as they are introduced, with a comprehensive glossary in the appendix.

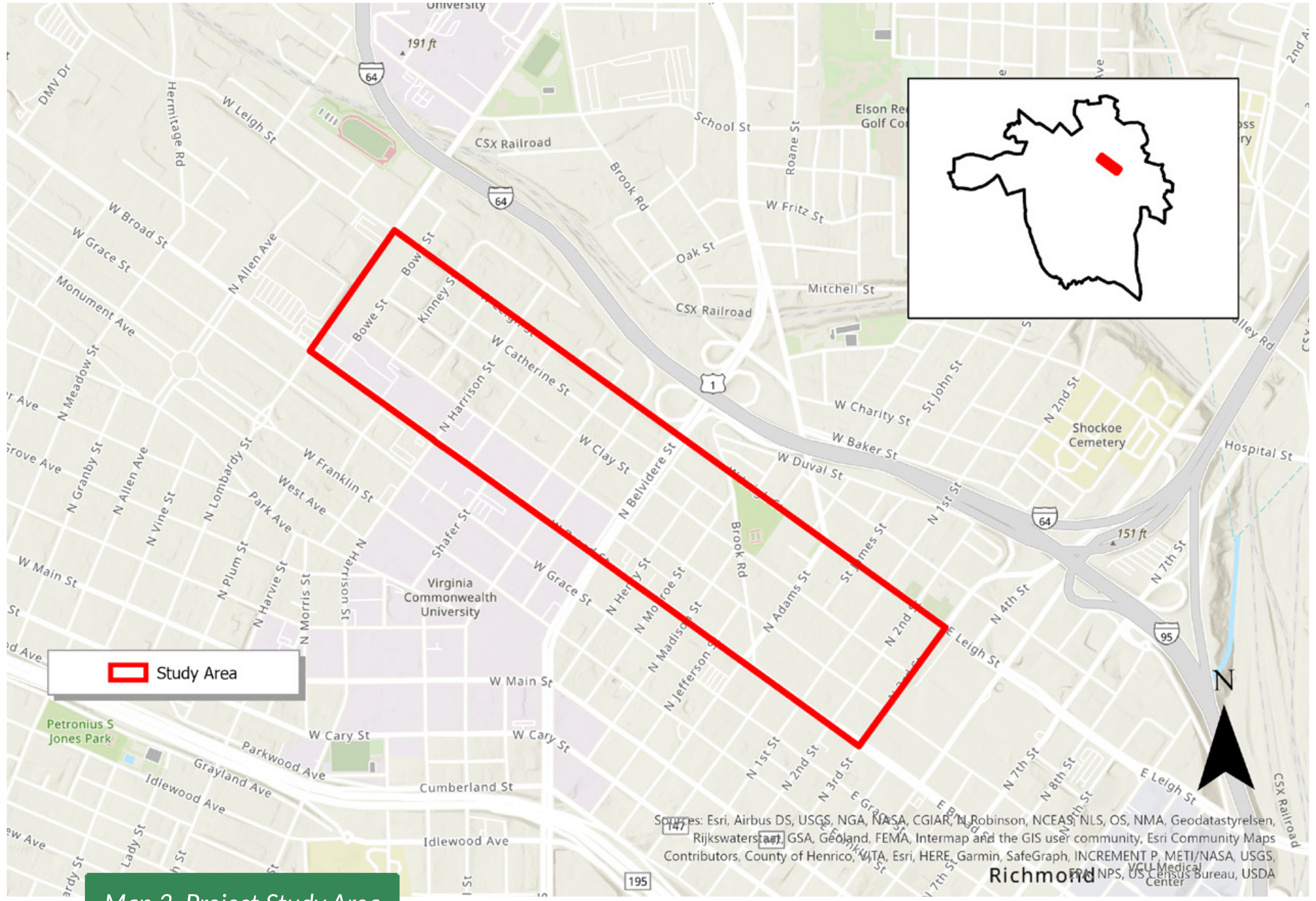
A resident-centered method of engagement focused on embedded planning, which stresses street-level engagement and an emphasis on working in the community, drives this plan while the resident survey helped frame research findings and inform recommendations. Research, fieldwork, and analysis were performed by a single planning graduate student and supported by dozens of resident planners using their knowledge and expertise of their own alleys and neighborhoods. The plan outline and framework attempt to reinforce this shared perspective.

A study area in Carver and Jackson Ward (Map 3) serves as a possible demonstration zone for significant green alley investment. It also doubled as the distribution area for the study survey flyer. In order to identify appropriate places for green alley projects, an intensive site assessment of the study area was conducted to identify specific opportunity sites. To better ensure success, the plan concludes with vital considerations and current strategies, including steps to implementation and a look at possible funding sources.

Recommendations and steps to implementations are presented in context of transportation and stormwater networks. The focus is on the more urban neighborhoods centered around Downtown Richmond to tie into the existing Capital Trail and eventual Fall Line Trail, which will run from Ashland to Petersburg, just south of MPO boundaries. While this plan is Richmond-centric, the goal is to also incorporate it within the framework of PlanRVA's updates to the Richmond Regional Bicycle and Pedestrian Plan and the long-range transportation plan, ConnectRVA 2045.

RICHMOND 300
A GUIDE FOR GROWTH

Connect RVA 2045



Map 3. Project Study Area

Context

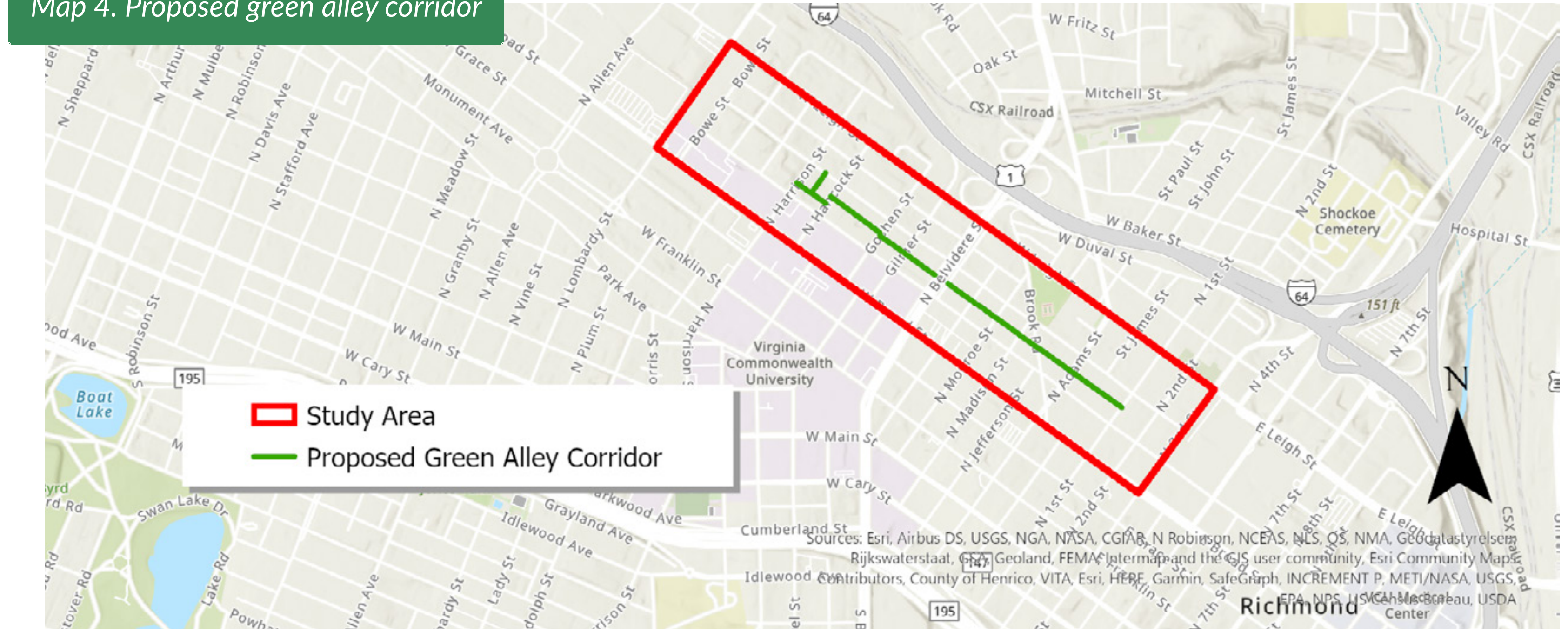
The primary study area of approximately fifty blocks in Carver and Jackson Ward is located within the bounds of Broad, Lombardy, Leigh, and North 3rd Streets. Study area boundaries also composed the survey flyer distribution area. The study area was selected a result of a preliminary analysis including area characteristics, benefits, and challenges explored in more detail over the next few pages.

An initial screening of existing conditions, an examination of the street network, and input from the public resulted in the corridor highlighted in Map 4 as a hypothetical Green Alley Network pilot project for Richmond. The plan ultimately presents general policy and action recommendations and concludes with a sampling of possible future alley corridors in other areas of the city. An examination of existing conditions in the study area are detailed in the subsequent pages.

Transportation

The proposed study area is located on multiple transit corridors, including GRTC's Pulse and Routes 1A/B/C, 2A/B/C, 3A/B/C,14, 50, 78, 87, (Appendix) and is within close proximity to the Temporary Transfer Plaza. This green alley corridor could also tie into existing bike lanes on Lombardy Street and/or future bike lanes on 1st Street into

Map 4. Proposed green alley corridor

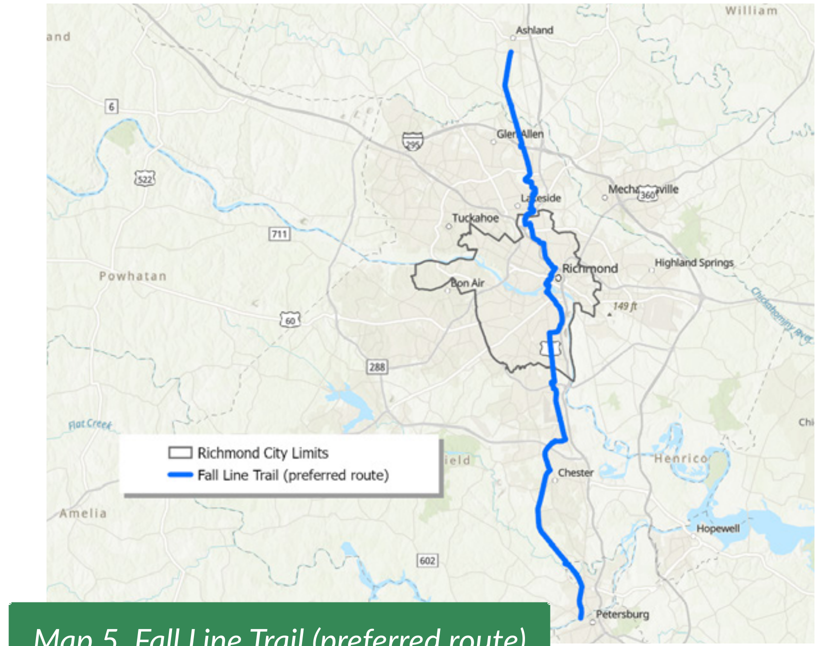


Gilpin. Additionally, nearby active transportation infrastructure includes the Franklin Street cycle track, Cannon Branch Greenway, Brook Road bike lanes, Virginia Capital Trail, and the future Fall Line Trail (Map 5), which will run through this study area. Beyond these regional connections, this area sits within a mixed-use urban space with a strong existing sidewalk and alley network, though conditions vary. While alleyways in the study area are largely in sync with surrounding transportation infrastructure, including the general street grid, they do not seamlessly connect. Connections are often fractured and conditions neglected where alleys meet other streets, leading to a further discouraged use of alley as transportation routes, particularly for people on foot or bike.

Community Assets

Community facilities (Appendix) and amenities within the study area and immediate surroundings include city parks, churches, public schools, hospitals, cemeteries, fire stations, two universities, and a community center. It also includes a variety of businesses, both old and new, and is close to Richmond's Central Business District. The space is within an Arts & Cultural District Incentive Zone, CARE Zone, Enterprise Zone, and several Redevelopment & Conservation Areas, indicating there may be a number of tax credits or funding sources for improvements within this area.

Some economic turbulence including business closures in relation to COVID-19 is also present, which may offer some further revitalization opportunities using existing assets in the community. Parts of the study area also include two Richmond Old and Historic Districts and multiple state/federal historic areas, which would



Map 5. Fall Line Trail (preferred route)

likely only provide peripheral benefits, as tax credits and incentives generally apply to historic building facades. However, the historic nature of the area strongly supports walkable and transit-oriented development.

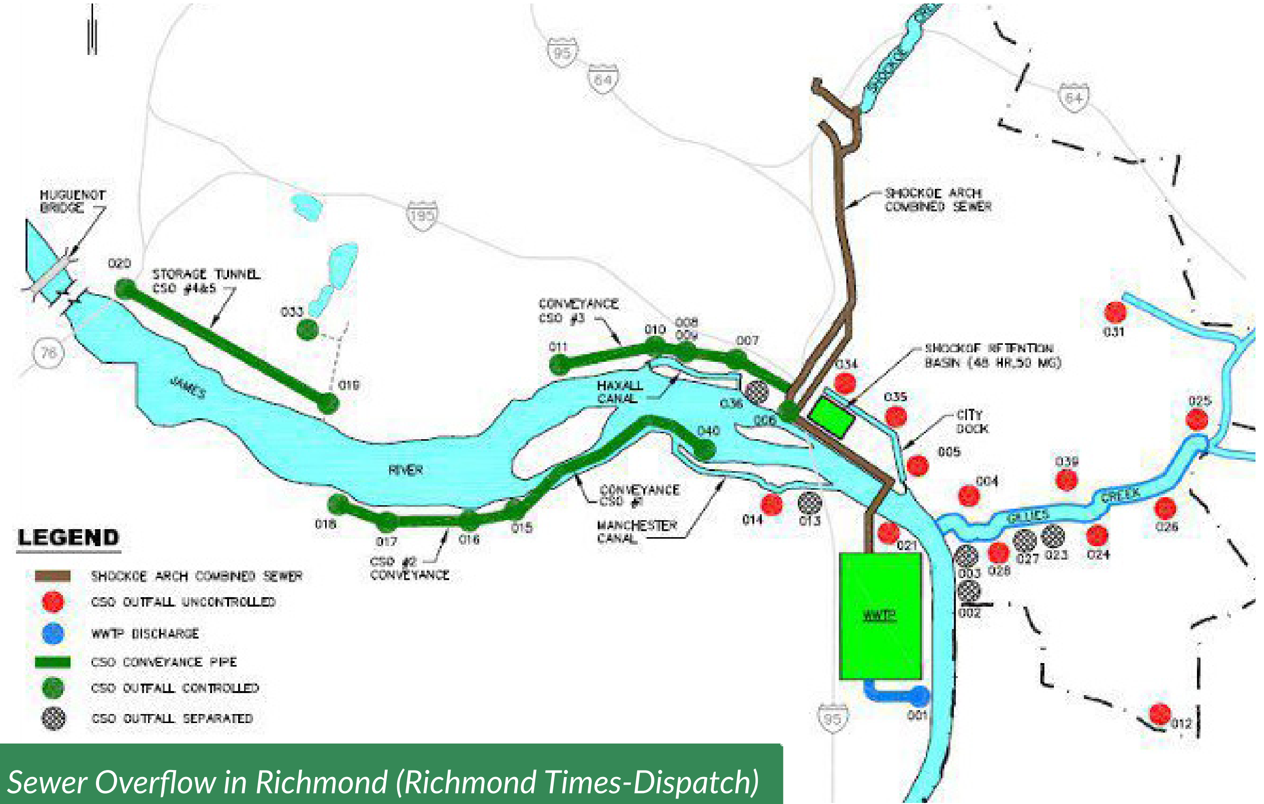
The Siegel Center is located within the proposed study area and the Greater Richmond Convention Center makes up its eastern boundary, providing major event space and two ends of the study area. There is also a strong VCU and VUU presence in the general area, with the VCU Monroe Campus to the south, the MCV Campus to the east, and VUU campus to the north— all of which would likely be interested in increased bike and pedestrian connections.

Environment

Environmental conditions that make this location particularly suitable for study (other than its close proximity to the James River) are the existence of a 100 year floodplain, 500 year floodplain, and Resource Management Area on the northern edge of the proposed study area. These environmentally sensitive areas would benefit from increased green stormwater management practices in nearby urban impervious services.

Richmond is also part of a maintenance area for national ambient air quality standards and is still eligible for Congestion Mitigation and Air Quality Improvement (CMAQ) Program funds. Due to its urban location and amount of impervious surface space, the study area is also more susceptible to the urban heat island effect. Green stormwater infrastructure can be strategically used to lessen the effects of the urban heat island in neighborhoods with fewer street trees and community parks.

Finally, the entire study area is served by the largest Combined Sewer Overflow (CSO) system in Virginia, which funnels stormwater runoff into a combined sewer system which discharges an untreated mix of stormwater and wastewater into the James River when the system is overloaded (Map 6). During the course of this study, twenty-three separate CSO events occurred in Richmond, which discharged hundreds of millions of gallons of mixed sewage into the James River. The City, through various efforts such as RVAH20, is working to decrease the amount of stormwater runoff impacting CSOs and related concerns.



Map 6. Combined Sewer Overflow in Richmond (Richmond Times-Dispatch)

Housing, Infrastructure, and Equity

While this project is a transportation plan in nature, transportation, by definition, works in concert with land use, housing, and environmental planning, making this topic of examination broad in scope. The proposed study area includes several examples of affordable housing, including dozens of units built with Low-Income Housing Tax Credits (LIHTCs). There are also high concentrations of Environmental Justice (EJ) populations in one Census Tract— taken as the top 20% of all census tracts in the PlanRVA TPO area by EJ population index, according to the Greater RVA Transit Vision Plan: Near-Term Strategic Technical Analysis[1]. High transit use (transit mode share of 2.63% or greater) and low vehicle ownership (fewer than 0.63 vehicles per person per household) is also present in both Census Tracts. Additionally, the area boasts transit supportive employment along Broad Street and 2nd Street and high worker populations (2.34 workers per acre or more) in both Census Tracts.

In the specific Richmond context of this project, the plan also considers how green alleys integrate into the city's transportation and green infrastructure, and particularly its existing and planned multi-modal systems. Equity is emphasized in order to recognize the historically rampant racism and discrimination in relation to where people live and their resulting quality of life. A key underlying question is identifying how and where green alleys can serve as active transportation infrastructure in areas with low vehicle ownership and high transit use. In an urban environment like Richmond, alleys literally and figuratively connect people and neighborhoods. Identifying where EJ populations and other communities that would

1. RRTPO & Kimley-Horn, 2020

most benefit from these connections is prioritized in order to meet Richmond's goals for equitable transportation.

Existing Policy

Finally, the plan examines the question of where Green Alley policies and practices overlap or complement already adopted Richmond policies and practices. A brief look into how city departments operate in relation to one another can help understand where improvements can benefit multiple focus areas. As green alleys provide opportunities for transportation and stormwater management, the Department of Public Works and the Department of Public Utilities can cooperate on this issue to reach their own goals, and also wider goals of the City. Efforts such as RVAH2O are examined as models for inter-governmental cooperation. The fundamental goal is to make implementation of green alleys an ingrained part of the City of Richmond policy.

Existing Alley Conditions

Existing conditions measured in this project vary widely by neighborhood and block. Information was gathered regarding land use and urban design, including current land use and zoning, as well as transportation, streets, transit, and bicycle or pedestrian facilities. Guidance on areas of examination is taken from municipal green alley plans and related documents, chiefly Seattle's Integrated Alley Handbook[2]. Data relating to stormwater runoff was considered, including direct observations of pooling, flooding, and other drainage issues. Finally, the general conditions of study area alleys was visually assessed. This includes the conditions of the pavement or pavers, existence of green space, and the general comfort of the space (sights, smells, ease of travel, perception of crime). By using this information to understand the true current conditions, this plan attempts to present design standards, policy recommendations, decision-making tools, and collaboration strategies to best implement Green Alleyway construction in Richmond, with the study area as an example demonstration project.

2. Fialko & Hampton, 2011

Existing Knowledge

Green alleys are no longer a new concept, but no standard definition has yet been recognized. The National Association of City Transportation Officials (NACTO) identify green alleys as alleyways that "use sustainable materials, pervious pavements, and effective drainage to create an inviting public space for people to walk, play, and interact"[1]. Different communities have reimagined alleyways in their own ways, with three general perspectives on green alleys emerging: (1) use as stormwater management, (2) use as community space, and (3) use as transportation networks. In practice, cities often mention co-benefits that cross into all three spheres, but existing green alley programs largely focus on one of the three areas above— with stormwater management the most citied reason[2]. Research indicates that the success of green alley programs depends on resident participation at the neighborhood level and cross-departmental cooperation in the municipal government.

Perceptions

The perceptions of alleys within a community are complex and nuanced. Research shows that while residents recognize the utility of alleyways and even their value as community space, many remain leery of them, with an idea of the creepy alley that is persistent across geographies[3]. Regardless of the area's actual crime rates, the image of an alleyway as a dark and hidden corner of urban life full of untold criminality appears repeatedly, indicating that any project involving public alleyways must adequately address this common concern[4]. Alley greening efforts typically enhance the physical space and this is reflected in the success green alleys enjoy among surrounding residents and businesses, including in Richmond.

1. NACTO, 2013
2. Berg, 2009; CCD & UDFCD, 2016; CDOT, 2010; City of Dubuque, n.d.; District Department of Transportation, n.d.; Fialko & Hampton, 2011; UCLA Luskin Center & Trust for Public Land, 2014

3. Mitchell, 2020
4. Cramer, 2005

Green alley and other green infrastructure programs can help refresh alleys and assuage concerns "by fostering increased visibility and use of previously feared spaces"[5]. Generally, the increased use of these "forgotten" spaces has resulted in a reduced fear of crime[6], as heightened visibility through "eyes on the street"[7] makes active places more inviting to individuals who may otherwise avoid these areas.

Common Uses

Reimagining alleyways using green infrastructure fits into the evolution of alleys within our cities, which always have held a vague role. For many residents, alley use goes beyond plain garage access and trash collection. Where they exist, alleys have often been an active part of the community—showing simultaneously some measure of "utility, hiddenness, and revealingness" that make them an important and favorable part of a neighborhood[8]. Throughout history and all over the globe, places that serve as alleyways often also operate as spaces for residents to meet and travel by foot or bike. People-oriented space to the rear of buildings in the UK and Commonwealth states are often called "laneways" and known as "living streets" in Germany (wohnstrasse), "community streets" in Japan (community doro), "integrated streets" in Israel (rehov meshulav), and the oft-cited "living gardens" in the Netherlands (woonerfs)[9]. These different concepts are all expressions of the same idea that alleyways and other areas within the public right-of-way can be utilized for green community space to connect people to one another.

5. Newell et al., 2013, p. 144
6. Wolch et al., 2010
7. Jacobs, 2016
8. M. Martin, 1996, p. 138
9. Wolch et al., 2010

Even in newer communities with reimagined "open-back" common space meant to be the spiritual successor to alleyways, their design makes a nod to the utility and unique social landscapes of alleys that exist in more dense urban settings[10]. Proponents of biophilic cities also acknowledge the usefulness of green alleys in enhancing the otherwise "grey space" of these urban corridors[11]. Public spaces that were once ignored can be used to help realize wider goals in sustainability, health, and economic vitality[12]. Many cities have embraced green alley policies to realize different goals, with two general goals of stormwater management and generally enhancing public space, often with a focus on economic development.

Stormwater Management

Stormwater management is often cited as a primary reason for green alley projects, though the ecological impacts go far beyond this specific benefit[13]. Local governments have been quick to adopt green alley policies, as the efficiency and frugality is demonstrably greater than conventional greening methods, in some areas being 3-6 times as effective[14]. Potential ecological benefits of a comprehensive green alley system are even larger due to the corridor-nature of most urban alleyways. Evidence has shown the importance of continuous green corridors in urban settings in

10. M. D. Martin, 2002
11. Beatley & Newman, 2013, p. 3330
12. Berg, 2009
13. CCD & UDFCD, 2016; CDOT, 2010; City of Dubuque, n.d.; District Department of Transportation, n.d.
14. Foster et al., 2004

BACKGROUND

relation to biodiversity, and green alleyways have the potential to serve as a wide network of green corridors in many cities[15]. Alley corridors have a real potential to be wildlife corridors[16], and often already serve as places of greater biodiversity where green space is present.

Community Space

Some green alley programs and policies take more of a focus on the alley as community space. Seattle's Integrated Alley Handbook focuses on reimagining alleyways as a vehicle to increase the quality of public space, health, and image of the city, as well as a safer environment for people

15. Ranta et al., 2015; Wolch et al., 2010
16. Richards, 2017

while providing important secondary pedestrian routes throughout the city. Montreal's green alleys (ruelles vertes) originally started as an unsanctioned project by a group of architectural students and has become an official city program where the alleys are now used as popular gathering spots for neighbors, "almost like linear pocket parks"[17]. Revitalization of laneways in Melbourne, Australia started three decades ago and involved a comprehensive redesign of the space as pedestrian-oriented living mixed-use corridors utilizing wayfinding and public art, which has been well-received by locals and tourists alike[18]. To date, there is not a green alley program with a focus on transportation, though Seattle and Melbourne's programs come the closest with pedestrian networks recognized as natural byproducts of alley networks. This vacuum presents an opportunity to design a green alley network with a focus on sustainable transportation, stormwater management, and community space.

Green Alley Evolution in Richmond

Locally, two previous professional plans from VCU's Master of Urban and Regional Planning program have looked at alleyway enhancements in Richmond, though specifically limited to the Fan District. These plans, the Alleyway Improvement and Alternate Pathway Plan[19] and Urban alleys as green infrastructure: A green alley plan for the Fan District[20] have introduced the concept of green alleys in Richmond and have contributed to visible and measurable changes in the neighborhood's alleys. Planning interventions such as green

17. Arvidson, 2008; Plourde-Archer, 2013
18. GDCI, 2016
19. Ward, 2006
20. Sanford, 2016

alleys have been no small part of the rise in the popularity of the Fan in recent decades. These two Fan plans are valuable examples of documents that built a local framework for green alley improvements that this project aims to build from.

Looking Forward

Success in implementation of green alley programs involves working with residents, including surveys, interviews, focus groups, and participatory action research[21]. As localities look forward to "the other side of COVID-19," we can assume that people will value and support development of authentic community assets that provide an intimate sense of place[22]. On the municipal government side, the complexities of these spaces require a diverse city staff and department coordination to ensure

21. Wolch et al., 2010
22. J. Martin, 2020

successful program implementation[23]. Planners and policymakers increasingly argue for the need for a nimble, improvisational approach to urban issues with community collaboration, stakeholder representation, and broad transparency and monitoring[24]. Green alley benefits are shown to be wide-ranging and include stormwater management, community placemaking, and improving sustainable transportation networks, though the latter is often cited as a secondary benefit. Even outside of urban and suburban areas with alleyways, green alley elements can be broadly applied to meet challenges where any development is present, like using pervious materials for paved driveways or parking lots[25]. The flexibility of using green alley elements in a wide variety of contexts is too great to be ignored.

23. Arvidson, 2008; Wolch et al., 2010
24. Zapata et al., 2020
25. McEnaney, 2013

Approach

Resident-Centered

A progressive and sustainable approach to urban space and civic life guides the plan's development. Planning is most successful when there is an open and diverse approach to societal problems, with responsive and transparent democratic institutions guiding progress. The individual planner can advance these ideals through compassionate interactions with members of the community, demonstrating that planning is actually a "democratic discourse instead of as the act of an unbiased, rational, and technical analyst"[1]. As a result, cooperation, mediation, and citizen power is referenced throughout the plan.

1. Lyles et al., 2018

This document relies on an egalitarian planning outlook. Effective, accessible transportation and sufficient green space is an essential step in building sustainable, equitable, and livable communities. New approaches to planning practice that emphasize resident knowledge and relationship building such as embedded planning[2] were used throughout the processes to take advantage of existing community assets. Jonathan Pacheco Bell, who coined the term, defines embedded planning as one that situates planners on the ground in the community to (1) understand people's needs, (2) build trust and authentic relationships, (3) increase participation for marginalized communities, (4) participate in daily community life, and (5) to advance equity[3]. By ensuring that methods and data are driven by community input, this plan hopes to identify solutions guided by neighborhoods and people who are tied to these spaces. We live in a time of crisis that requires swift and bold action. This plan can and should exist alongside more traditional, long-range planning processes, but with it comes the implication that our approach to planning should be more responsive, progressive, and sustainable.

Biophilic City

Concepts of livable sustainability and biophilia—humanity's innate connection with nature— guided analysis and (especially) recommendations[4]. The recognition that nature has a transformative impact on human well-being and behavior reinforces the importance of green infrastructure in our communities. There is immense evidence for real benefits of exposure to nature such as increased positive health, lowering crime, encouraging individual generosity, and promoting community engagement and stronger neighborhoods[5]. Biophilic Cities are also better equip to "successfully cope with and adapt to future stressors and shocks", often referred to as resiliency[6]. These advantages are felt by residents who experience positive effects such as an increase in generally well-being, better health, and the ability to be more adaptable to challenges in their daily life[7]. This, in turn, means a healthier civic environment and planning process.

2. Pacheco Bell, 2018
3. Pacheco Bell, 2021

Local and regional agencies can go a long way to ensure environmental sustainability and social equity in their communities and provide a practical vision for the future[8]. This includes societal change such as incorporating active transportation education into driver's education[9] and more generally change the way we discuss sustainability and associated benefits in health, economics, and the environment[10]. We must also be more upfront about framing policies around biophilia and reducing car use as issues of equity. The "Green Street Principles" laid out in NACTO's Urban Street Stormwater Guide are consistent with sustainability

and resiliency goals of this plan and are explained in greater detail throughout the document. These principles are to (1) protect and restore natural resources; (2) promote health, equity, and human habitat; (3) design for safety and mobility; (4) design for life cycle; (5) design for resilience; and 6) optimize for performance.

4. Beatley & Newman, 2013; Gough, 2015; Wilson, 1984
5. Beatley, 2010; Beatley & Newman, 2013
6. Beatley & Newman, 2013, p. 3337
7. Mueller & Dooling, 2011
8. Beatley, 2012
9. Sadik-Khan & Solomonow, 2017
10. Speck, 2018

Walkable City

This plan aims to strengthen the idea of walkable cities and walkable communities, regardless of strict density. There is heavy influence from Jeff Speck's *Walkable City* and companion *Walkable City Rules*, which doesn't describe how cities work, but rather "about what works in cities. And what works in cities is walkability"[11]. Both books center themselves around Speck's "General Theory of

11. Speck, 2012; 2018

Walkability," which describes how "to be favored, a walk has to satisfy four main conditions: it must be useful, safe, comfortable, and interesting".

The principles Speck presents are not meant to be exclusive to cities, even as the subtitle of the book, *How Downtown Can Save America, One Step at a Time*, is undeniably biased toward cities. However the idea of cities themselves are a matter of semantics, as the legal definition varies from place to place. We would benefit from disabusing ourselves from the idea that walking and biking for transportation is an *urban* or *city* thing, as this is a disservice to non-city residents. All communities can incorporate walkable elements in their built design, regardless of size or urban character. Examples in the Richmond Region include the growing pedestrian network in Powhatan Village and the Virginia Capital Trail in rural Charles City County, with spurs to recreational, historic, civic, and educational destinations.

Soft City

The soft city is a relatively new idea put forth by David Sim in his 2019 book of the same name. Sim describes the soft city as a counterpoint or compliment to a smart city: "rather than looking to complex new technologies to solve the challenges of increasing urbanization, we can instead look to simple, small-scale, low-tech, low-cost, human-centered, gentle solutions to help make urban life easier, more attractive, and more comfortable"[12]. As with *Walkable City*, it is primarily, but not exclusively for cities or dense areas.

Sim offers the idea of a *neighborhood* that would instead be more appropriate to use. "More than anything," Sim writes, "the human environment is about relationships: relationships between people and planet, relationships between people and place, and relationships between people and people"[13]. The benefits of building toward neighborhoods with walkable city and soft city principles (which could include modest increases in density for suburban and rural areas) include greater access to opportunities, greater integration of activity into everyday life, higher independence for seniors and kids, lower infrastructure costs, a healthy environments, and a stronger community identity.

12. Sim, 2019 (4)
13. Sim, 2019 (11)

Research Questions

A series of questions (Figure 1) were examined to understand existing conditions and to best determine which green infrastructure (GI) strategies can be applied to alleyways in the study area. The central question was how to best incorporate green alley networks into the existing community context. To identify what is feasible in the study area, emphasis was put on archival research, physical observation, and correspondence with residents and City representatives. To identify what is appropriate for the community, primary consideration was given to residents and neighborhood groups to help shape the recommendations and plan.

With GI elements in mind, the aim is to find which alleys can better facilitate safe and accessible mobility within the community and connection to the regional network. It was necessary to examine the physical realities of alleyways in relation to other transportation networks to gain a nuanced understanding of how alleys are used day-to-day.

Gaining a better understanding of how alleys are used in a particular neighborhood was vital to this project, as alley usage can vary block to block. Opinions of alleyways that residents currently hold were solicited to determine what interest there is in improvement of alleyways as green transportation networks. After working with residents to help understand these questions, a working set of vision, goals, and objectives was developed to guide the project and best pinpoint what assets and resources can be used for implementation and maintenance of green alley networks.

QUESTIONS

How are alleys currently used?

How can green alley networks be incorporated into the existing community context?

Which alleys can better facilitate safe and accessible mobility?

How do residents want to use alleys and how can green infrastructure facilitate that vision?

Figure 1. Project Research Questions

Community Outreach

Sources of information included observation, consultation with the client and other agencies, research into state and federal programs as well as local non-profits, and substantial community outreach. Resident input greatly influenced the direction of the project, though the nature of in-person outreach was restricted due to the COVID-19 Pandemic. A campaign to seek community feedback largely depended on a combination of email, paper survey (Figure 2) distribution, video conferencing, and limited street-level engagement following social distancing guidelines set by the Center for Disease Control and the Virginia Department of Health.

A survey was employed to better understand how local stakeholders (including residents, business owners, and employees) view city alleys and possible improvements using green infrastructure and enhanced bike and pedestrian facilities. Survey flyers were distributed to residences and businesses within the bounds of Lombardy Street, Leigh Street, 3rd Street, and Broad Street in January 2021. The survey flyer directed individuals

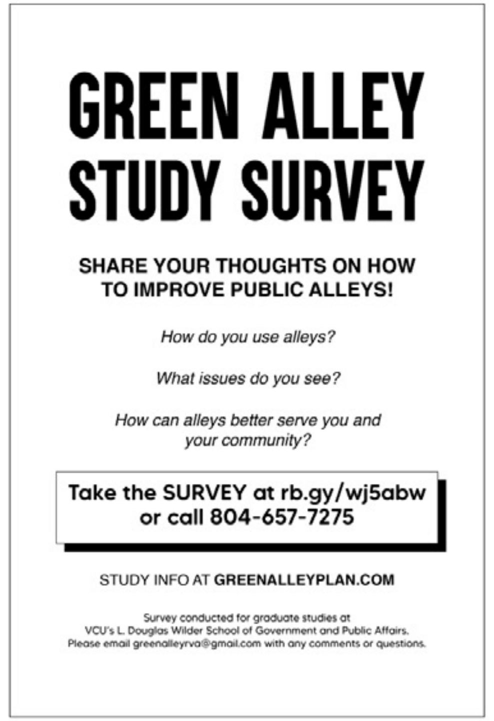


Figure 2. Survey flyer left at residences and businesses within the study area.

to a short online survey using a visual preference component. Google Voice was also utilized to set up a phone number for comment collection and a project-branded email was provided to collect input and field questions, concerns, or problems from the community.

To comply with social distancing guidelines in response to the COVID-19 Pandemic, engagement efforts were rarely in-person. Flyers were left at residences and businesses via mail slots, mailboxes, or similar delivery vessel. The survey distribution area was chosen to target likely frequent-users of the subject alleyways.

Interviews with City and regional departments and agencies were used to tie into resident comments and were vital in learning what is possible in the short and long-term when it comes to green alleys. Representatives from the Department of Public Utilities, the Office of Sustainability, the Department of Public Works, the Department of Planning and Development Review, and PlanRVA—among others— were interviewed in the early development stage. Interview protocols are provided in the Appendix.

COVID-19 Precautions

This project was developed from August 2020 – April 2021, taking place entirely during the COVID-19 Pandemic, which was declared on March 11, 2020. As a result, meetings took place entirely by phone or video conferencing such as Zoom and Google Meet. The exception being two alley tours lead by residents where participants wore masks and maintained social distance as recommended by the CDC and VDH.

Field research and minimal street level engagement was always conducted wearing a mask and with an attempt to maintain appropriate social distance. Due to the style of approach and proximity of the study area to the author's home, research was conducted almost entirely on foot or bike. This allowed an informed approach to field research that ensured avoidance of crowds and heavy foot traffic areas.

Green Alley Network Website

A publicly-facing website (Figure 3) was designed at the beginning of this project to serve as a resource for community residents, project panel members, and to serve as an executive summary upon completion of the plan. The survey flyers that were distributed to the entire study area featured the website name and interested parties were directed their for more information.

For branding purposes and to assist in navigation, the web domain "greenalleyplan.com" was purchased for the duration of a year for a cost of about eight dollars. The page was constructed using an ArcGIS StoryMap, which allowed the use of integrated mapping, surveys, and other multimedia.

The website received regular updates at different milestones of the project, keeping interested parties up-to-date. For the duration of the community survey open period, a link was prominently displayed on the website and results were displayed in full upon closure of the survey. Draft recommendations were posted on the website for a duration of two weeks to solicit final plan input from stakeholders. Visitors to the site during these two weeks were greeted with the following message when entering the 'Draft

Recommendations' section:

You can provide input on these draft recommendations until April 14, 2021. Input in the form of comments, suggestions, questions, or concerns can be sent to greenalleyrva@gmail.com. You may also call 804-675-7275 to leave your comments in a voicemail message.

The ultimate goals of the website were to keep individuals in the loop about the project, promote detailed engagement, and provide an open source of contact.

A combination of **greenalleyplan.com**, the project Google Voice number, and the initial survey flyers promoted active dialogues with several community members throughout the process.

Green Alley Logo

A simple logo (Figure 4) was developed to help with branding and to provide a sample design for a hypothetical alley network.

For this project, the logo was used on the website, email avatar, and research update material. In the future, a design chosen or created by residents could be used in marketing and educational material as well as on wayfinding signs.

This design was created through the process described in Figure 5.

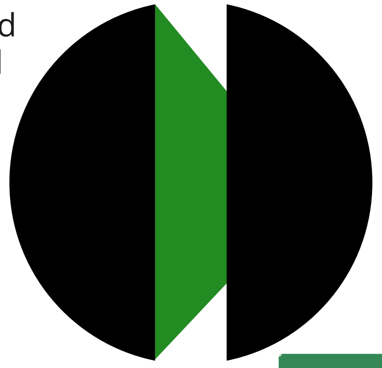


Figure 4

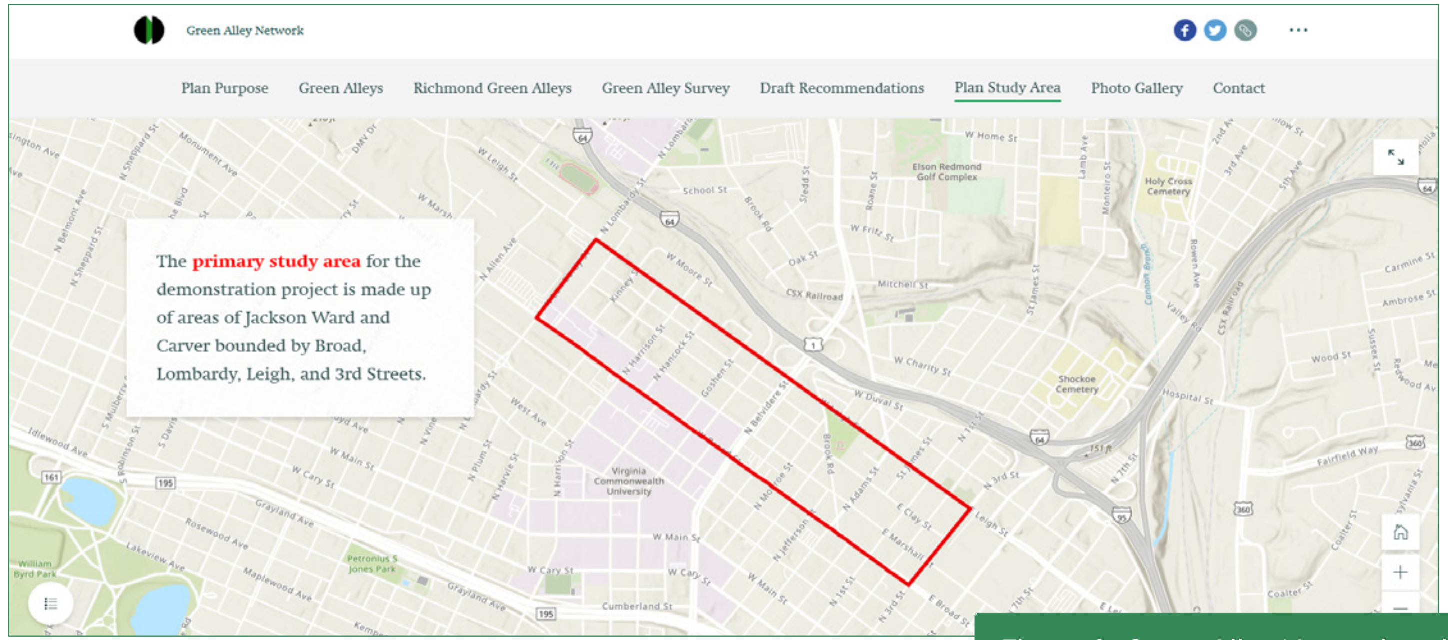
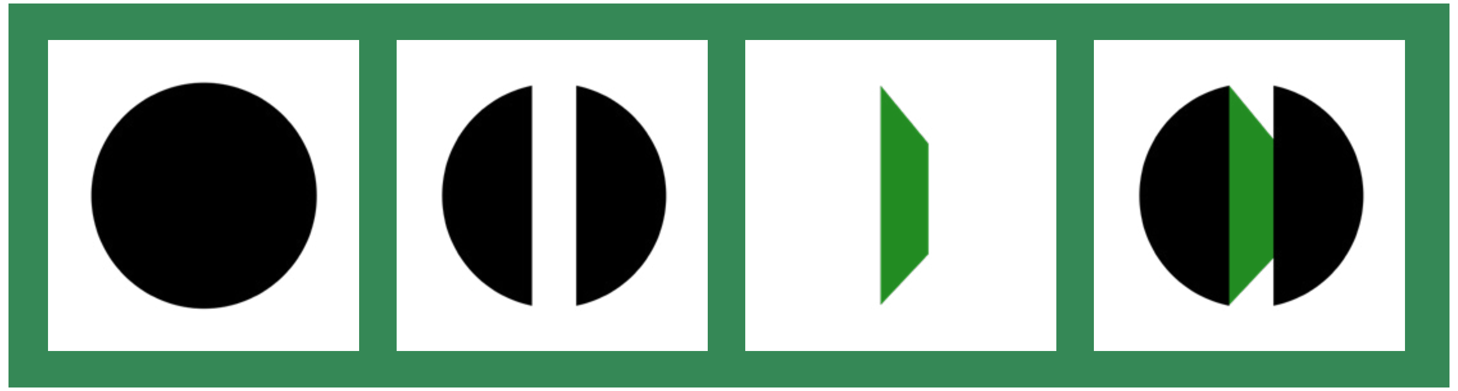


Figure 3. Green Alley Network website

Figure 5. Green Alley logo process



A black circle represents unity, resilience, and a nod to a figure-ground image.

Separation into two halves suggests a disunion and a depiction of the space between buildings.

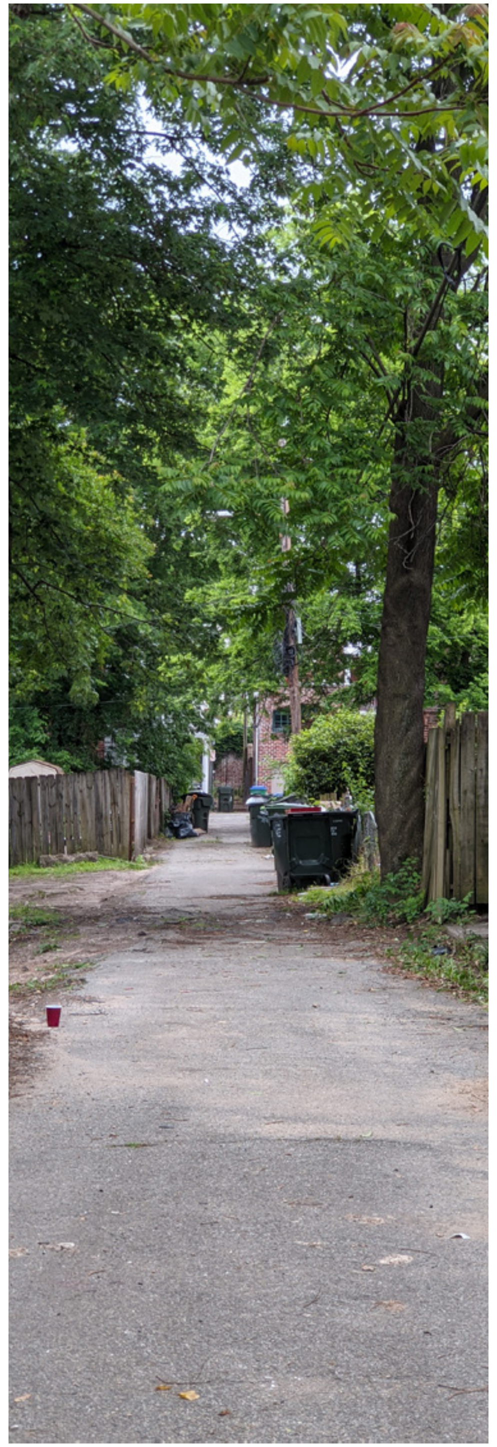
A green plane on a skewed perspective represents the biodiversity in our urban areas, often in hidden spots.

The green plane brings connection where there was division, bridging gaps and healing neglected spaces.

Summary of Findings

Surveyed residents indicated a strong interest for investment in alleys as public space as indicated by their open comments and design preferences. An analysis of resident comments indicates opportunities in trash collection, accessibility, stormwater, and general improvements including public art and landscaping. Sometimes the referenced issue overlapped into one or more other categories, but each comment was paired with a primary opportunity. Case in point, general presence of trash and loose refuse is a main concern among surveyed residents, which can in-turn complicate stormwater management and contribute significantly to accessibility issues. The way trash, stormwater, and existing accessibility problems combine in the study area contribute to a cycle of alley degradation that can only be addressed through municipal and community investment.

Despite a strong negative opinion of alleys among surveyed residents, open ended responses indicate a recognition of usefulness of the space and a desire to see improvements that would allow more comfortable multi-modal travel and community use. Research, including interviews with City workers and residents, indicates that knowledge of City agencies roles and responsibilities can be confusing and opportunities exist for public outreach, education, and community involvement around alleys.



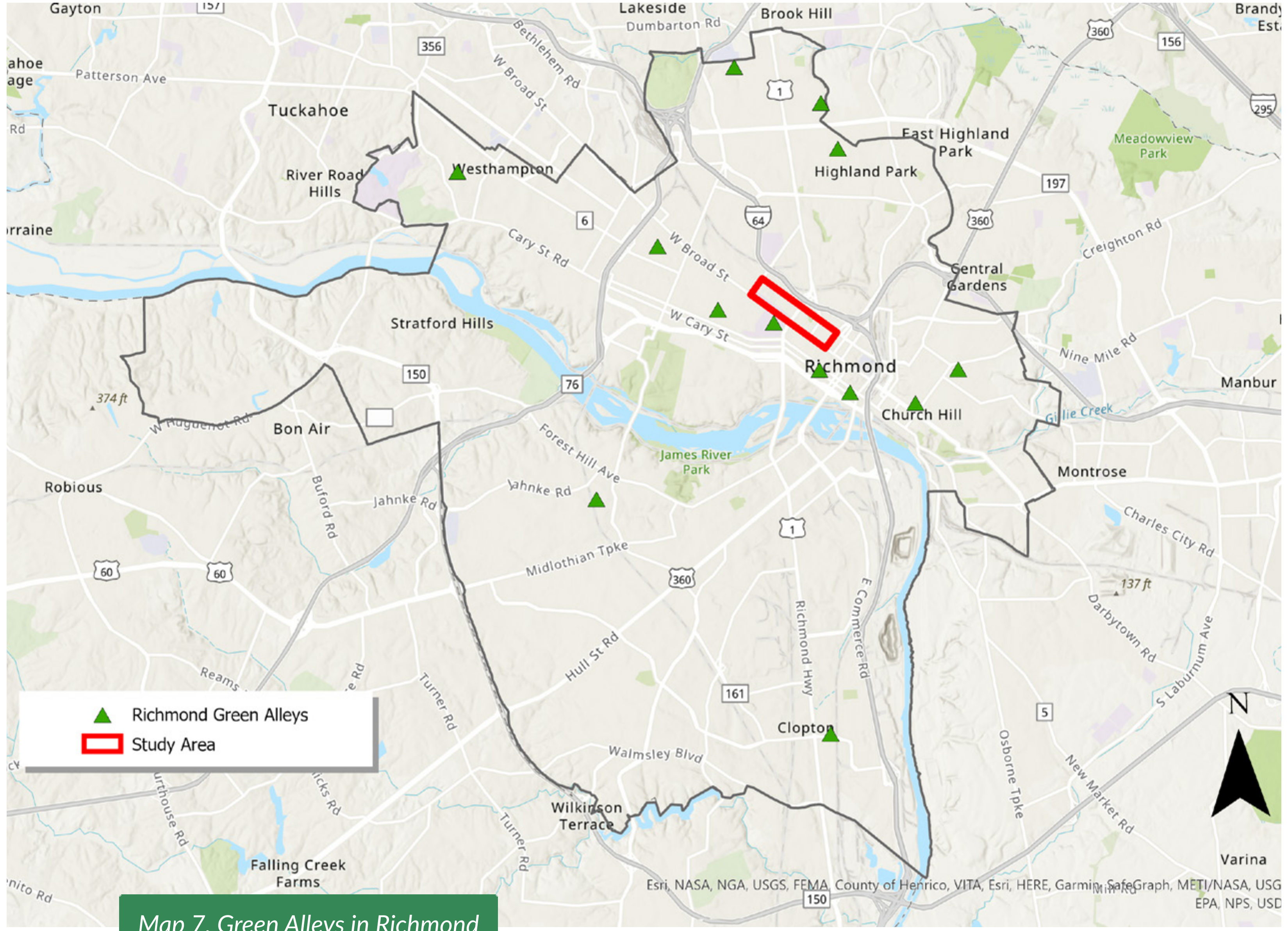
Green Alley Program

Interviews with City officials and concurrent on-the-ground research resulted in a better understanding of Richmond's current green alley program. As of April 2021, 13 alleys in Richmond have been converted to green alleys (Map 7 and Table 1). Time for conversion takes about 6-7 months using contracted labor, with regular maintenance later performed by City crews. Depending on the specific size, terrain, and condition, initial construction can be up to three times the cost of repaving a traditional alley, but the lifetime cost of a green alley is equal or substantially less. Green alleys have proven to be popular with residents and businesses who benefit from these improvements since the design of the permeable pavers reduce stormwater runoff, help make alleys look like more inviting streets, and reduce the perception of these spaces as dirty or dangerous.

Other alleys have been identified for green alley conversion, but there is currently no detailed plan for implementation or a dedicated funding source for the program.

Green Alley	Location	Year Built
12th Street	12th – Main – 13th – Cary	2010
5th Street	5th – Main – 4th – Cary	2010
Monument Avenue	Monument – Cleveland – Tilden – Franklin	2012
Grace Street	Grace – Laurel – Franklin – Shafer	2012
St Christopher's Road	St. Christopher's – Wesley – Henri – Bay	2012
N 23rd Street	N. 23rd – Clay – 24th – Marshall	2013
Meridian Avenue	Meridian – Bells – Lynhaven	2016
Fendall Avenue	Fendall – Garland – Culpepper	2016
Cheatwood Avenue	Cheatwood – Akron – Moss Side	2016
Grove Avenue	Grove – Meadow – Hanover – Granby	2016
Lorraine Avenue	Lorraine – Crestwood – Westbrook – Stratford	2018
T Street	T – 27th – S – 26th	2018
Forest View	Forest View – Bassett – Hill Top – Clarence	2021

Table 1. Green Alleys in Richmond



Map 7. Green Alleys in Richmond

12th Street

Location

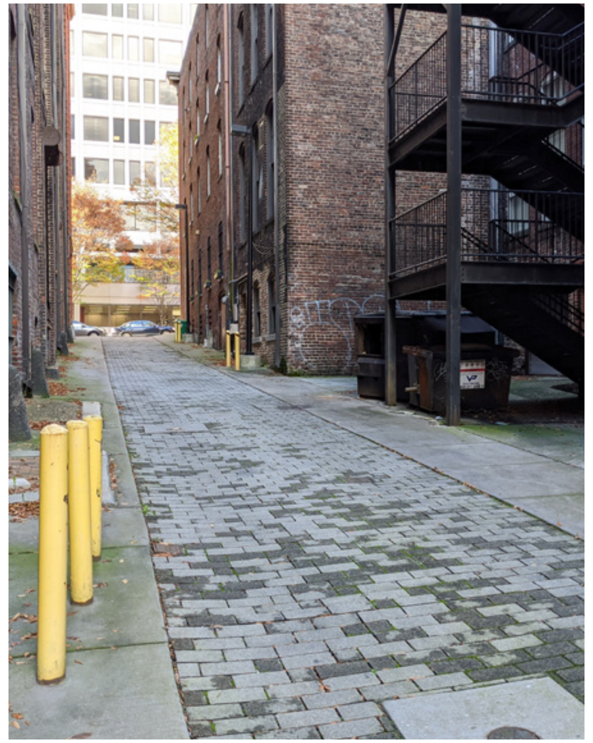
Shockoe Slip

Year Built

2010

Surface Material

Permeable pavers



5th Street

Location

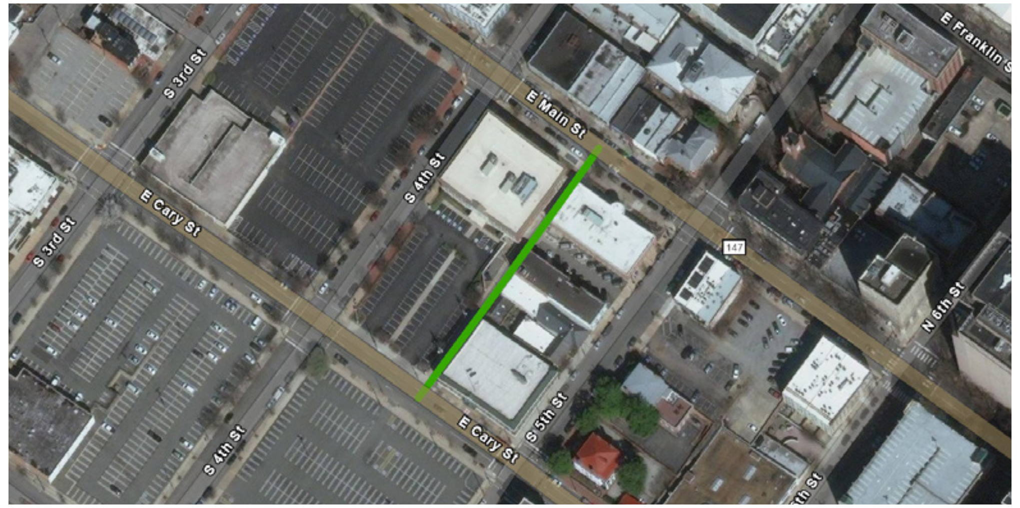
City Center

Year Built

2010

Surface Material

Permeable pavers



Monument Avenue

Location

Museum District

Year Built

2012

Surface Material

Permeable pavers

Grove Avenue

Location

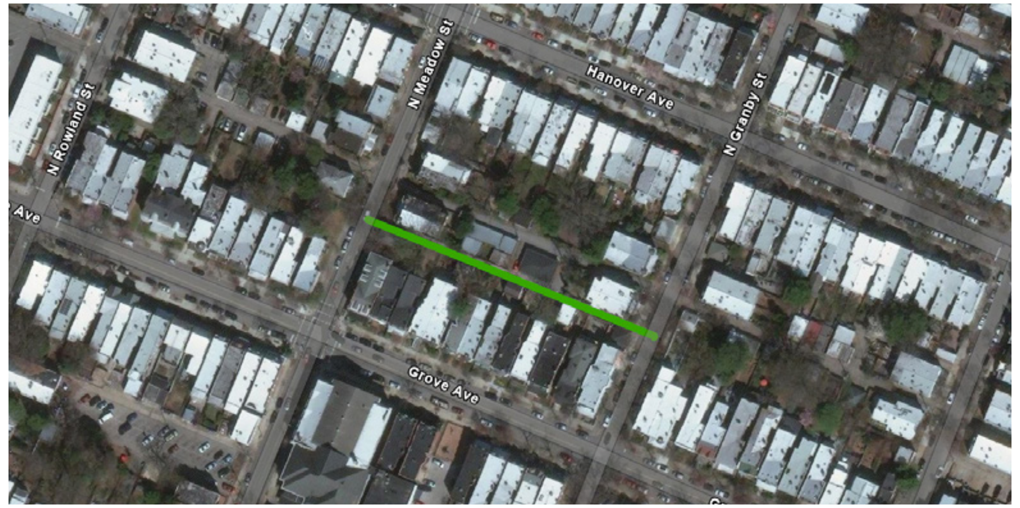
The Fan

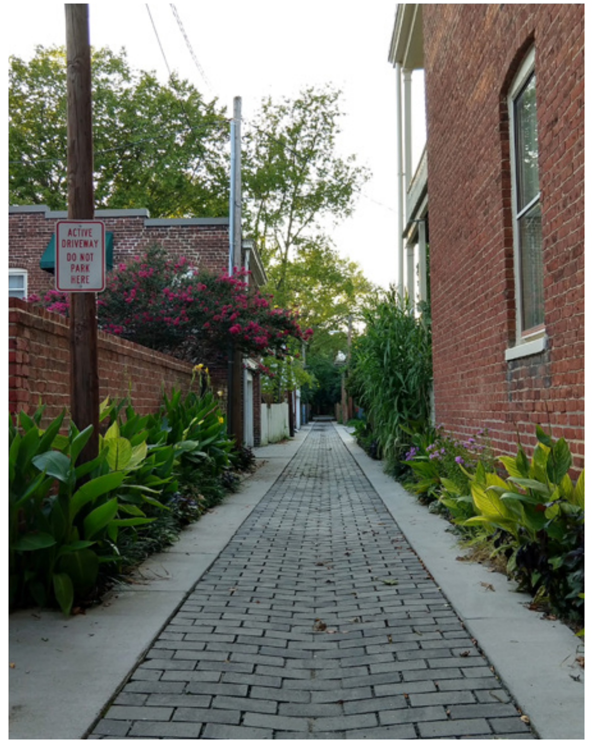
Year Built

2016

Surface Material

Permeable pavers





St Christopher's Road

Location

Three Chopt

Year Built

2012

Surface Material

Permeable pavers

N 23rd Street

Location

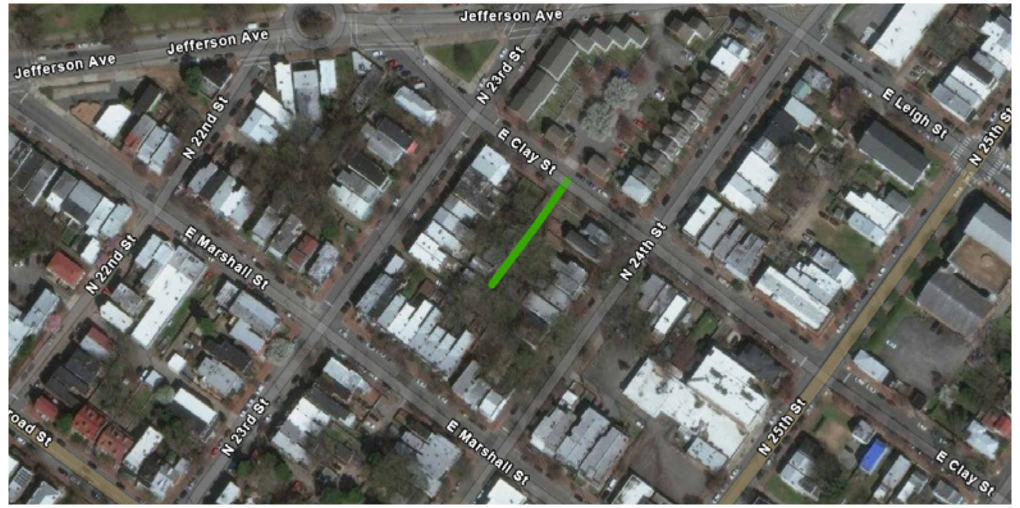
Church Hill

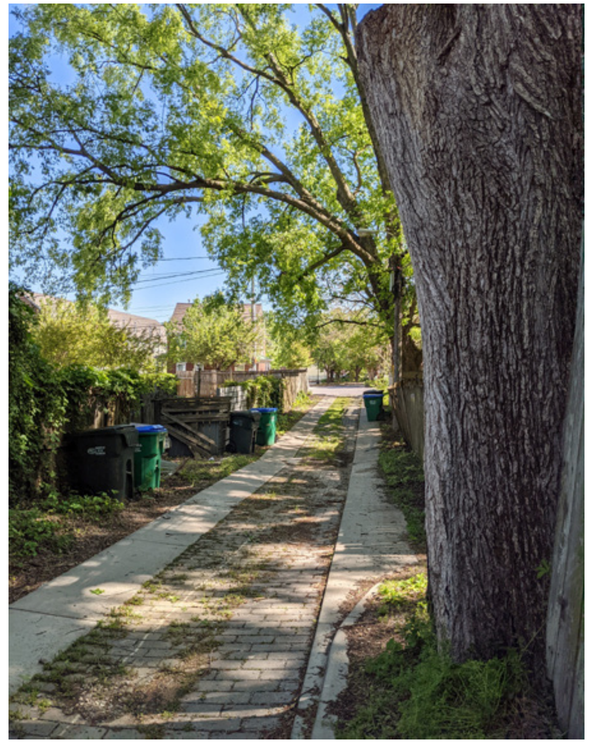
Year Built

2013

Surface Material

Permeable pavers





FINDINGS

Meridian Avenue

Location

Clopton

Year Built

2016

Surface Material

Permeable concrete

Fendall Avenue

Location

Edgewood

Year Built

2016

Surface Material

Permeable concrete

Cheatwood Avenue

Location

Washington Park

Year Built

2016

Surface Material

Permeable concrete

Lorraine Avenue

Location

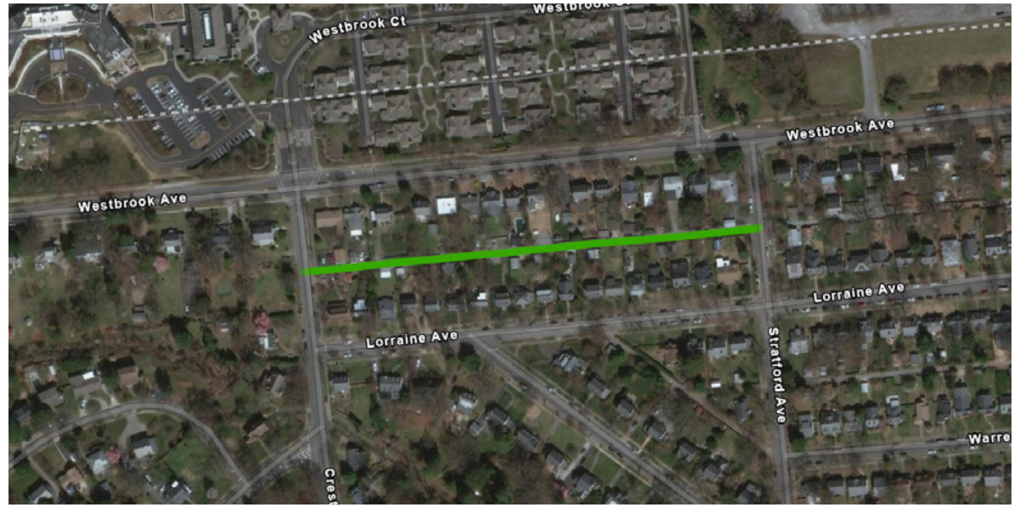
Bellevue

Year Built

2018

Surface Material

Permeable concrete



Grace Street

Location

VCU

Year Built

2018

Surface Material

Permeable pavers

T Street

Location

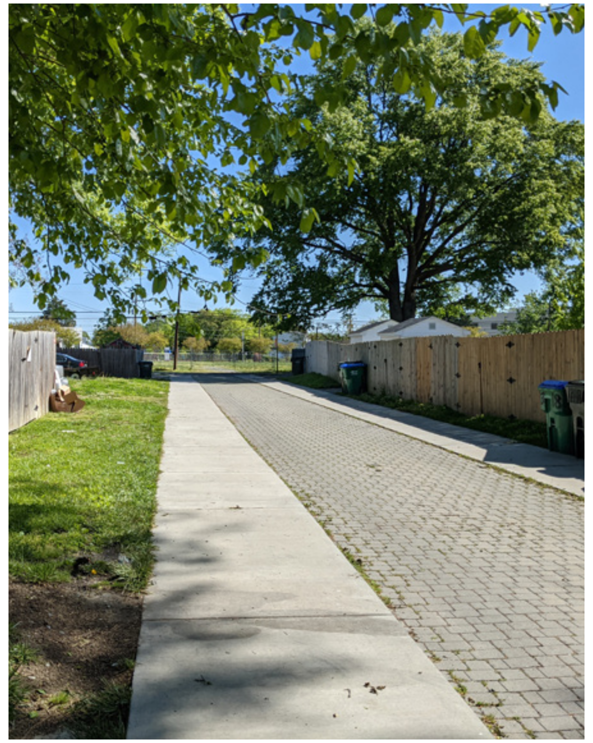
Church Hill

Year Built

2018

Surface Material

Permeable pavers



Forest View Drive

Location

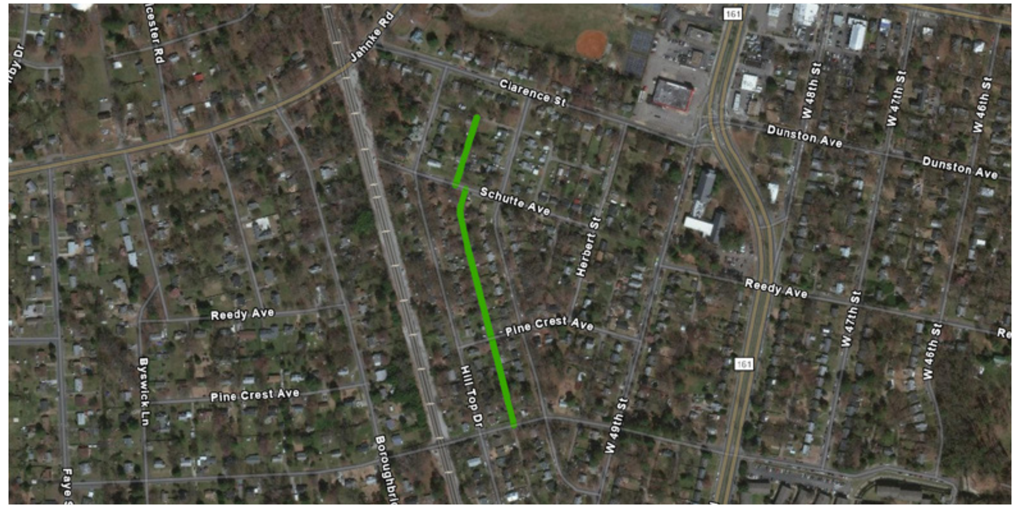
Forest View

Year Built

2021

Surface Material

Permeable pavers



FINDINGS

FINDINGS

Survey Insights

Almost all respondents report seeing poor surface condition in alleys (92%), but only 68% report poor drainage or flooding. This may indicate that many people do not recognize the connection between stormwater and roadway surface condition and necessitate the need for further stormwater education. Green alleys using previous pavers can virtually eliminate runoff that causes severe damage to street surfaces and reduce instances of potholes and other surface damage.

When considering surface conditions, related survey insights tell a more complete story of how respondents currently use and want to use their neighborhood alleys. First, and perhaps surprisingly, a lot of people use their bikes in alleys, with 40% report biking. This includes people using alleys as bicycle routes, shortcuts, and to access garages and rear yards. Whatever the reason, the high number of bike users indicates these are fairly popular avenues for active transportation when conditions allow accessibility. Additionally, cars in alleys are a split issue at 50%, with walking and biking access preferred at 30+ point margins. Taken with the numbers on alley bike activity, that may suggest the need for further investments in walking and biking infrastructure in alleys and the reinforcement of current automobile activity— primarily parking and garage access— while limiting further motor vehicle traffic. Finally, respondents indicate a strong preference for pervious pavers at 74%, choosing the favored design for Richmond's green alleys. This surface type emphasizes aesthetics while providing subtle speed control cues for motorists to slow down while the outer concrete aprons can act as a pseudo-advisory bikeway in moderate-to-wide alleys.

Four more survey insights can be taken together to tell another story. Responses suggest that public art is very popular, with 84% selecting it as a preferred amenity. Open comments greatly supported this number as individuals commonly referenced murals and artistic displays as features they appreciate seeing in their alleys. There are a number of large murals in Jackson Ward and a few in Carver, which further supports this view.

While public art is undeniably popular, seating as an amenity is not as popular, with only 40% showing support. This may suggest that residents have a transitory public gallery-type view of this art— that passersby are welcome to view and enjoy the work for a few moments, but for the most part, alleys are not a place to dwell (with some exceptions like community gardens and designated pocket parks).

Over 78% of respondents report using alleys daily and 18% report using them weekly, supporting the view of alleys as central to community life. It is natural that people would like to see more beautification and comfort in a space that is frequently used in the course of daily life.

Finally, survey results indicate that crime is an issue, but among the fewest number (22%). This number is the exact inverse of the number who report using alleys daily (22-78), which could suggest a relationship between those who infrequently use alleys and those who perceive alleys as dangerous. However, this plan cannot dismiss even the perception of crime, as the belief that alleys are unsafe may be one of the primary reasons behind infrequent use and neglect of alleys.

Word cloud constructed from survey open comments

Themes Identified by Residents

Trash

"More thought needs to go into city trash storage and collection for residential and businesses to make sure there's capacity for the increased occupancy. I believe it's been overlooked and is a disservice to those who are occupying these areas."

-resident response

Trash and refuse collection was shown to be the primary topic of concern, dominating open comments with "trash" being the most common word submitted just behind "alley". Several responses suggested that there is not one common source for the problem in most alleys, but rather the issue is systemic. This presents an opportunity for a revaluation of current refuse practices and how we design areas for garbage collection in the public realm: in alleys, side streets, and main streets. Residents reported "haphazard supercan locations" and "old, abandoned, and broken trash cans that are clogging our alleys," expressing frustration at a problem that seems to never improve. Beyond the feeling of comfort,

Overflowing trash containers and loose trash in a Carver alley.

trash collection is a public health issue, from direct dangers like broken glass, rusty metal, pet waste, and medical waste to more hidden dangers such as toxins leeching into groundwater, supporting rodent populations, and contributing to the spread of disease. As stated earlier, trash can exacerbate current problems with accessibility and stormwater management, so sustainable trash collection systems will be a vital aspect of the final recommendations.

Accessibility

"I think it's really important to make EVERY roadway, street, or alley accessible to all people, regardless of physical ability."

-Resident Response

Since alleys are a kind of omnipresent public space in many parts of Richmond, it is important to make them safe and accessible to the public. Survey responses indicate a strong desire for alleys to be more accessible to those on foot and bike. During field research, conditions were often unfavorable to walking (which was the primary method of travel during the study along with biking) and many times would have been completely impossible for someone in a wheelchair or in a stroller to navigate. There was exasperation conveyed by residents who navigate these spaces daily, with irritation at the condition of alleys summarized in this response:

"I would like to walk down the alleyways in my neighborhood and enjoy them - not having to back track because they are so muddy, smell bad (especially in the summer). I'd like to be able to drive down my alley when I need to without navigating all of the deep holes/ruts."

Some residents specifically called for alleys as active transportation routes in their input, some thinking "they could be great alternate walking or biking routes if you want to get off the street or sidewalk," with many more stating they would like to have them as options when walking or biking. When taken with the earlier insight that 40% of respondents already use alleys for biking, we can identify a lot of unmet demand for more bike-friendly surface conditions in these spaces. Some respondents also reported tripping and falling due to potholes and uneven cobblestones, highlighting the need for greater non-automotive accessibility in these public rights-of-way.

Field observations were largely consistent with resident reporting, with relatively poor walking and biking conditions in study area alleys despite being located in a fairly flat part of the city with a strong grid network (Figure 4). Poor conditions are largely

Resident navigating around standing water in a Carver Alley.

due to surface conditions and resulting stormwater issues.

Stormwater

> *"I would like to see the alleyway cleared of debris as well as drainage issues rectified."*
>
> *- Resident response*

Though not directly identified as much as trash and accessibility, better stormwater management was also an opportunity identified by respondents. The topic was usually combined with another issue, such as potholes or general accessibility problems: "The alley way between Goshen and Hitchcock... has many potholes that fill with water and pose hazards". Responses often identified the specific alley in question when sharing stormwater and stormwater-related problems, implying that these conditions have long been a source of difficulty in their daily lives: "Drainage issues need to be addressed in Carver, especially the alley between Marshall and Clay in the 800 block". Indeed, some severe accessibility issues were observed to have quick, ad hoc fill-ins of dirt, gravel, crushed brick, and other materials that show some residents felt it necessary to attempt to rectify some of these issues themselves.

These stormwater concerns were evident from

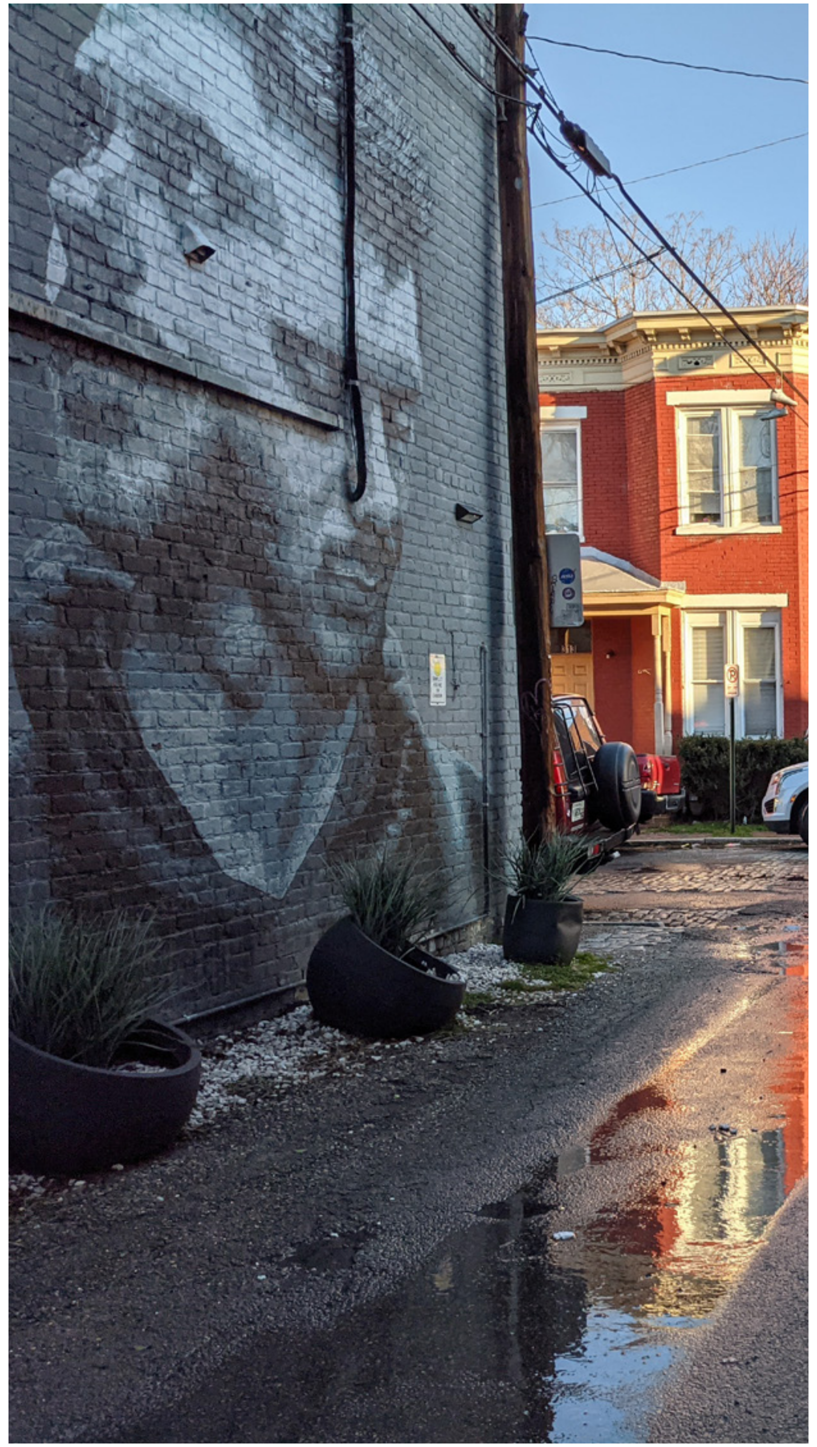
Figure 6. The top two pictures depict an alley in Carver, one after a snowfall on February 12, 2021 (top left) and again on February 16, 2021 (top right). The bottom two pictures depict a green alley in the Fan, one after the same snowfall on February 12, 2021 (bottom left) and again on February 16, 2021 (bottom right).

direct field observations during February 2021 (Figure 6), when the Richmond region experienced a heavy amount of rain, snow, and ice. Each of these events alone can be a major concern, but when they happen during the same weather event, alleys can see immediate stormwater runoff combined with a gradual snowmelt that can exacerbate and prolong flooding and hazardous conditions. During the week of February 7—12, which saw a modest inch of snow and 1.76 inches of precipitation, two alleys were observed and recorded on February 12 after the more significant snowfall of the week. One is a green alley in the Fan and the other is a typical alley that can be found in Carver, comprised of pavers, dirt, gravel, and various other patchwork surfaces. Four days later, after snow had melted, the same two alleys were recorded to gather a visual comparison of standing water found in each alley. It should be noted that both are active alleys that experience resident access, utility vehicles, and cut-through traffic.

General Improvements

> *"I love finding murals and art in alleys. I think that it would be good to take advantage of the privacy of alleys to implement more artistic projects."*
>
> *-Resident response*

Comments related to general improvements were broad, but generally include remarks on public art, landscaping, gardens, and community space. Many responses are largely in-line with the multi-faceted goals laid out in this plan: "more grass, flowers and shrubbery; more lighting; less trash; like small parks". Still others were even more spot-on: "I'd like to convert alleyways into green community spaces... like a network of parks - giving dwellers places to explore and express creativity, to play, to sit and meditate, to plant herbs, fruits, and vegetables.". It is unknown which surveys were taken after respondents viewed the project website, which may have influenced responses.



Recommendations

Combining resident input, field research, and consideration of best practices, a set of goals, objectives, and actions are presented in this section as means to realize the overall **vision** for the Green Alley Network Plan:

Richmond's public alleyways are utilized to their full potential as biodiverse shared streets acting as active transportation corridors, stormwater management systems, and public spaces that support high quality of life and community health.

The plan's four goals are to (1) reduce stormwater runoff from Richmond alleys, (2) increase the comfort of alley spaces, (3) improve mobility in and between alleys, and (4) engage in public outreach and awareness of green alleys. The first three goals mirror opportunities identified by residents and the fourth goal is presented as a way to bring green alleys and green stormwater infrastructure to more residents of Richmond and the wider region. Following these recommendations, implementation measures will be presented to provide next steps to carry on the momentum gained in this particular green alley study.

GOALS

1. **Reduce stormwater runoff from Richmond alleys**
2. **Increase the comfort of alley spaces**
3. **Improve mobility in and between alleys**
4. **Engage in public outreach and awareness of green alleys**

Goal 1: Reduce stormwater runoff from Richmond alleys

Objective 1.1
Increase number of green alleys

Action 1.1.1: Establish a dedicated green alley program in the City of Richmond that focuses on stormwater management, mobility, and quality of life. Keep data and records updated and publicly available to encourage interest and resident-led projects.

Action 1.1.2: Pursue funding through grants and local, state, and federal sources in transportation, stormwater, climate, equity, and health. Take advantage of the broad area that transportation covers and its relation to land and energy use. Transportation infrastructure is responsible for a large portion of stormwater runoff and turning these grey areas into green areas will make our communities more sustainable and resilient.

Action 1.1.3: Require green alley-friendly elements or other green stormwater infrastructure in new development. Even if an alley cannot immediately be converted into a green alley, requirements to meet a certain amount of stormwater capture in the form of green roofs, rain barrels, and edge vegetation can be examined as options to reduce stormwater entering alleys from adjacent properties in the first place.

Objective 1.2
Encourage utility-friendly vegetation along alleys

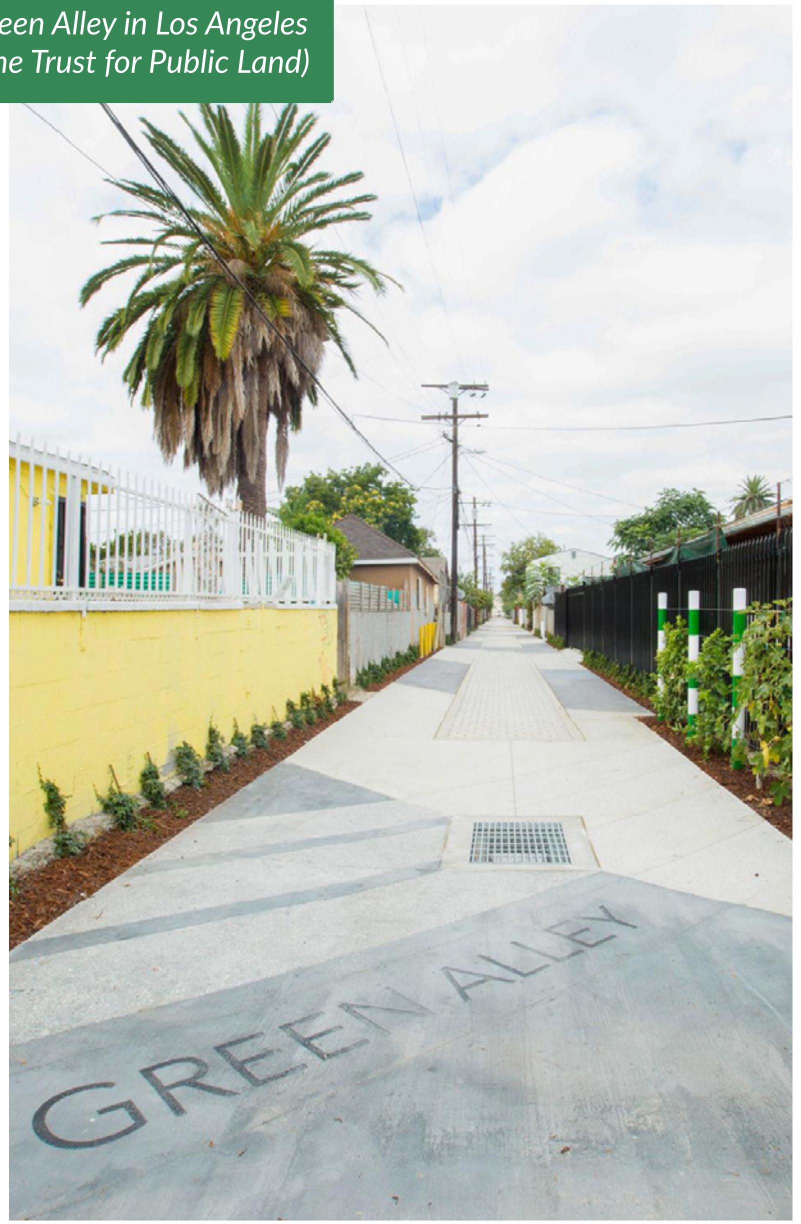
Action 1.2.1: Establish a one-page resident's guide to utility-friendly vegetation. Focus on native plantings using resources such as Plant RVA Natives Campaign's Native Plants for Virginia's Capital Region to identify species appropriate for each project. Emphasize that alleys are unique, often harsh, environments with specific needs and considerations. [Will include callout about utility-friendly vegetation.]

Action 1.2.2: Work with residents and local non-profits to establish community gardens and plant trees. Reforest Richmond is one such program that is committed to help realize the goal of increasing the city-wide tree canopy to 60% by 2037, as outlined in Richmond 300, in an effort to dismantle systemic racism and environmental injustice. Planting more trees near alleys in cooperation with adjacent property owners can help capture stormwater runoff and meet urban tree canopy goals while expanding their benefits into lower income neighborhoods and communities of color.

Objective 1.3
Utilize stormwater as a resource

Action 1.3.1: Require new transportation projects to integrate green stormwater infrastructure in its design. Bioretention planters, stormwater trees and permeable pavements are examples of infrastructure that can effectively manage stormwater along transportation corridors while improving the well-being of movement. This decision would be consistent with the Virginia Coastal Zone Management Program's goals on resource protection and is locally in-line with the 2019 declaration of Richmond as a biophilic city and the Richmond 300 vision of a thriving environment.

Green Alley in Los Angeles (The Trust for Public Land)



Action 1.3.2: Set a goal of capturing a minimum of 85% of stormwater runoff[1] with new alley construction. Green alley conversion projects are an excellent time to introduce other GI elements. In areas slated for new development where the grid and alley network can be enhanced, such as Greater Scott's Addition and Manchester, stormwater can be utilized as a vital resource to create biophilic districts and city-wide eco-corridors.

Action 1.3.3: Introduce minimum green stormwater infrastructure in routine alley repavings of all materials. Where conversions to green alleys cannot yet take place, include edge vegetation or pervious pavement at alley entrances to mitigate runoff around common problem areas.

Goal 2: Increase the comfort of alley spaces

Objective 2.1
Work toward greater biodiversity in alleys

Action 2.1.1: Create incentive programs for residents to maintain greenspace on alley edges and for planting of trees and thick vegetation near the rear of property lines. While the right-of-way is public space, individual residents have a big part to play in the health of alleys. Giving residents more ownership and decision-making about certain elements can exponentially save municipal maintenance costs. [Callout will detail possible neighborhood programs.]

Action 2.1.2: Establish full-time tree steward positions within the Urban Forestry Division to be responsible for specific geographic areas of the city, including coordinating with the Department of Public Utilities on the City's green alleys. Additionally, provide funds to volunteer tree stewards to provide a basic stipend fund for volunteers. This reorganization can strengthen the city's urban canopy and ecological health by providing more comprehensive care for urban forests and opportunities for public education.

Objective 2.2
Explore sustainable waste collection practices

Action 2.2.1: Utilize submerged refuse containers (Figure 7) in alleys with high volumes of trash. Placing shared submerged trash containers in the public right-of-way where space and clearance allows can improve the comfort of alleys by providing a safe and secure method of waste disposal that prevents overflow and issues with lose trash. [Callout will reference submerged trash containers in other cities.]

Action 2.2.2: Provide incentives, designs, and support for construction of trash can enclosures or screenings. Such improvements can improve visible aesthetics and comfort within alleys and streamline trash disposal and collection. Vegetation on alley edges in Action 2.1.1 can help form enclosures or effectively screen sights and smells associated with trash containers.

Action 2.2.3: Require developers and public projects to incorporate sustainable waste guidelines early in the design process. This would reduce the impact of waste on the public realm, often located temporarily or permanently in alleys. Proper waste collection would lessen the negative impact of waste in public health, stormwater runoff, and mobility.

Action 2.2.4: Adopt city-wide Zero Waste policies, building upon the language in Richmond 300 about demonstrating zero-waste behaviors in the design and expansion of City operations.

Action 2.2.5: Initiate a plastic bag ban to protect local environments and eliminate a common litter source.

Figure 7. Submerged refuse container in Kissimmee, Florida (Zero Waste Design Guidelines)

[1]This is derived from the goal stated by the City of Dubuque to reduce stormwater runoff from alleys within the Bee Branch Watershed by up to 80% by converting them all to green alleys by 2040 (every alley within this watershed is located in Dubuque). I'm combining this with data from a Seattle Street Edge Alternatives program that utilized intensive green infra-structure along a residential urban street to reduce stormwater runoff by 99%.

Action 2.2.6: Promote residential and commercial composting by partnering with regional food producers. This will greatly reduce the amount of waste in landfills while making use of organic materials that would end up in the trash. A compost bin in an alley emits no bad odors and serves an important community purpose.

Objective 2.3
Improve lighting in alleys

Action 2.3.1: Require new lighting in alleys to have zero uplighting to reduce light pollution. Focus on expanding pedestrian-level lighting that is dark sky compliant to improve visibility and comfort while reducing energy costs, glare, and disorienting effects on urban wildlife.

Action 2.3.2: Survey residents when adding lighting to understand the area's needs. Municipal lighting could be coordinated with a private lighting installation or surrounding residents may be open to hanging cross-lights or other statement lighting.

Action 2.3.3: Create incentive program for property owners to install pedestrian-level, zero uplighting fixtures in alleys near lot lines. Make sure incentives require lighting that is dark sky compliant and ensure fixtures are properly installed.

Action 2.3.4: Install hanging lights over the alley rights-of-way in certain commercial and mixed-use districts. This is also an opportunity to get creative and incorporate ideas from the community. In Richmond's Art District, street art installations such as the various examples of "umbrella alleys" can serve as inspiration for permanent infrastructure that could provide a canopied alley with increased nighttime visibility and comfort.

Post Alley in Seattle, Washington (HDR Creme)

Goal 3: Improve mobility in and between alleys

Objective 3.1
Invest in alleys as shared streets

Action 3.1.1: Conduct and maintain a comprehensive alley inventory with periodic walk-throughs and audits. Keeping an accurate record of alleys can help determine best candidates for green alley conversion and possibilities for corridor enhancement or incorporation into adjacent trails.

Action 3.1.2: Work with communities around Richmond to designate local shared streets in alleys that demonstrate the need for green infrastructure or other speed and volume management improvements.

Action 3.1.3: Utilize simple street calming measures in alleys to discourage non-resident automobile use

Objective 3.2
Facilitate accessible travel through alleys

Action 3.2.1: Set target speeds for alleys at 5 mph. This helps ensure a safe environment for these often narrow shared spaces and remains consistent with recommendations from NACTO and AASHTO. Since environment influences behavior and driving is no exception, designing for high speed invariably invites high speeds. Cars traveling in alleys at very low speeds are more likely to avoid people and pets in the shared right of way, cause less noise, and are less likely to cause property damage.

Community alley in the UK (Daily Mail)

Action 3.2.2: Establish alley corridors with route planning and connections to existing infrastructure in mind. Green alleys serving as active transportation networks are able to serve as alternate routes in a low-stress system, complimenting on-road cycle tracks and bike lanes.

Action 3.2.3: Create a branded alley wayfinding system. This can help improve navigation and orientation while linking alley users to popular sights, neighborhoods, and commercial districts.

Action 3.2.4: Establish a quick-response task force for minor paver/surface repairs with an emphasis on maintaining original accessibility and aesthetic. Fix minor problems as they form in designated shared streets and transportation corridors.

Objective 3.3
Facilitate safe and accessible travel between alleys

Action 3.3.1: Daylight the intersection of alleys with other streets to provide a clearer sight line free of vehicles. These spaces can instead be used to strengthen the adjacent green alley and aid in wayfinding and placemaking. [Will include callout on daylighting.]

Action 3.3.2: Utilize speed management techniques such as raised crosswalks and curb extensions at alley-street intersections. Bio-planters and swales can be placed in curb extensions to provide more safety, comfort, and consistency along green alley corridors. Stormwater trees placed at extension planters at alley entrances can calm motor vehicle traffic and serve as visual gateways to green alleys.

Action 3.3.3: Place bicycle and pedestrian crossing signs (MUTCD sign W11-15) at intersections of alleys with other streets where cross traffic experiences higher speed or volume than ordinary. Since alleys usually intersect with smaller, low-volume streets, the minor delay to motor traffic should be considered a fair trade for improved safety.

Figure 8. Balmy Alley in San Francisco, California (John Wachunas)

Action 3.3.4: Use contrasting pavements (Figure 8), markings, and other directional means to provide continuation between disjointed and offset alleys. A green alley network doesn't require a completely uninterrupted straight line to remain a corridor. Alley networks can remain malleable and adapt to slight directional variations while retaining their usefulness as eco-transportation corridors— biodiverse urban passages that are built to efficiently utilize our natural resources while serving mobility needs.

Action 3.3.5: Adopt regulations that prohibit automated vehicle (AV) storage or circulation in and through alleys, providing a residential parking exception. As the use of AVs increase, the constant flow of empty vehicles on streets may increase, especially by rideshare services waiting for the next fare. Such growth in volume would have a negative impact on comfort, safety, and pavement conditions.

Goal 4: Engage in public outreach and awareness of green alleys and green stormwater infrastructure

Objective 4.1:
Improve communication channels between residents and municipal departments

Action 4.1.1: Hold a hybrid in-person/virtual community event about green alleys to provide

"Dally in the Alley" event in Detroit, Michigan (Javin Hampton-Latimore)

education and recruit green alley ambassadors (see Action 4.2.1). This study indicated that many residents are open to green alley improvements and want to see more usable alley space. Build upon interests in open streets and interventions in public space that increased during the past year by starting conversations about expanded uses for alleys.

Action 4.1.2: Create webpage dedicated to green alley information, contacts, tools, and status of projects. The webpage designed for this plan using ArcGIS Online provides an example for how to incorporate mapping, alley indexing, and public engagement.

Action 4.1.3: Optimize mobile applications for residents to report alley problems more easily. Crowdsourcing the location of stormwater and transportation challenges can offer insights on patterns and opportunities for comprehensive improvements. The RVA311 app is an example of a tool that can help people feel more invested and connected to their neighborhood. Utilize technology such as augmented reality to increase interest among mobile users and visualize possibilities in real-time.

Objective 4.2
Foster sustainable community involvement in alleys

Action 4.2.1: Create a resident alley ambassador program to put more power in the hands of communities. Activities and responsibilities could include collecting reports to submit, holding cleanups, conducting walk audits, and holding community events. Allow ambassadors to engage in certain community-led improvements and limited use of tactical urbanism.

Alley lighting audit in Seattle, Washington (Alliance for Pioneer Square)

Action 4.2.2: Develop an "adopt an alley" program to partially fund alley improvement projects. Possible patrons could include neighborhood associations, social clubs, non-profits, businesses, private schools, and individual residents.

Action 4.2.3: Create district-specific accessory dwelling unit (ADU) incentive programs as a further investment in the future of alley space. The benefit of ADUs include increasing property value, providing natural supervision by landlords, and providing an option for individuals to age in place, strengthening ties to the adjacent alley and community.

Objective 4.3
Establish clear roles and responsibilities about maintenance and repair

Action 4.3.1: Incorporate communication and education into signs and murals. Themes and displays of biophilia, neighborhood history, and civics can help inspire a sense of pride in place, especially when residents can make collective decisions about projects and design. Ecological imagery in public art can help educate alley users about issues like stormwater, climate health, and heat islands, and how alleys play a role. On wayfinding signs, contact information and public service announcements can help remind residents of green alleys, their benefits, and how they can help ensure the health of Richmond's alleys.

Action 4.3.2: Ensure residents have the tools they need to maintain comfortable and accessible alleys. Check in with surveys and direct-on street/alley engagement by a multi-disciplinary team of Richmond employees.

Could this be the future of Richmond's alleys?

Dutch Woonerf (Canin Associates)

Implementation

This plan is not meant to have a completion date. Instead, it hopes to invoke conversations about these forgotten spaces and stoke long-term involvement to make alleys into a treasured part of a neighborhood. Like alleys themselves, responsibilities throughout different interventions are complex and multi-layered.

This section also includes a list of funding sources (Table 3) intended to support implementation. Many recommendations were developed to be relatively quick actions that are intended to be consistently applied over the long-term. Responsibility for implementation is geared toward the City of Richmond in keeping with the study area of Carver and Jackson Ward, but the equivalent party for any respective municipality can be substituted.

Short Range (S): 0–2 years

Mid Range (M): 2–5 years

Long Range (L): 5+ years

Table 2. Plan Implementation Steps

Goal	Objective / Action	S	M	L	Responsibility
Goal 1: Reduce Storm-water runoff from Richmond alleys	**Objective 1.1: Increase number of green alleys**	✔	✔	✔	
	Action 1.1.1: Establish a dedicated green alley program	✔			Public Utilities, Public Works
	Action 1.1.2: Pursue funding through grants and local, state, and federal sources in transportation, stormwater, climate, equity, and health	✔	✔	✔	Public Utilities, Public Works, PDR
	Action 1.1.3: Require green alley-friendly elements or other green stormwater infrastructure in new development	✔	✔	✔	City Council, PDR
	Objective 1.2: Encourage utility-friendly vegetation along alleys	✔	✔		
	Action 1.2.1: Establish a one-page resident's guide to utility-friendly vegetation	✔			Public Utilities, Public Works
	Action 1.2.2: Work with residents and local non-profits to establish community gardens and plant trees	✔			Residents, Non-Profits, Public Utilities, Public Works
	Objective 1.3: Utilize stormwater as a resource	✔	✔	✔	
	Action 1.3.1: Require new transportation projects to integrate green stormwater infrastructure in its design	✔	✔	✔	City Council, Public Utilities, PDR
	Action 1.3.2: Set a goal of capturing a minimum of 85% of stormwater runoff with new alley construction	✔			City Council, Public Utilities, PDR
	Action 1.3.3: Introduce minimum green stormwater infrastructure in routine alley repavings of all materials	✔	✔	✔	City Council, Public Utilities, PDR
Goal 2: Increase the comfort of alley spaces	**Objective 2.1: Work toward greater biodiversity in alleys**	✔	✔	✔	
	Action 2.1.1: Create incentive programs for residents to maintain greenspace on alley edges	✔			Public Utilities, Public Works, PDR
	Action 2.1.2: Establish full-time tree steward positions within the Urban Forestry Division		✔		Public Works
	Objective 2.2: Explore sustainable waste collection practices	✔	✔		
	Action 2.2.1: Utilize submerged refuse containers in alleys with high volumes of trash		✔	✔	Public Works
	Action 2.2.2: Provide incentives, designs, and support for construction of trash can enclosures or screenings	✔			Public Works, PDR
	Action 2.2.3: Require developers and public projects to incorporate sustainable waste guidelines early in the design process	✔	✔		City Council, PDR
	Action 2.2.4: Adopt Zero Waste policies	✔			City Council
	Action 2.2.5: Initiate a plastic bag ban	✔			City Council
	Objective 2.3: Improve lighting in alleys	✔	✔	✔	
	Action 2.3.1: Require new lighting in alleys to have zero uplighting	✔			City Council, Public Utilities, PDR
	Action 2.3.2: Survey residents when adding lighting to understand the area's needs	✔	✔	✔	Public Utilities, PDR
	Action 2.3.3: Create incentive program for property owners to install pedestrian-level, zero uplighting fixtures in alleys near lot lines	✔			Residents, Public Utilities, PDR
	Action 2.3.4: Install hanging lights over the alley rights-of-way in certain commercial and mixed-use districts	✔	✔		Residents, Public Utilities
Goal 3: Improve mo-bility in and between alleys	**Objective 3.1: Invest in alleys as shared streets**	✔	✔	✔	
	Action 3.1.1: Conduct and maintain a comprehensive alley inventory with periodic walk-throughs and audits	✔	✔	✔	Public Works, Public Utilities, PDR
	Action 3.1.2: Work with communities around Richmond to designate local shared streets in alleys	✔	✔	✔	Residents, Public Works, Public Utilities, PDR

Goal	Action	S	M	L	Responsibility
Goal 3: Improve mobility in and between alleys	Action 3.1.3: Utilize simple street calming measures in alleys	✓	✓	✓	Public Works, Public Utilities, PDR
	Objective 3.2: Facilitate accessible travel through alleys	✓	✓	✓	
	Action 3.2.1: Set target speeds for alleys at 5 mph	✓			Public Works
	Action 3.2.2: Establish alley corridors with route planning and connections to existing infrastructure in mind		✓	✓	Public Works, Public Utilities, PDR
	Action 3.2.3: Create a branded alley wayfinding system		✓		Public Works, Public Utilities, PDR
	Action 3.2.4: Establish a quick-response task force for minor paver/surface repairs		✓		Public Works, Public Utilities
	Objective 3.3: Facilitate safe and accessible travel between alleys		✓	✓	
	Action 3.3.1: Daylight the intersection of alleys with other streets		✓	✓	Public Works, PDR
	Action 3.3.2: Utilize speed management techniques such as raised crosswalks and curb extensions at alley-street intersections		✓	✓	Public Works, PDR
	Action 3.3.3: Place bicycle and pedestrian crossing signs		✓		Public Works
	Action 3.3.4: Use contrasting pavements, markings, and other directional means to provide continuation		✓	✓	Public Works
Goal 4: Engage in public outreach and awareness of green alleys and green stormwater infrastructure	**Objective 4.1: Improve communication channels between residents and municipal departments such as public utilities, public works, and departments of transportation**	✓	✓		
	Action 4.1.1: Hold a hybrid in-person/virtual community event about green alleys	✓			Public Utilities, PDR
	Action 4.1.2: Create webpage dedicated to green alley information	✓			Public Utilities
	Action 4.1.3: Optimize mobile applications for residents to report alley problems more easily	✓	✓		Citizen Service and Response
	Objective 4.2: Foster sustainable community involvement in alleys	✓	✓	✓	
	Action 4.2.1: Create a resident alley ambassador program	✓			Residents, Public Works, Public Utilities
	Action 4.2.2: Develop an "adopt an alley" program	✓			Residents, Public Works, Public Utilities
	Action 4.2.3: Create district-specific accessory dwelling unit (ADU) incentive programs	✓			PDR

Goal	Action	S	M	L	Responsibility
Goal 4: Engage in public outreach and awareness of green alleys and green stormwater infrastructure	**Objective 4.3: Establish clear roles and responsibilities about maintenance and repair**	✓	✓	✓	
	Action 4.3.1: Incorporate communication and education into signs and murals	✓	✓	✓	Residents, Public Works, Public Utilities
	Action 4.3.2: Ensure residents have the tools they need	✓	✓		Residents, Public Works, Public Utilities, PDR

Table 3. Possible Funding Sources (Table constructed with data compiled by Indya Woodfolk)

Funding Source	Facilitator	Eligible Projects	Eligible Applicants
BUILD Discretionary Grants	Department of Transportation	Infrastructure Improvement	State, tribal, and local governments
Chesapeake Bay Restoration Fund	Division of Legislative Services	Environmental education and restoration projects relating to the Chesapeake Bay and its tributaries	State agencies, local governments, and tax-exempt nonprofit organizations
Chesapeake Bay Stewardship Fund: Innovative Nutrient and Sediment Reduction Grants	National Fish and Wildlife Foundation	Water Quality Improvements, Habitat Restoration/ Enhancement, Climate Resilience	Non-profit organizations, state governments, local governments, native tribes, educational institutions
Chesapeake Bay Stewardship Fund: Small Watershed Grants	National Fish and Wildlife Foundation	Water Quality Improvements, Habitat Restoration/ Enhancement	Non-profit organizations, state governments, local governments, tribal governments, educational institutions, for-profit entities
Choice Neighborhoods Implementation Grants	Department of Housing and Urban Development	Neighborhood Redevelopment	PHAs, local governments, tribal governments, non-profit organizations

Funding Source	Facilitator	Eligible Projects	Eligible Applicants
Civic Innovation Challenge	National Science Foundation	Community Mobility, Resilience to Natural Disasters	State, municipal, or tribal government officials, non-profits representative, community organizers
Clean Water Act Section 319 Grant	Virginia Department of Environmental Quality	Water Quality Improvements, Stormwater Management	Local governments, higher education institutions, planning district commissions, regional commissions, non-profit environmental organization
Clean Water Revolving Loan Fund	Virginia Department of Environmental Quality	Green Stormwater Infrastructure, Water Quality Improvements, Land Acquisition, Conservation Easement, Natural and Nature Based Features	Local governments, inter-municipal, interstate, or state agency
Climate Adaptation Fund	Wildlife Conservation Society	Climate Resilience, Habitat Restoration/Enhancement	Non-profit conservation organizations
Climate Change, Health, & Equity Initiative	Kresge Foundation	Climate Resilience, Environmental Justice, Community Engagements	Non-profit organizations with climate, health, and/or equity focused goals
Coastal and Marine Habitat Restoration Grants	National Oceanic and Atmospheric Administration	Habitat Restoration/ Enhancement	Institutions of higher education, non-profits, for profit organizations, state, tribal, and local governments
Coastal Resilience Fund	National Fish and Wildlife Foundation	Habitat Restoration/ Enhancement, Natural and Nature Based Features, Resilient Infrastructure	Non-profits, state and territorial government agencies, local governments, tribal governments, educational institutions, commercial organizations

Funding Source	Facilitator	Eligible Projects	Eligible Applicants
Community Development Block Grants (CDBG) - Community Improvements Grants	Virginia Department of Housing and Community Development	CDBG Community Improvement Grants are competitive grants, which aid eligible localities in implementing projects that will most directly impact the greatest needs of the community. There are five primary project types under this funding source: comprehensive community development, business district revitalization, housing, community facility (infrastructure) and community service facility.	Local governments, can contract with PDCs or others to undertake project activities
Conservation Innovation Grants	United States Department of Agriculture	Habitat Restoration/ Enhancement	State, local, or tribal governments, non-governmental organizations, and individuals
Coordination and Collaboration in the Resilience Ecosystem	Climate Resilience Fund	Climate Resilience, Community Engagement	Local governments, non-profit organizations
Emergency Coastal Resilience Fund	National Fish and Wildlife Foundation	Emergency Management, Natural and Nature Based Features, Habitat Restoration/ Enhancement	State, tribal, and local governments, non-government organizations, and educational institutions
Five Star and Urban Waters Restoration Program	National Fish and Wildlife Foundation	Habitat Restoration/ Enhancement, Community Engagement	Non-profit organizations, state governments, tribal governments, educational institutions
Green Streets, Green Towns, Green Jobs	Chesapeake Bay Trust	Green Infrastructure, Stormwater Managements	Local governments, non-profit organizations

Funding Source	Facilitator	Eligible Projects	Eligible Applicants
HMA Pre- Disaster Mitigation Grant	Virginia Department of Emergency Management	Stormwater Management, Flood Mitigation, Resilient Infrastructure, Drainage Improvements, Habitat Restoration/Enhancement, Structural Acquisition, Non-Structural Floodproofing	State and tribal governments
James River Water Quality Improvement Program	Virginia Environmental Endowment	Water Quality Improvements, Habitat Restoration/ Enhancement, Natural and Nature Based Features	Non-profit, tax-exempt charitable organizations and institutions, and governmental agencies
Land Acquisition Loan Program	United States Department of Agriculture	Water, sewer, and waste related construction and improvement	State, tribal, and local governments
National Coastal Wetlands Conservation Grant Program	United States Fish and Wildlife Service	Habitat Restoration/ Enhancement, Natural and Nature Based Features	Federal, state, tribal, and local governments, non-profit organizations, private landowners
Resilient Communities Program	National Fish and Wildlife Foundation	Habitat Restoration/Enhancement, Natural and Nature Based Features	Non-profits, local governments, tribal governments
Stormwater Local Assistance Fund (SLAF)	Virginia Department of Environmental Quality	Stormwater Management, Habitat Restoration/Enhancement	Local governments
Transportation Alternatives Program (TAP)	Virginia Department of Transportation	Small scale, non-traditional transportation projects. TA, SRTS, and highway to boulevard activities	Local or regional governmental entity with responsibility for oversight of transportation or recreational trails
Urban & Community Forestry Program	Virginia Department of Forestry/ United States Department of Agriculture Forest Service	Urban and community forestry projects	State agencies, local and regional governments, tribal governments, non-profit organizations, neighborhood groups, civic groups, public education institutions
VEE Virginia Program	Virginia Environmental Endowment	Water Quality Improvements, Habitat Restoration/Enhancement, Climate Resilience	Non-profit, tax-exempt charitable organizations and institutions, and governmental agencies

Funding Source	Facilitator	Eligible Projects	Eligible Applicants
Virginia Conservation Assistance Program (VCAP)	Virginia Association of Soil and Water Conservation Districts	Property owners installing eligible Best Management Practices (BMPs)	Public, private, non-profits, and commercial landowners
Water & Waste Disposal Loan & Grant Program	United States Department of Agriculture	Water, sewer, and waste related construction and improvement	State and local governments, private non-profit, federally-recognized tribes

Definitions

*Biofiltration**

The process of removing particulate matter and other pollutants by filtering stormwater runoff using biological material to detain and degrade pollutants. Biofiltration is a technique used in stormwater management that uses living plant material to process stormwater runoff.

Biophilia

A term coined by E. O. Wilson to describe a human's innate connection with nature and other forms of life.

*Bioretention**

The process of capturing stormwater runoff, absorbing and retaining pollutants, and then infiltrating, transpiring, or evaporating the water.

*Combined sewer overflow**

An event that occurs in combined sewer systems when the volume of stormwater and wastewater exceeds the capacity of the sewer system or treatment plant, often due to a storm event. When this occurs, untreated wastewater and stormwater discharge directly into receiving water bodies, such as rivers and lakes.

Eco-transportation corridor

Walking, biking, and transit routes that emphasises biodiversity and green stormwater infrastructure in an effort to create sustainable transportation systems.

Embedded Planning†

A planning praxis that situates planners on the ground in the community to understand people's needs, build trust and authentic relationships, increase participation for marginalized communities, participate in daily community life, and to advance equity.

*Green Alley***

An alley design that uses sustainable materials, pervious pavements, and effective drainage to create an inviting public space for people to walk, play, and interact.

*Green stormwater infrastructure**

Techniques used to collect, filter, and manage stormwater runoff from streets, sidewalks, parking lots and other impervious surfaces, and direct the runoff to engineered facilities that use natural processes to treat and manage the water. Examples of green stormwater infrastructure include bioretention facilities, stormwater trees, and permeable pavements.

*Impervious surface**

A non-vegetated surface area which prevents the entry of water into the soil, causing water to run off the surface in greater quantities or at an increased rate of flow than would occur under natural conditions prior to development.

*Permeable pavement**

Pervious or porous paving material intended to allow passage of water through the pavement section.

Resiliency‡

The ability to identify risks and build the capacity to maintain or rapidly regain functionality and vitality in the face of chronic stressors or severe disturbances.

*Stormwater tree**

A tree planted in a tree well or tree pit, designed to maximize stormwater retention.

**Definition sourced from NACTO Urban Street Stormwater Guide*

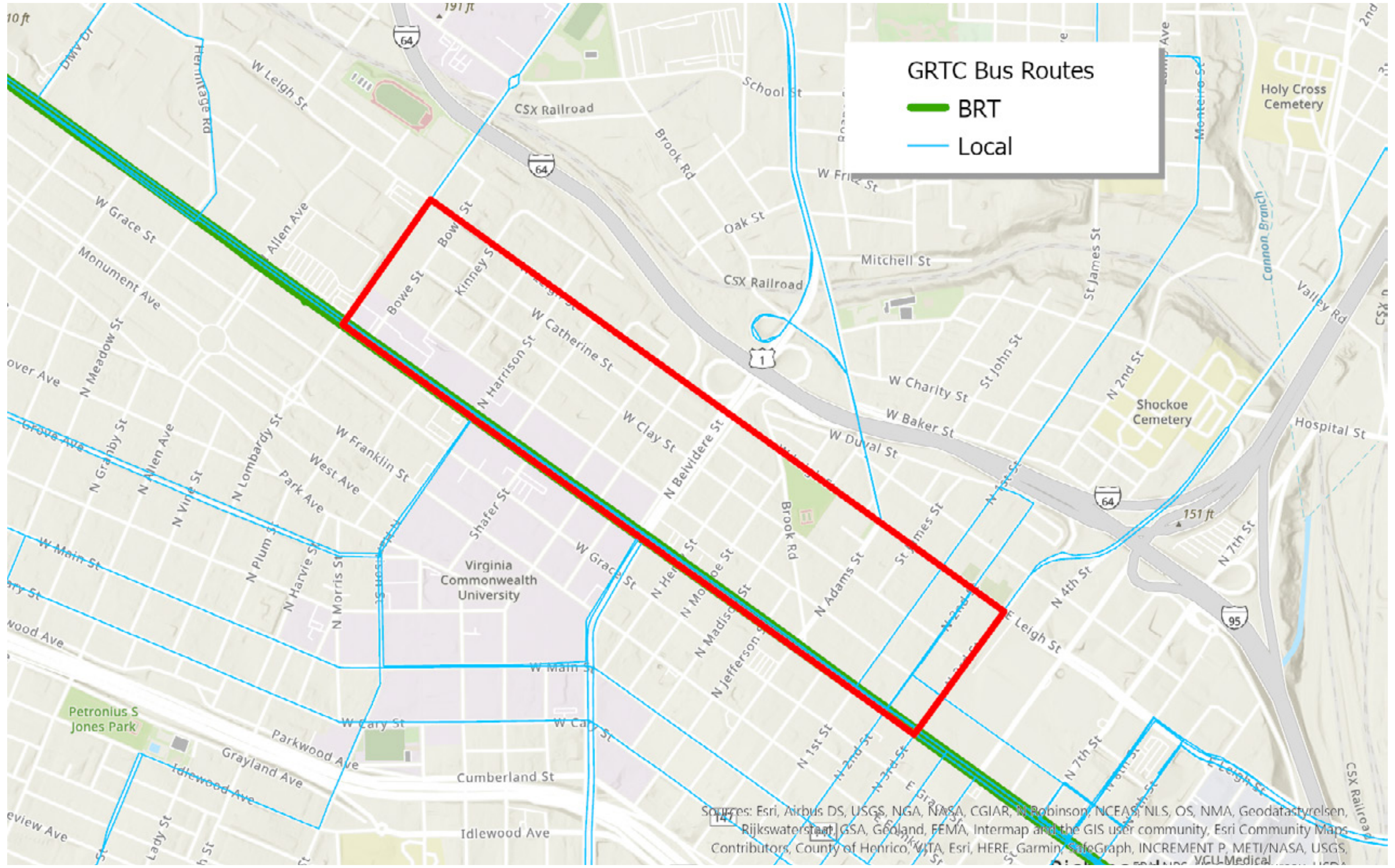
***Definition sourced from NACTO Urban Street Design Guide*

†Definition sourced from Bell, 2021

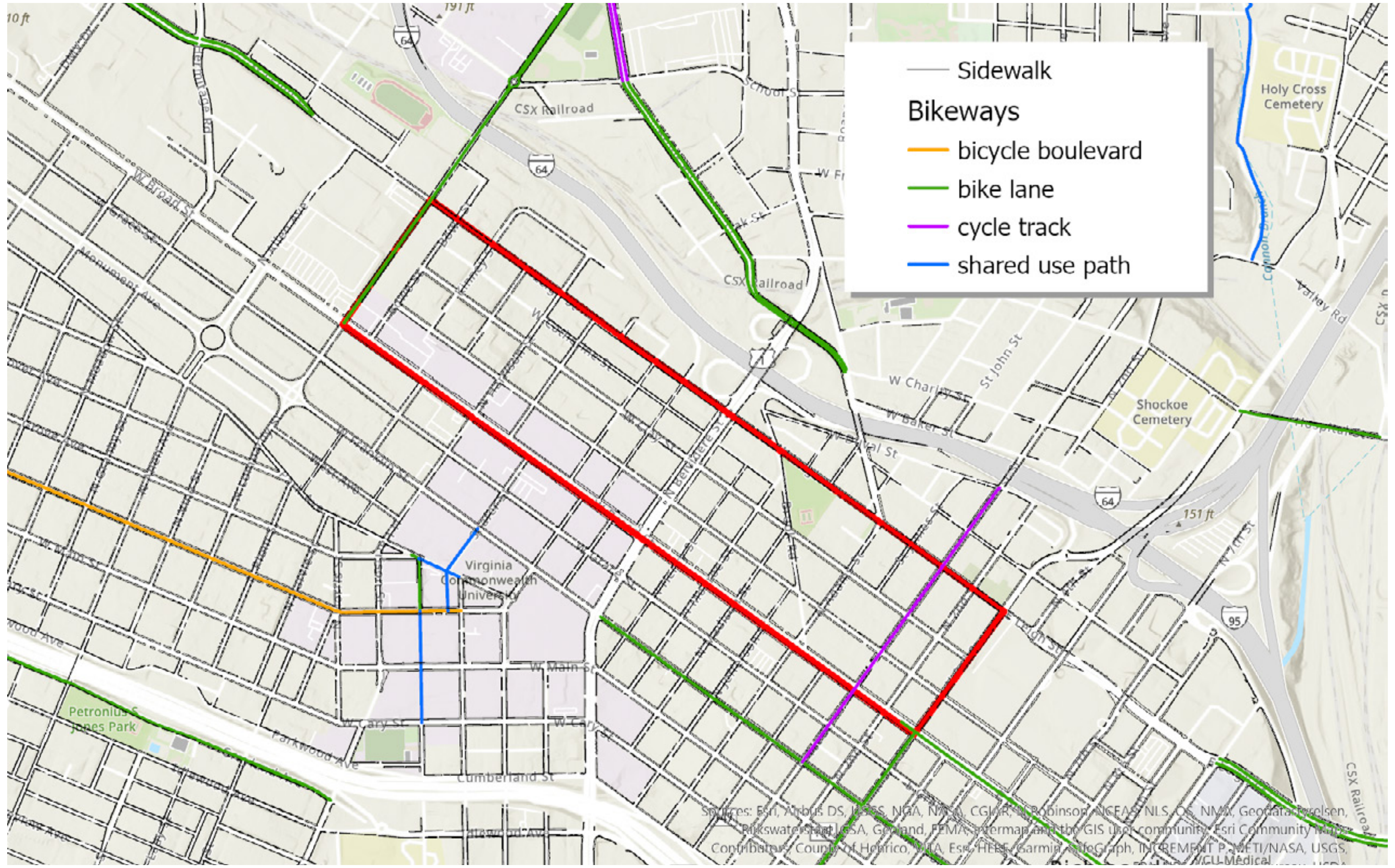
‡Definition sourced from Resilient Virginia

Additional Maps

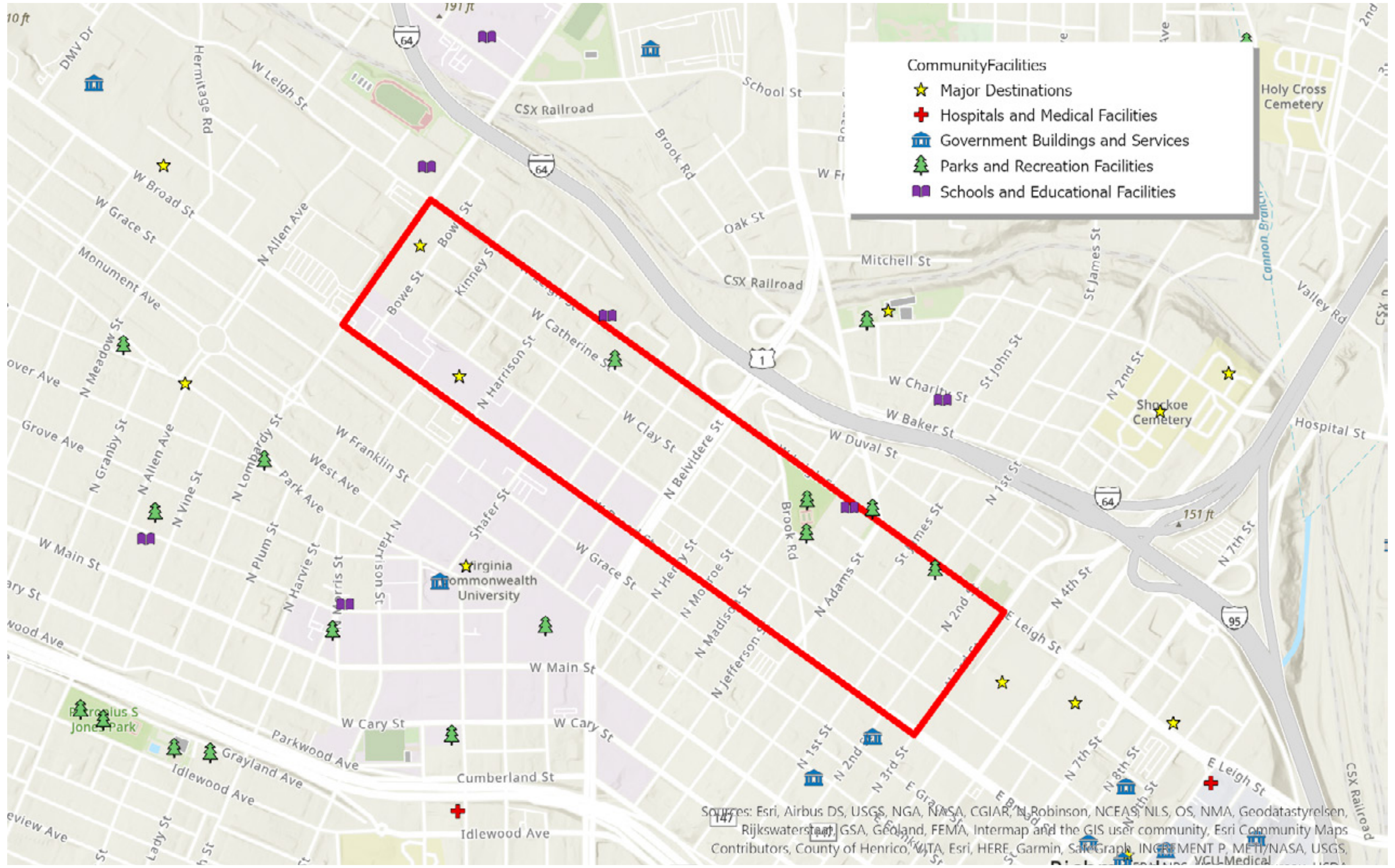
GRTC Bus Routes (PlanRVA)



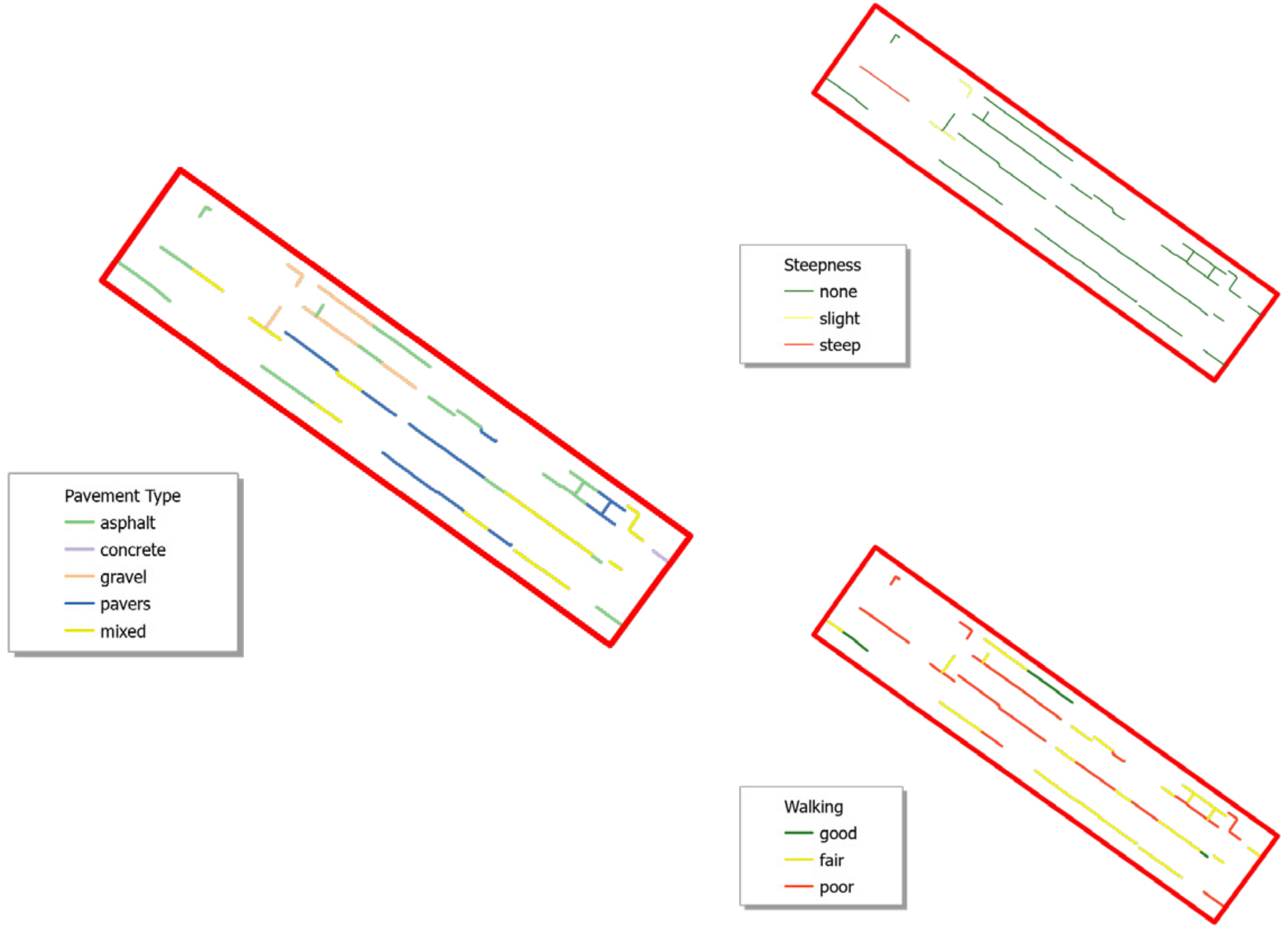
Walking and Biking Infrastructure (PlanRVA)



Community Facilities (PlanRVA)



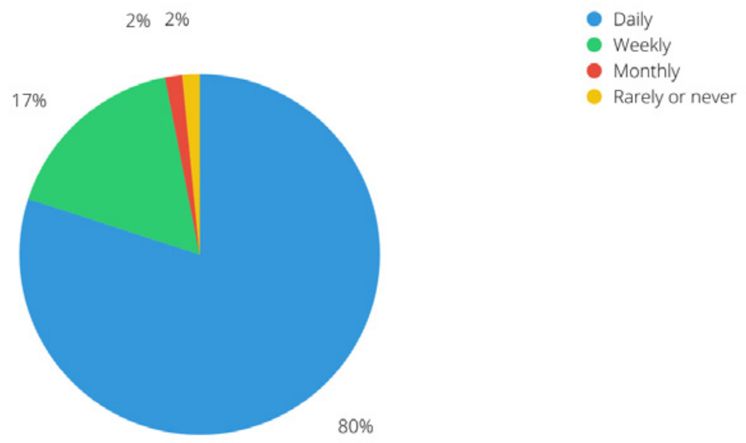
Alley Conditions (data collected during research phase)



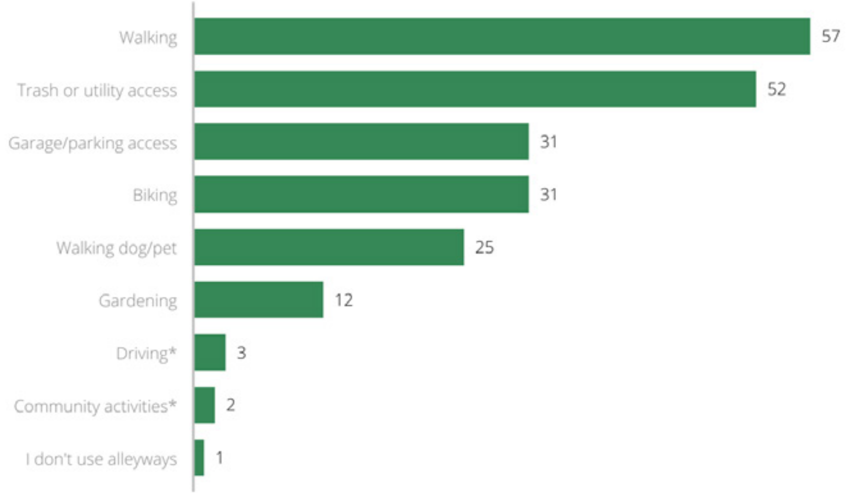
APPENDIX

Survey Results

Question #1: How often do you use alleyways in your neighborhood or community?

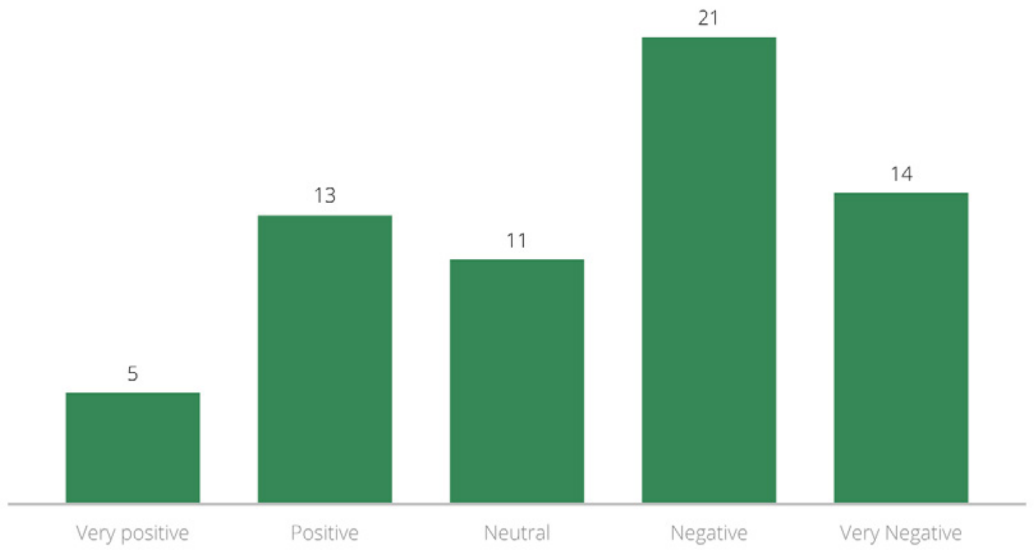


Question #2: How do you currently use alleyways? Please select all that apply.

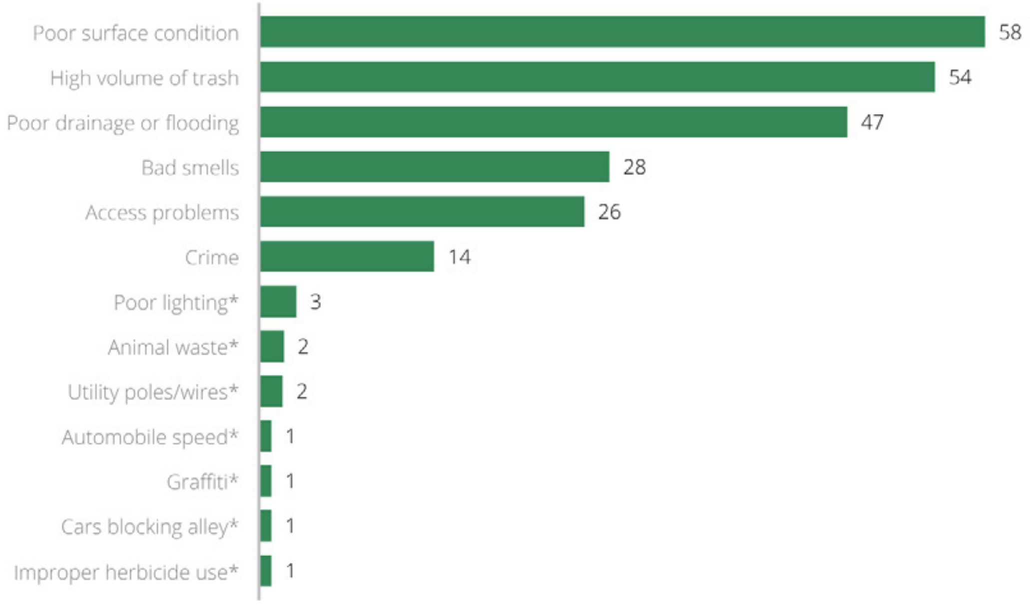


* indicates filled-in answer

Question #3: How would you describe your general opinion of alleyways?



Question #4: What issues do you see with alleys in your community? Please select all that apply.



* indicates filled-in answer

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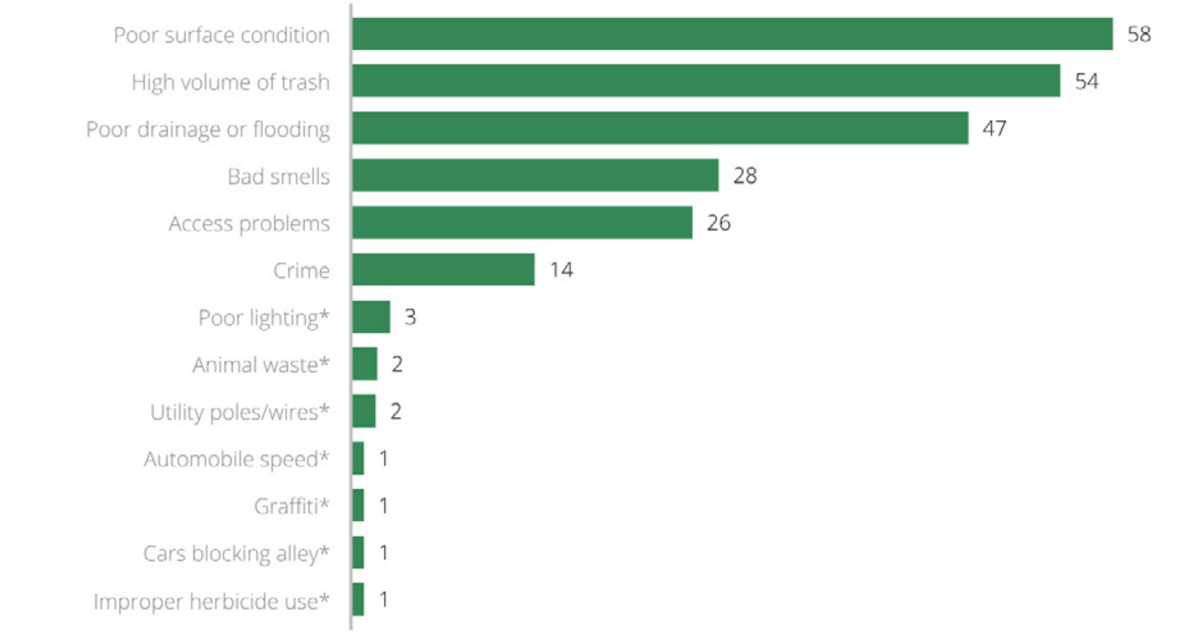
Question #5: What issues do you see with alleys in your community? Please select all that apply.



* indicates filled-in answer

Question #6: Please Share any other thoughts you have about alleyways. For example, how would you like to use them? How would you like them to look?

1. More taken care of and not seeming so neglected. The installation of either plants and/or art would certainly make the space more appealing.
2. They should be bricked or paved../drainage issues need to be addressed in carver/esp the alley between Marshall and clay in the 800 block.
3. Its disgusting and attracts homeless and drug activity...
4. Its totally neglected and full of overgrown weeds and trash
5. More grass, flowers and shrubbery; more lighting; less trash; like small parks
6. Would like to see less haphazard supercan location
7. Potholes have damaged my car here and in other neighborhoods so I no longer drive in them
8. Please for the love of god institute a compulsory recycling program run and managed by the city. Can we please get some litter PSA's?
9. I would like to walk down the alleyways in my neighborhood and enjoy them - not having to back track because they are so muddy, smell bad (especially in the summer). I'd like to be able to drive down my alley when I need to without navigating all of the deep holes/ruts.
10. They could be great alternate walking or biking routes if you want to get off the street or sidewalk. Is there a way to encourage mini commercial or ADU development in certain alleys?
11. I would like to be able to walk or ride my bike through them. I so
12. I'll also like to be able to drive through when needed. I would like them to be consistent throughout the city. There are places in the city that the alley is nicer than some of the streets.
13. I do not use a car but the alley is full of them and there are no designated places for them. I'd like to see less cars by putting in signs that designate the maximum parked number of cars that can reasonably fit and where they can park.
14. accessible
15. I would like for the trash company to collect the old/ abandoned /broken trash cans that are clogging our alleys. I would like to see the alley way cleared of debris as well as drainage issues rectified.
16. I would like for the alley way to be paved
17. We live in the 1300 block of Catherine Street. It is in deplorable condition. Not sure if it is considered an alley or a Street as the name implies. There are at least three different surface types. Its riddled with pot holes . Danger to walk or drive on it.
18. Jackson Ward has a serious problem with trash littering alleys, lots of broken glass, I have seen rats on more than a few occasions. Walnut Alley LLC has told residents of our block that they manage our lot and alleys in the area and they do absolutely nothing to keep them clean they just move trash cans to the curb and mow the grass in the summer once every two weeks but that's all.
19. I'd like to convert alleyways into green community spaces... like a network of parks - giving dwellers places to explore and express creativity, to play, to sit and meditate, to plant herbs, fruits, and vegetables.

    It could be an open opportunity to add jobs to manage the garden network, and we could provide qr codes on-location for neighbors to invest.

    It would be amazing to provide public electric outlets for anyone to have access to plug smartphones

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and charge up.
I'd like to switch from inner - city properties having individual trash cans, to each ally having a large group trash compressor... eliminating bad smells, unsightly, overflowing trash cans (which have been stolen in the past), and even provide an opportunity space for community advertising spend. Please contact me at ______________________ to discuss further.

I am happy to lend my mind to strategy for the benefit of the community in re-designing alleyways to become spaces full of light and love.

Thank you for your attention to these spaces. Every space deserves to be taken care of, every space deserves fung shui.

20. The alley way between goshen and hitchcock(the first one if you turn off of W Leigh st.) has many potholes that fill with water and pose hazards.
21. Less cluttered
22. We have an entire design proposal for our alley that we are preparing for Venture Richmond to attempt to find funding. It is so great to hear others are as interested in improving them as I am. Please contact me ____________________________.
23. I love finding murals and art in alleys. I think that it would be good to take advantage of the privacy of alleys to implement more artistic projects. I use alleys for walking my dogs and they are ALWAYS full of trash and a lot of broken glass :/
24. Better designated trash zones, (like in Japan) better lighting, cleaning up of extraneous and broken cables, purposeful planting so that it's not filled with aggressive weeds.
25. I'm a jackson Ward resident and have recently started parking on the back of my property off the alley as there are more cars for people living in my block than can be parked on Clay Street. The Permitted Parking Program for Jackson Ward which includes most of Clay Streeet is not beneficial to the residents on the west end of the street. The alleys are 'supposedly' considered streets in the City of Richmond, but their condition is worse than Clay Street runing in front of my 1885 house. Clay Street condition is terrible. for cars and especially cyclists.

    The lighting in the alleys is very poor which does not help curtail the breaking in to vehicles parked on the back of the property and vandalism where there is not enough light to prevent it.

    I know the DPU is stretched thin to cover the existing trash collections scheduled one a week, but they indicated a year ago that the weekly truks would be talking some of the larger items that had required the boom truck to remove them. The items like chairs small dressers, bookcases, and tables are not being picked up and clutter the alleys. People seem to feel these are OK places to place a trash bag. Our homeless, wild animals and domestic cats and dogs tear open the bags and the contents goes all over the alley. On trash days things that fall out of the trash cans as they are be dumped into the truck are not picked up but left to blow around the alley and into yards and under bushes.

    The regulation that the trash cans can only be at the alley's edge from 7PM the day before the schedule pickup until 7PM the day of the pickup is not enforced. Trash cans remain at the edge and sometimes even in the edge of the roadway which make navigation difficult.
26. I would love them to be greener with more plant life.
27. I think it's really important to make EVERY roadway, street, or alley accessible to all people, regardless of physical ability.
28. it is very difficult to drive over the very large potholes and trash is always over flowing with furniture and bags.
29. Clean , organized, more trash and recycling bins
30. I would like them to be crime-free, furniture-free, and pothole-free. I have seen everything from dead bodies, to people using and selling drugs, to furniture and trash all over the alleys in the neighborhoods I frequent.
31. Basically just trying to waste less space. More plants would be fantastic. More art, more public spaces.
32. Before we can begin to beautify the alleyways, there needs to be a better plan for monitoring and maintenance; especially if the trash and recycle trucks must come through.
33. have better lighting
34. Public rubbish bins that are thought fully designed and regularly serviced by city funds. Street cleaning done regularly, weed control, drainage improvements
35. regarding my add-on: more green spaces and trash bins can help reduce dog waste in/near alleys!
36. Car free shopping districts, markets.
37. I appreciate their handsome granite construction and careful engineering. I very much prefer their maintenance in this original form instead of repair and/or replacement with asphalt, concrete and gravel.
38. Greater police presence would be helpful particularly bicycle and mounted police.

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39. VCU should give every freshman or new student a condition that says the trash goes "into" the trash can, and that they should take their pets with them when they leave. They could also stand to explain what recycling is and why we use it.

40. Owner-occupants and responsible renters should be given acknowledgement for good efforts.

41. I love the idea of green space in alleys , especially as many downtown buildings have been repurposed and are actually getting use. More thought needs to go into city trash storage and collection for residential and businesses to make sure there's capacity for the increased occupancy. I believe its been overlooked and is a disservice to those who are occupying these areas. There are many buildings in the city that are not being used and are boarded up. These areas need to be redeveloped prior to any discussion on alleys in order to get interest and money for a project like this.

42. I would like to see potholes filled, cobblestones repaired, and inclines paved a little flatter. I have fallen and sprained my ankle on these uneven alleys AND SIDEWALKS. Feels like we are living in a post-apocalyptic society with a crumbling infrastructure. Thank you!

43. It would be nice to have wider access to our alley for parking in the rear.

44. I love seeing things living in alleys, they can feel so refreshing and peaceful with just a little bit of growth instead of plain everything

45. I love Richmond's alleyways. I use them ALL THE TIME and I would love if they all started to look more like some of the alleyways in the Fan district (I'm in Jackson Ward). I especially love the alleyway that runs from Strawberry Street to North Stafford Avenue. If we could get our alleys looking even remotely similar to that, I would be ecstatic.

46. I would like to be able to move through alleys on foot, bike or in a car. Greener, cleaner alleys would be an improvement.

47. Would really appreciate apartment building companies were held accountable for the trash their tenants throw in the alley. The alley behind my house is always filled with trash from tenants moving out, or people using the dumpster for their own private use. If companies were fined for the amount of trash thrown in there they would perhaps be more diligent about communicating about this issue with their tenants.

48. The alley behind my house (and others I have seen in Richmond) are always riddled with pot holes or massive gaps in cobble stone which cause a lot of car accidents. Furthermore, people will park in the alleyway blocking trash trucks and other emergency/civil service vehicles. We need to post "tow away" warnings in areas that suffer from chronic blocking. Perhaps the trash folks could carry "first notice" paperwork with them and leave whenever necessary.

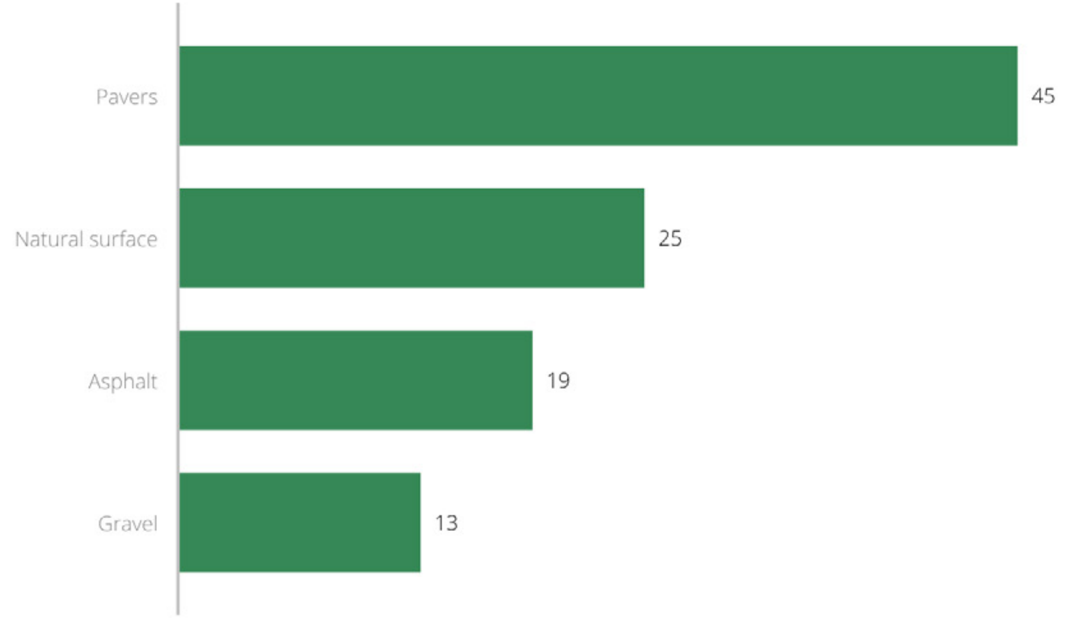
49. Greenery would be positive, safe use for homeless folks and underprivileged people is the main priority. Some alleyways foot use only. Rent caps for properties connected or adjacent to alleyways. No police use of alleyways.

50. 1st & foremost the alleyways in Jackson Ward where I live need to be cleared of trash on a regular basis. Trash is strewn everywhere. Constant battle to keep it clean. Most trash is people who eat lunch in cars throw trash out of their car windows. Masks are an issue.Immediate solution- add more trash cans - too few currently. Another issue is that people will drop off their household trash into trash cans, thereby filling the bin & offering fewer options for people until the bins are emptied.
Spray painting of walls is also an issue in the Jackson Ward alleys.

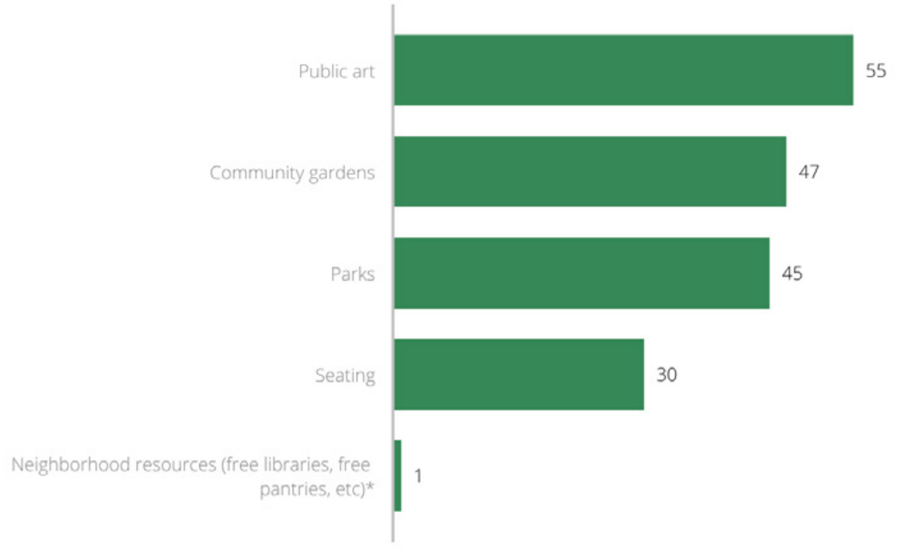
51. i would like to feel more comfortable using them for everyday travel I often feel as if i am trespassing when i enter an alley way and i do not like that feeling. I think alleys should aim to be more welcoming and suitable for passers bye and not just people that walk the streets frequently.

52. As pedestrian/bike shortcuts and gardening areas. Paved better, especially in Carver and Jackson Ward.

Question #7: Which alleyway surface options do you prefer? Please select all that apply.

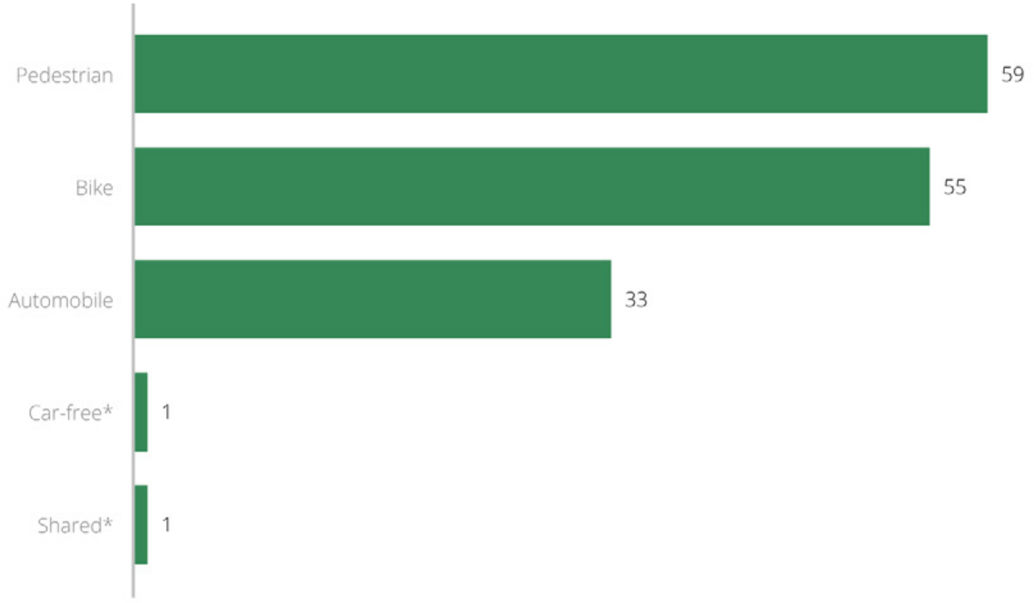


Question #8: Which alleyway amenity options do you prefer? Please select all that apply.



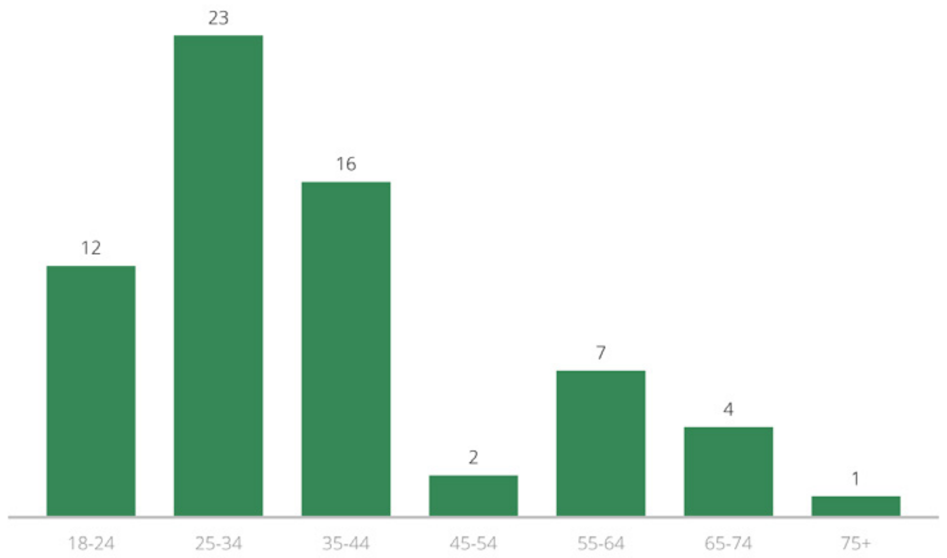
* indicates filled-in answer

Question #9: What type of alleyway access do you prefer? Please select all that apply.

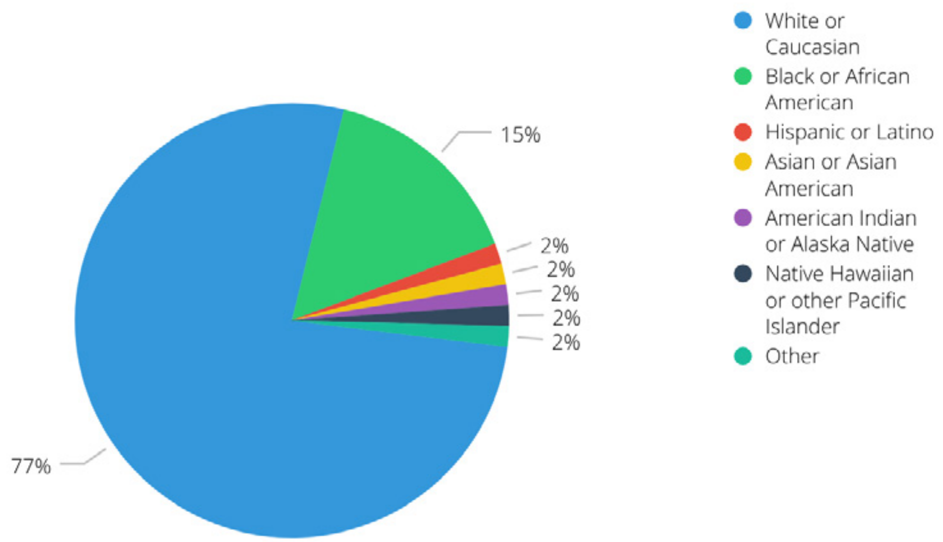


* indicates filled-in answer

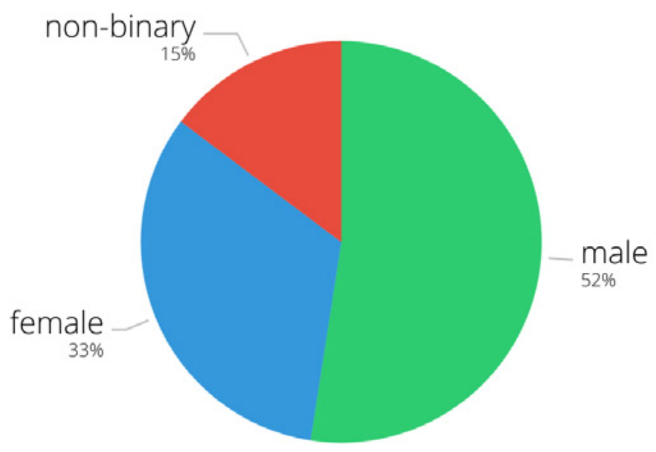
Question #10: What is your age?



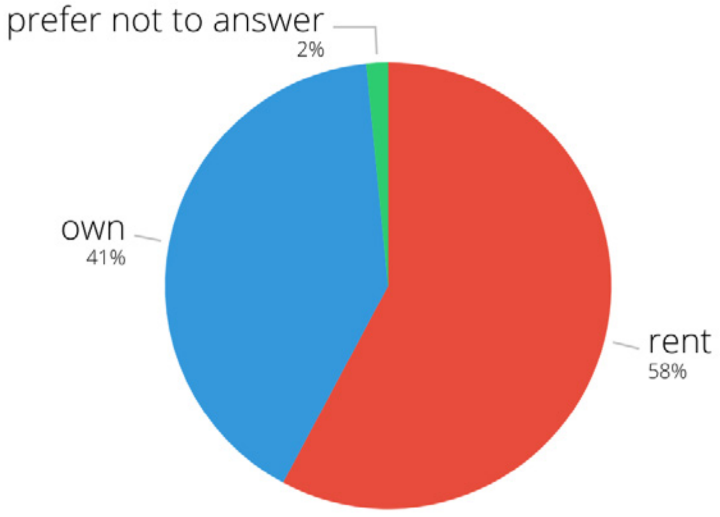
Question #11: What is your race? Please select all that apply.



Question #12: What is your gender?



Question #13: Do you rent or own your home?



Question #14: What is your zip code?

*indicates zip code in study area

References

Adaptation Clearinghouse. "Seattle Public Utilities - Street Edge Alternatives." Accessed August 18, 2020. https://www.adaptationclearinghouse.org/resources/seattle-public-utilities-street-edge-alternatives.html.

Arvidson, Adam Regn. "A Greener City Grid." Landscape Architecture 102, no. 6 (2012): 74–80.

Arvidson "Streets Behind the Scenes." Landscape Architecture 104, no. 2 (2014): 32–34.

Arvidson. "Unseen Green." Landscape Architecture 98, no. 9 (2008): 88–98.

Beatley, Timothy. Biophilic Cities: Integrating Nature into Urban Design and Planning. 2nd None ed. Edition. Washington, DC: Island Press, 2010.

Beatleu. "Sustainability in Planning: The Arc and Trajectory of a Movement, and New Directions for the Twenty-First-Century City." In Planning Ideas That Matter: Livability, Territoriality, Governance, and Reflective Practice, edited by Lawrence J. Vale and Christina D. Rosan. Cambridge, Mass.: The MIT Press, 2012.

Beatley, Timothy, and Peter Newman. "Biophilic Cities Are Sustainable, Resilient Cities." Sustainability 5, no. 8 (August 2013): 3328–45. https://doi.org/10.3390/su5083328.

Berg, Nate. "From Utility to Amenity: Greening the Alleys of Los Angeles." Planetizen (blog), January 22, 2009. https://www.planetizen.com/node/37038.

CCD, and UDFCD. "Ultra-Urban Green Infrastructure Guidelines." City and County of Denver and Urban Drainage and Flood Control District, 2016, 110.

CDOT. "The Chicago Green Alley Handbook: An Action Guide to Create a Greener, Environmentally Sustainable Chicago," 2010, 24.

Charleston Insider. "9 Secret Alleyways in Charleston." Explore Charleston Blog (blog), October 14, 2016. https://www.charlestoncvb.com/blog/secret-alleyways.

City of Chicago. "Street and Site Plan Design Standards," April 2007. https://nacto.org/docs/usdg/street_and_site_plan_design_standards_chicago.pdf.

City of Dubuque. "Green Alley Reconstruction." City of Dubuque, Iowa. Accessed August 31, 2020. https://www.cityofdubuque.org/1818/Green-Alley-Reconstruction.

Commonwealth of Virginia. Code of Virginia § 46.2-100. Definitions. Accessed November 2, 2020. https://law.lis.virginia.gov/vacode/title46.2/chapter8/section46.2-100/.

———. Electric personal assistive mobility devices, electrically powered toy vehicles, electric power-assisted bicycles, and motorized skateboards or scooters, § 46.2-908.1 Code of Virginia § (2020). https://law.lis.virginia.gov/vacode/title46.2/chapter8/section46.2-908.1/.

Cramer, Gary W. "Light at the Ends of the Alley." Landscape Architecture 95, no. 6 (2005): 48–56.

Dewey, John. "Creative Democracy: The Task Before Us." Southern Illinois University Press, 1939. https://chipbruce.files.wordpress.com/2008/11/dewey_creative_dem.pdf.

District Department of Transportation. "Green Alley Projects." Washington, DC. Accessed August 18, 2020. https://ddot.dc.gov/GreenAlleys.

Drucker, Jesse, and Eric Lipton. "How a Trump Tax Break to Help Poor Communities Became a Windfall for the Rich - The New York Times." New York Times. 2020. https://www.nytimes.com/2019/08/31/business/tax-opportunity-zones.html.

Duncan, Chandler, and Michael Brown. "Right-Sizing Transportation Investments." American Planning Association, September 2020. https://www.planning.org/planning/2020/aug/right-sizing-transportation-investments/.

Fainstein, Susan S. The Just City. 1st Edition Kindle. Ithaca London: Cornell University Press, 2010.

Fialko, Mary, and Jennifer Hampton. "Activating Alleys for a Lively City: Seattle Integrated Alley Handbook." UW Green Futures Lab, Scan Design Foundation, & Gehl Architects, 2011. https://nacto.org/docs/usdg/activating_alleys_for_a_lively_city_fialko.pdf.

Foster, Josh, Ashley Lowe, and Steve Winkelman. "The Value of Green Infrastructure for Urban Climate Adaptation." Center for Green Air Policy, 2011.

Freehill-Maye, Lynn. "To Battle Floods, Cities Revive Their Long-Forgotten Alleyways." JSTOR Daily, September 11, 2018. https://daily.jstor.org/to-battle-floods-cities-revive-their-long-forgotten-alleyways/.

GDCI. "Case Study: Laneways of Melbourne, Australia." Global Designing Cities Initiative, 2016. https://globaldesigningcities.org/publication/global-street-design-guide/streets/pedestrian-priority-spaces/laneways-and-alleys/case-study-laneways-of-melbourne-australia/.

———. "Global Street Design Guide." Global Designing Cities Initiative, 2016.

Gehl, Jan, and Birgitte Svarre. How to Study Public Life. Illustrated edition. Washington: Island Press, 2013.

Gough, Meghan Z. "Reconciling Livability and Sustainability: Conceptual and Practical Implications for Planning," 2015. https://www.huduser.gov/portal/sites/default/files/pdf/2015_VCU_Gough_Journal-of-Planning-Education-and-Research.pdf.

Handy, Susan. "Active Transportation in an Era of Sharing, Electrification and Automation." Policy Brief. UC Davis, 2017.

Horst, Megan, Nathan McClintock, and Lesli Hoey. "The Intersection of Planning, Urban Agriculture, and Food Justice: A Review of the Literature." Journal of the American Planning Association 83, no. 3 (July 3, 2017): 277–95. https://doi.org/10.1080/01944363.2017.1322914.

Imai, Heide. "The Liminal Nature of Alleyways: Understanding the Alleyway Roji as a 'Boundary' between Past and Present." Cities 34 (October 2013): 58–66. https://doi.org/10.1016/j.cities.2012.01.008.

Jacobs, Jane. The Death and Life of Great American Cities. Reissue Edition. Vintage, 2016.

Jennings, Viniece, April Baptiste, Na'Taki Osborne Jelks, and Renée Skeete. "Urban Green Space and the Pursuit of Health Equity in Parts of the United States." International Journal of Environmental Research and Public Health 14, no. 11 (November 22, 2017): 1432. https://doi.org/10.3390/ijerph14111432.

Klook. "10 Melbourne Laneways You Can Get Lost In." Klook (blog), March 14, 2020. https://www.klook.com/blog/melbourne-laneways-australia/.

Lake, Robert W. "On Poetry, Pragmatism and the Urban Possibility of Creative Democracy." Urban Geography 38, no. 4 (April 21, 2017): 479–94. https://doi.org/10.1080/02723638.2016.1272195.

Lyles, W., S. S. White, and Brooke D. Lavelle. "The Prospect of Compassionate Planning," 2018. https://doi.org/10.1177/0885412217735525.

Martin, John. "The Other Side of COVID-19: A Futurist's View." Webinar presented at the VAPDC Summer Series Program, Online, July 9, 2020.

Martin, Michael. "Back-Alley as Community Landscape." Landscape Journal 15, no. 2 (1996): 138–53.

Martin, Michael David. "Replacing Alleys." Landscape Journal 21, no. 1 (2002): 123–33.

McEnaney, Liz. "Green Alleys: Servicing the Future." Build a Better Burb (blog), July 8, 2013. http://buildabetterburb.org/green-alleys-servicing-the-future/.

Mitchell, Don. "Doing Antisocial Things." In Mean Streets, 47:145–56. Homelessness, Public Space, and the Limits of Capital. University of Georgia Press, 2020. https://doi.org/10.2307/j.ctvqmp379.11.

Mueller, Elizabeth J., and Sarah Dooling. "Sustainability and Vulnerability: Integrating Equity into Plans for

Central City Redevelopment.” Journal of Urbanism: International Research on Placemaking and Urban Sustainability 4, no. 3 (November 2011): 201–22. https://doi.org/10.1080/17549175.2011.633346.

Murphy, Frank J. “City of Baltimore Department of Transportation,” 2015, 6.

NACTO. “Green Alley,” July 11, 2013. https://nacto.org/publication/urban-street-design-guide/streets/green-alley/.

NATCO. Urban Bikeway Design Guide. Second edition. Washington Covelo London: Island Press, 2014.

———. Urban Street Design Guide. 3rd None ed. edition. Washington: Island Press, 2013.

———. Urban Street Stormwater Guide. 1st edition. Washington, DC: Island Press, 2017.

Newell, Joshua P., Mona Seymour, Thomas Yee, Jennifer Renteria, Travis Longcore, Jennifer R. Wolch, and Anne Shishkovsky. “Green Alley Programs: Planning for a Sustainable Urban Infrastructure?” Cities 31 (April 1, 2013): 144–55. https://doi.org/10.1016/j.cities.2012.07.004.

Pacheco Bell, Jonathan. “Internalizing Equity: The Need for Embedded Planning.” April 9, 2021. https://www.youtube.com/watch?v=7Y1vPHXHl_Q.

———. “We Cannot Plan from Our Desks.” American Planning Association, October 2018. https://www.planning.org/publications/planningmagarticle/9159433/.

People for Bikes. “Virginia’s E-Bike Law.” Accessed November 2, 2020. https://wsd-pfb-sparkinfluence.s3.amazonaws.com/uploads/2020/03/E-Bike-Law-Handouts_VA_2020.pdf.

Perec, Georges. An Attempt at Exhausting a Place in Paris. Translated by Marc Lowenthal. Reprint edition. Cambridge, MA : New York: Wakefield Press, 1975.

———. Species of Spaces and Other Pieces. Edited by John Sturrock. New Ed edition. London: Penguin Classics, 1974.

PlanRVA. “Transportation Planning Organization,” 2020. https://planrva.org/transportation/.

Plazier, Paul A., Gerd Weitkamp, and Agnes E. van den Berg. “‘Cycling Was Never so Easy!’ An Analysis of e-Bike Commuters’ Motives, Travel Behaviour and Experiences Using GPS-Tracking and Interviews.” Journal of Transport Geography 65 (December 1, 2017): 25–34. https://doi.org/10.1016/j.jtrangeo.2017.09.017

Plenge, Rick, Greg Adelberg, Artie Bonney, and Rosie Jaswal. “Corridors in the COVID-19 Era: Complete Streets Approaches to Address Societal Needs.” Webinar presented at the HDR Transportation Webinar, Online, July 30, 2020.

Plourde-Archer, Léa. “Montreal’s Ruelles Vertes: Green Alleyways Help the Environment and Create a Sense of Community.” Untapped New York (blog), August 7, 2013. https://untappedcities.com/2013/08/07/montreals-ruelles-vertes-green-alleyways-help-the-environment-and-create-a-sense-of-community

Pollard, Trip, Ruth Morrison, and Louise Lockett Gordon. “Smart Growth & Healthy Communities.” Webinar presented at the Partnership for Smarter Growth Webinar, Online, May 22, 2020. https://docs.google.com/presentation/d/1P_byZ4tVwfxrCV--Nr5_Hdj5bolwA-WJ5kSA7XTP4Qw/edit#slide=id.p1.

Popovich, Natalie, Elizabeth Gordon, Zhenying Shao, Yan Xing, Yunshi Wang, and Susan Handy. “Experiences of Electric Bicycle Users in the Sacramento, California Area.” Travel Behaviour and Society 1, no. 2 (May 1, 2014): 37–44. https://doi.org/10.1016/j.tbs.2013.10.006.

Ranta, P., J. Kesulahti, A. Tanskanen, V. Viljanen, and T. Virtanen. “Roadside and Riverside Green – Urban Corridors in the City of Vantaa, Finland.” Urban Ecosystems 18, no. 2 (June 2015): 341–54. https://doi.org/10.1007/s11252-014-0402-z.

Richards, Michael A. Regreening the Built Environment: Nature, Green Space, and Sustainability. 1st ed. Routledge, 2017. https://doi.org/10.4324/9781315195681.

Richmond. “RVAGreen_ARoadmapToSustainability.Pdf.” City of Richmond, 2011.

RRTPO. “ConnectRVA 2045.” ConnectRVA2045, 2020. https://www.connectrva2045.org.

RRTPO, and Kimley-Horn. “Greater RVA Transit Vision Plan: Near-Term Strategic Technical Analysis.” PlanRVA, Richmond Regional Transportation Planning Organization, August 2020.

Sadeghi, K. Majid, Shahram Kharaghani, Wing Tam, Natalia Gaerlan, and Hugo Loáiciga. “Green Stormwater Infrastructure (GSI) for Stormwater Management in the City of Los Angeles: Avalon Green Alleys Network.” Environmental Processes 6, no. 1 (March 2019): 265–81. https://doi.org/10.1007/s40710-019-00364-z.

Sadik-Khan, Janette, and Seth Solomonow. Streetfight: Handbook for an Urban Revolution. Reprint edition. New York, New York: Penguin Books, 2017.

Safe Routes to School and American Public Health Association. “Promoting Active Transportation - Public Health,” 2012.

Sanford, Will. “Urban Alleys as Green Infrastructure: A Green Alley Plan for the Fan District.” Virginia Commonwealth University, 2016.

Schmitt, Angie, Veronica O’Davis, Jorge C□ñez, Anna Zivarts, and Edward Saltzberg. “Right of Way: How Racial and Class Disparities Created a Silent Epidemic of Pedestrian Deaths in America.” Webinar, September 24, 2020.

Sennett, Richard. Building and Dwelling: Ethics for the City. First American Edition. New York: Farrar, Straus and Giroux, 2018.

Seymour, Mona, Jennifer Wolch, Kim D. Reynolds, and Hilary Bradbury. “Resident Perceptions of Urban Alleys and Alley Greening.” Applied Geography 30, no. 3 (July 2010): 380–93. https://doi.org/10.1016/j.apgeog.2009.11.002.

Sim, David. Soft City: Building Density for Everyday Life. Washington ; Covelo ; London: Island Press, 2019

Speck, Jeff. Walkable City: How Downtown Can Save America, One Step at a Time. Farrar, Straus and Giroux, 2012.

———. Walkable City Rules: 101 Steps to Making Better Places. Washington, DC: Island Press, 2018.

Sprague, Mike. “‘Green Alley’ Project Completed in La Cañada Flintridge.” Pasadena Star News (blog), March 26, 2021. https://www.whittierdailynews.com/2021/03/26/green-alley-project-completed-in-la-canada-flintridge.

Trust for Public Land. “Why Green Alleys? Ask a Fourth-Grader.” The Trust for Public Land, 2015. https://www.tpl.org/blog/green-alleys-update.

UCLA Luskin Center, and Trust for Public Land. “Avalon Green Alley Network Demonstration Project,” 2014

University of Texas at Austin. “Green Alley Demonstration Project - PID 2014 | Texas Architecture | UTSOA.” Accessed August 18, 2020. https://soa.utexas.edu/work/green-alley-demonstration-project-pid-2014.

US EPA, OW. “Green Infrastructure.” Collections and Lists. US EPA, April 24, 2015. https://www.epa.gov/green-infrastructure.

Walczak, Johanna, Chris Martin, Arek Galle, Daniel Amstutz, and Paolo Beria. “Speeding Up Slow Street Projects.” Webinar presented at the APA Planning Webcast Series, Online, July 1, 2020. https://www.youtube.com/watch?v=i6wTtidMQBY.

Ward, Christopher. “Alley Improvement and Alternative Pathway Plan.” Virginia Commonwealth University, 2006.

Wild, Kirsty, and Alistair Woodward. “Why Are Cyclists the Happiest Commuters? Health, Pleasure and the e-Bike.” Journal of Transport & Health 14 (September 1, 2019): 100569. https://doi.org/10.1016/j.jth.2019.05.008.

Williams, Reed. "Witnesses Describe Clash at Lee Circle between Caravan of Trump Supporters and a Crowd of Opponents." Richmond Times-Dispatch, November 2, 2020. https://richmond.com/news/local/witnesses-describe-clash-at-lee-circle-between-caravan-of-trump-supporters-and-a-crowd-of/article_473ba282-d762-54b1-97da-c365ccf903ca.html.

Wilson, Edward O. Biophilia. Revised Edition. Cambridge, Mass.: Harvard University Press, 1984.

Wolch, Jennifer, Josh Newell, Mona Seymour, Hilary Bradbury Huang, Kim Reynolds, and Jennifer Mapes. "The Forgotten and the Future: Reclaiming Back Alleys for a Sustainable City." Environment and Planning A: Economy and Space 42, no. 12 (December 2010): 2874–96. https://doi.org/10.1068/a42259.

Zapata, Marisa, Laura Harjo, Jeffrey Lowe, Samina Raja, Shannon Van Zandt, and Rob Olshansky. "Planning During and After the COVID-19 Pandemic." Webinar presented at the ACSP Committee on the Academy, Online, April 24, 2020. https://www.youtube.com/watch?v=4byYiZ4tKks.

Unless otherwised sourced, all photos in this plan were taken by Dan Motta.

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GREEN ALLEY NETWORK

Virginia Community Flood Preparedness Fund

City of Richmond Department of Public Utilities - Stormwater Division

Historic flood damage data and images

Location 1: Within District 3 parallel and east of Chamberlayne Ave and between W Brookland Park Blvd and Hammond Ave.

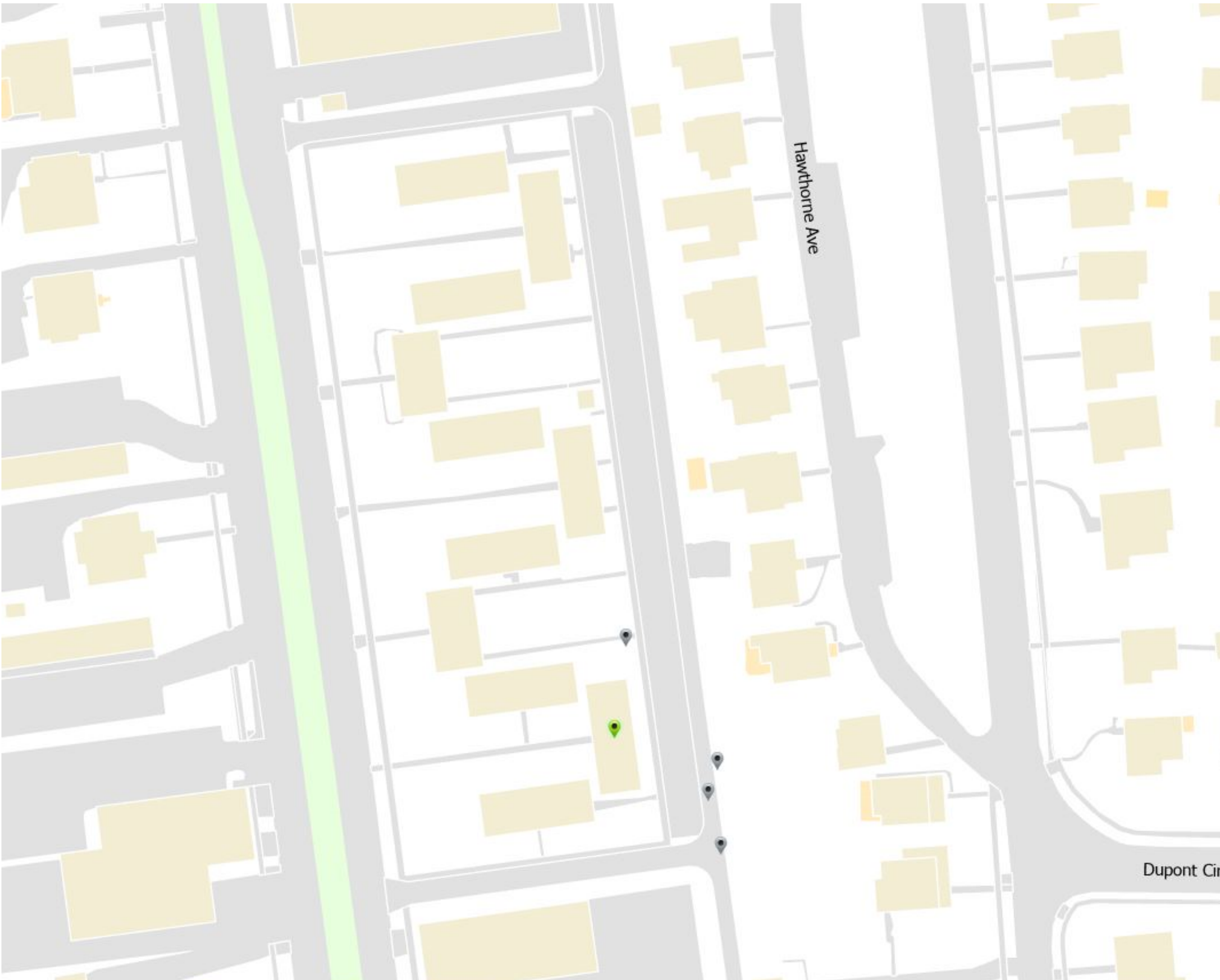


Figure 1: Flooding complaint map of location 1.

Service Request

Description: 2997A0000011 Alley Gravel Repair

Request Id: 370393

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 06/21/2018 10:08 AM

Investigation: ☑

Date: 06/9/2021 10:27 AM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 06/21/2018 10:08 AM

Dispatch To: FIELDS, EVERETT

Date: 04/15/2021 2:12 PM

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: FIELDS, EVERETT

Date: 6/9/2021 10:27:48 AM

Comments: Add Comment

Sort ▲

By Interface, Cityworks: 6/21/2018 10:08:44 AM

Problem Description: Potholes in the alley need to be repaired. Along the entire alley;

By LEWIS, TRACEY N: 7/18/2018 5:59:57 PM

Forwarding the request to the supervisor for investigation and scheduling

Storm Drain Problem

By LOCKETT, LEONARDO L: 1/25/2021 9:36:08 AM

R.Brown Inpected the location and reported the it a pot hole issue at the location.

Alley Gravel Repair

By GLENN, HOWARD W: 4/15/2021 2:12:22 PM

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No:

Map Page:

District:

Location:

Details: CRMDPW000000847 - There is no media or attachements linked to this SR

Facility Id

Level Id

X: -8,621,044.156

Y: 4,518,882.307

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comment
☐	ROBERTSON	ROBIN	80	6/21/2018 2:08:35 PM	RES	CRMDPW

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Search...

GLENN, HOWARD W

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 446416

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 06/11/2021 9:19 AM

Investigation: ☑

Date: 09/1/2021 11:01 AM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 06/11/2021 9:19 AM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: WILLIAMS JR, JAMES

Date: 9/1/2021 11:01:11 AM

Comments: Add Comment | Sort ▲

▶ By Interface, Cityworks: 6/11/2021 9:19:03 AM Problem Description: ...

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave,

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No: 2

Map Page: 3

District:

Location:

Details: CRMDPW000080898 - https://e311production.blob.core.windows.net/rvaone/SRImages/20210611131806_1567910712_.jpg;https://e311production.blob.core.windows.net/rvaone/SRImages/20210611131820_20

Facility Id

Level Id

X: -8,621,017.324

Y: 4,518,873.789

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comment
☐	MAHMOOD	YASMEEN	57	6/11/2021 1:18:59 PM		CRMDPW(

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Search...

GLENN, HOWARD W

Inbox | Recent | Requests | Work Orders | Inspections | Crews | GIS Search

Calendar | Reports

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 453650

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 09/3/2021 12:28 PM

Investigation: ☑

Date: 12/14/2021 5:08 PM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 09/3/2021 12:28 PM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: Fleming, Darrist

Date: 12/14/2021 5:08:42 PM

Comments: Add Comment | Sort ▲

By Interface, Cityworks: 9/3/2021 12:28:36 PM

Problem Description: Alley is so worn/deep that when it rains, its enough to drown a toddler;

By Fleming, Darrist: 12/14/2021 5:08:42 PM

per W.D complete 12-14-21

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave,

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No: 2

Map Page: 3

District:

Location:

Details: CRMDPW000088517 - https://e311production.blob.core.windows.net/rvaone/SRImages/20210903162533_1430650561_.jpg

Facility Id | Level Id
X: -8,621,041.060 | Y: 4,518,906.103

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comments
☐	MAHMOOD	YASMEEN	57	9/3/2021 4:28:28 PM		CRMDPW0

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Service Request

Description: 2997A0000011 Alley Gravel Repair

Request Id: 488335

Category: Roadway Maintenance

Priority: Medium

Status: Open

Initiated By: Interface, Cityworks

Date: 12/4/2022 9:26 AM

Investigation: ☐

Date:

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 12/4/2022 9:26 AM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By:

Date:

Comments: Add Comment | Sort ▲

By Interface, Cityworks: 12/4/2022 9:26:45 AM

Problem Description: The alley behind the Gate Oaks Apts at 2909 Chamberlayne Ave has been in disrepair for years and must be reapired in a way that is lasting. Following a rain event, there is always 3-4" of standing water, this is not ok. The alley appears to be a a combination of gravel and asphalt, maybe ghisnisnpart of the problem. Regardless, neighbors on both sides of the alley are fed up and want this fixed.;

Resolution:

Incident Information

Address: 2909 Chamberlayne Ave,

Apt #:

City:

State:

Zip Code: 23222

Landmark:

Shop:

Tile No: 2

Map Page:

District:

Location:

Details: CRMDPW000127245 - https://e311production.blob.core.windows.net/rvaone/SRImages/20221204142537_967110667_.jpg;https://e311production.blob.core.windows.net/rvaone/SRImages/20221204142559_1831

Facility Id | Level Id

X: -8,621,016.297 | Y: 4,518,851.599

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Comments
☐	LEASE	MICHAEL K.	80	12/4/2022 2:26:39 PM		CRMDPWC

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Location 2: Within District 6 and west of Willis St between Chesterman Ave and Mimosa St.

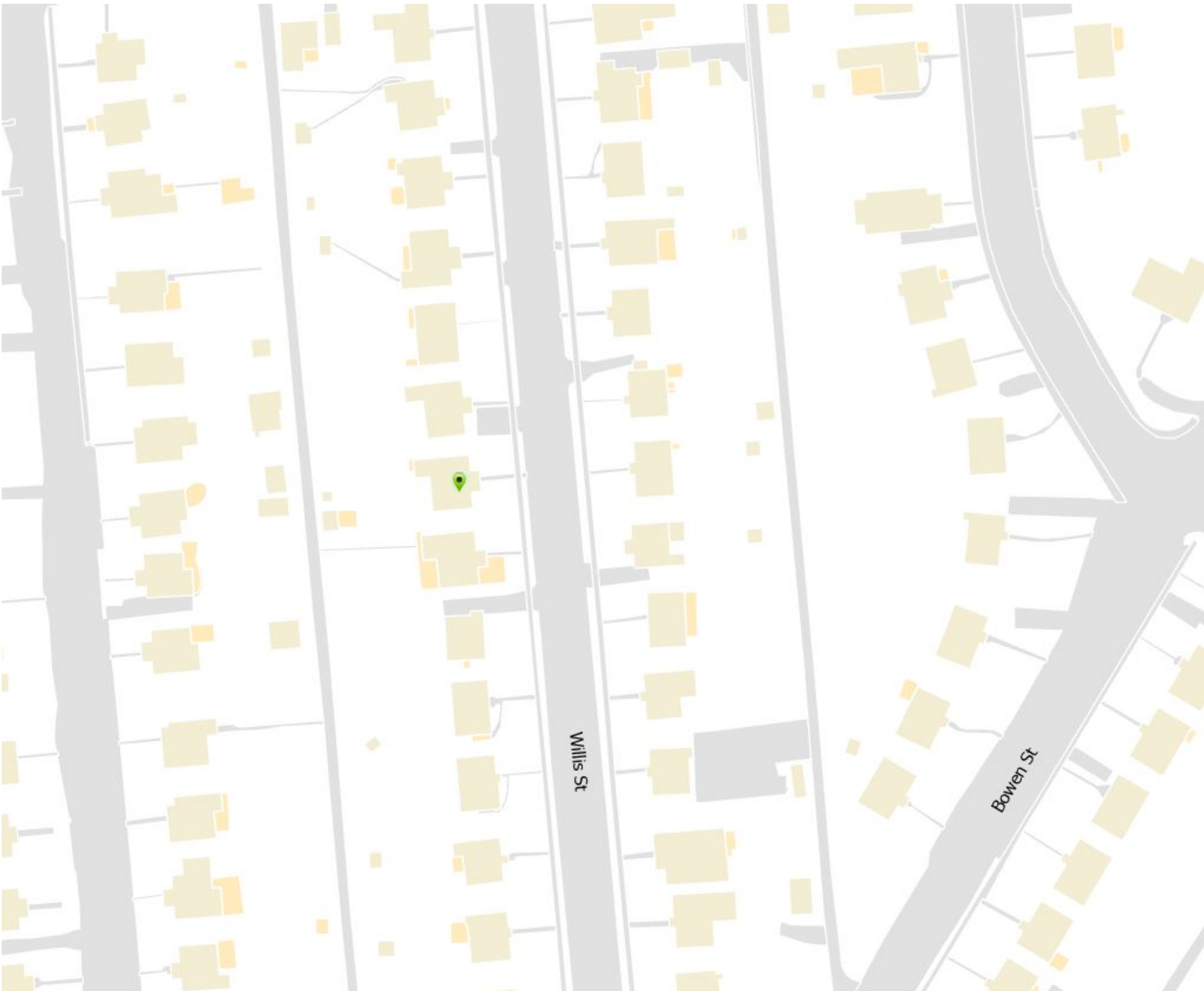


Figure 2: Flooding complaint map of location 2.

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 425507

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 08/13/2020 1:01 PM

Investigation: ☑

Date: 08/18/2021 8:49 AM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 08/13/2020 1:01 PM

Dispatch To:

Date:

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: WILLIAMS JR, JAMES

Date: 8/18/2021 8:49:59 AM

Comments: Add Comment Sort ▲

By Interface, Cityworks: 8/13/2020 1:01:37 PM

Problem Description: Water after continuous raining has continuously food the entire property, crawl space and damage air conditions unit. Which has cause continuous costly repair. Due to know fault but The City of Richmond paving the alley way. Every time it rains if floods our property. I have pictures and video for proof. Some from Storm Drain came out this morning, stating you all need to put up a barrier. The water from the alley comes from both ways, flooding our entire property. I have all of my receipts.;

By Interface, Cityworks: 8/13/2020 3:22:52 PM

yard is being flooded when it rains. would like for someone to come out. she said she is having expenses and feels she should be reimbursed. Provided info to file a claim.

Streets PotholesAlley Asphalt Repair

By Interface, Cityworks: 10/20/2022 10:53:02 AM

Resolution:

Incident Information

Address: 1413 Willis St

Apt #:

City:

State:

Zip Code:

Landmark:

Shop:

Tile No: 4

Map Page: 6

District:

Location:

Details: CRMDPW000058043 - There is no media or attachements linked to this SR

Facility Id

Level Id

X: -8,620,639.224

Y: 4,509,156.828

Callers

	Last Name	First Name	M.I.	Call Time	Caller Typ
☐	COLEMAN, JR.	DEITTRA & BENJAMIN	80	8/13/2020 5:02:35 PM	RES

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Search...

GLENN, HOWARD W

Inbox | Recent | Requests | Work Orders | Inspections | Crews | GIS Search

Calendar | Reports

Service Request

Description: 2997A0000010 Alley Asphalt Repair

Request Id: 425690

Category: Roadway Maintenance

Priority: Medium

Status: Closed

Initiated By: Interface, Cityworks

Date: 08/15/2020 1:38 PM

Investigation: ☑

Date: 04/12/2021 9:51 AM

Emergency: ☐

WO Needed: ☐

Submit To: LEWIS, TRACEY N

Date: 08/15/2020 1:38 PM

Dispatch To: STEWART, ROSALIND

Date: 10/14/2020 9:12 AM

Project Name:

Prj. Comp. Date:

Project Tree

Cancel? ☐

Date:

Cancel Reason:

Canceled By:

Closed By: STEWART, ROSALIND

Date: 4/12/2021 9:51:05 AM

Comments: Add Comment

Sort ▲

By Interface, Cityworks: 8/15/2020 1:38:47 PM

Problem Description: Everything time it rain the water from the alley runs into my yard and causing damage to my property. It is causing flooding in my yard and flooding my crawls pace and causing damage to my property.

;

By STEWART, ROSALIND: 4/12/2021 9:51:05 AM

duplicate request, cw 425507 dpw 000058043 remains open

Resolution:

Incident Information

Address: 1413 Willis St,

Apt #:

City:

State:

Zip Code: 23224

Landmark:

Shop:

Tile No: 4

Map Page:

6 District:

Location:

Details: CRMDPW000058214 - There is no media or attachements linked to this SR

Facility Id | Level Id

X: -8,620,639.224 Y: 4,509,156.828

Callers

	Last Name	First Name	M.I.	Call Time	Caller Type	Commer
☐	COLEMAN JR	BENJAMIN	80	8/15/2020 5:39:45 PM		CRMDPV

New Request From Caller

Related Work Activities

Inspections

Add:

Create

Work Orders

Add:

Group assets? ☑ Create

Attachments

Add attachment... **Remove all attachments**

Drag and drop files here to attach them.

Permit

Case Type: Create

Map Layer Fields

Reset

Existing Requests with the Same Problem Code

Search

Custom Fields

Category:

Figure 3: Photo of flooding at location 2. Ponding is visible. Alley conditions are not suitable for walking and drivers are unable to see the road.

Figure 4: Photo of flooding at location 2. Ponding is visible and seen to be flowing into the backyard of residential property 1413 Willis Street.

Figure 5: Photo of flooding of 1413 Willis Street backyard as seen from the inside of the residential house.

Figure 6: Photo of flooding of 1413 Willis Street backyard as seen from the alley.

Figure 7: Photo of flooding of 1413 Willis Street front year as seen from Willis Street side of the property.

Maintenance Plan – Green Alleys

City of Richmond

The City of Richmond has no detailed maintenance plan for existing green alleys. Existing green alleys are currently maintained with a combination of sidewalk maintenance, street maintenance, and green infrastructure maintenance practices as required by each site. All alleys receive maintenance by the City of Richmond Department of Public Utilities – Stormwater Division maintenance crew twice annually.

Attached are posts from the rvah2o Instagram account with Richmond Green Alley maintenance information as well as the City of Richmond sidewalk and street maintenance information.

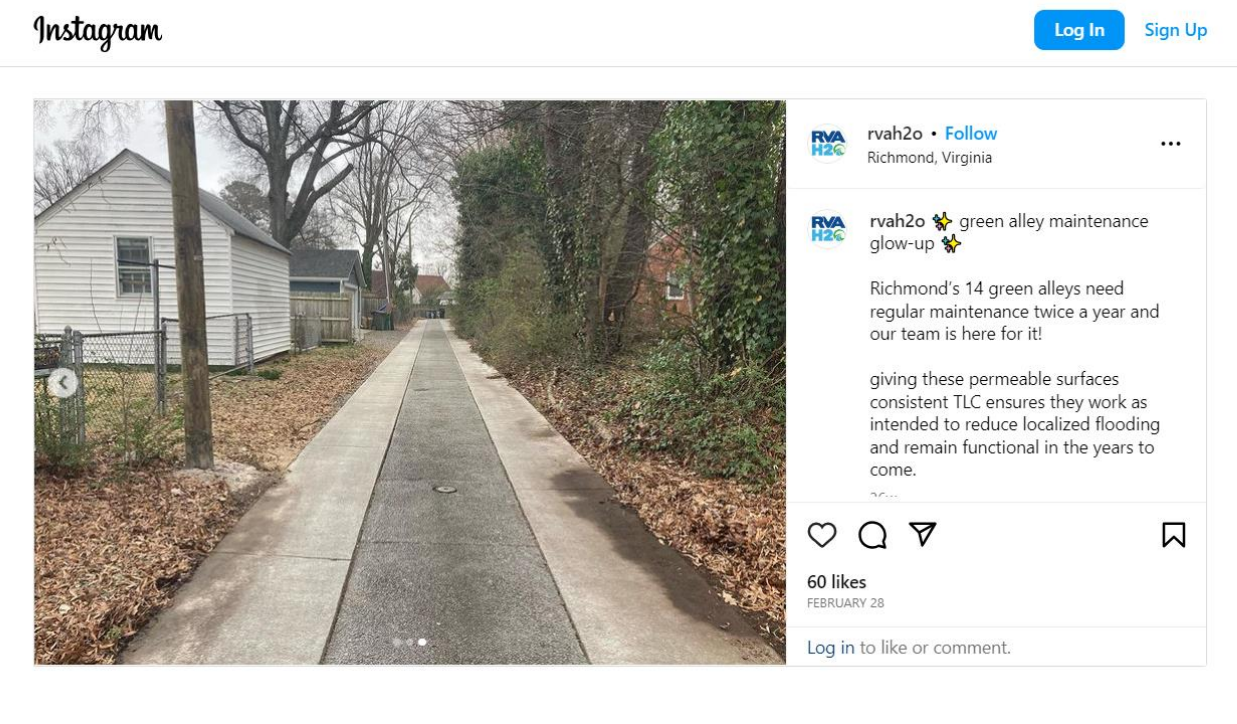


Figure 1: @rvah2o Instagram post regarding Richmond green alley maintenance.

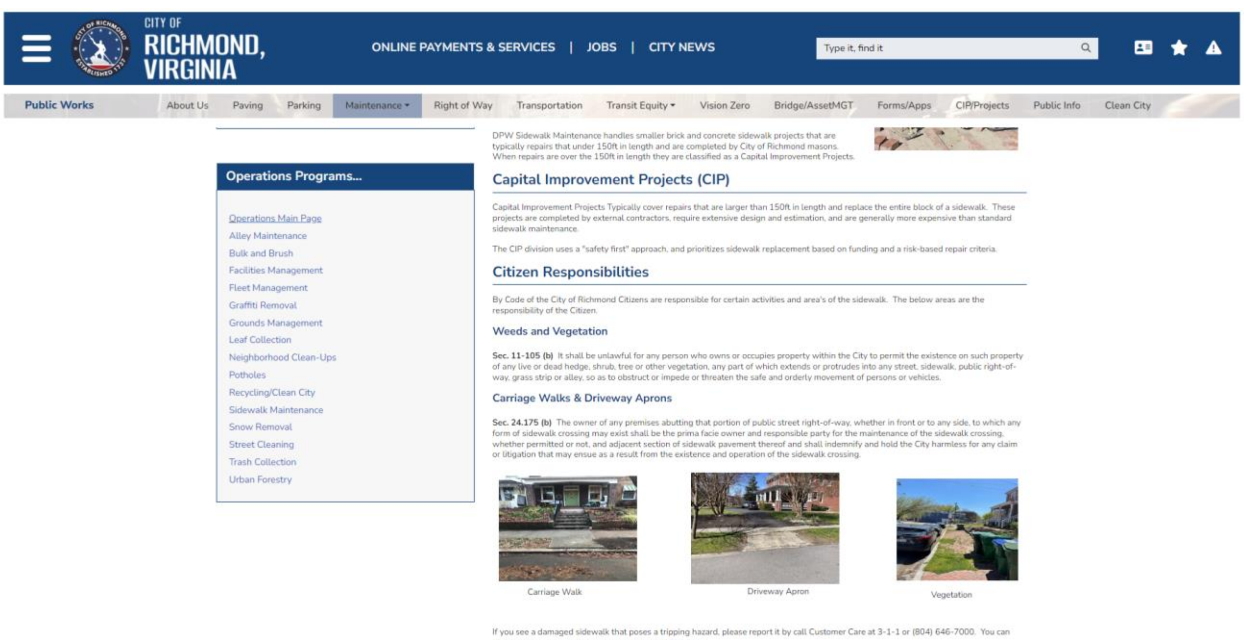
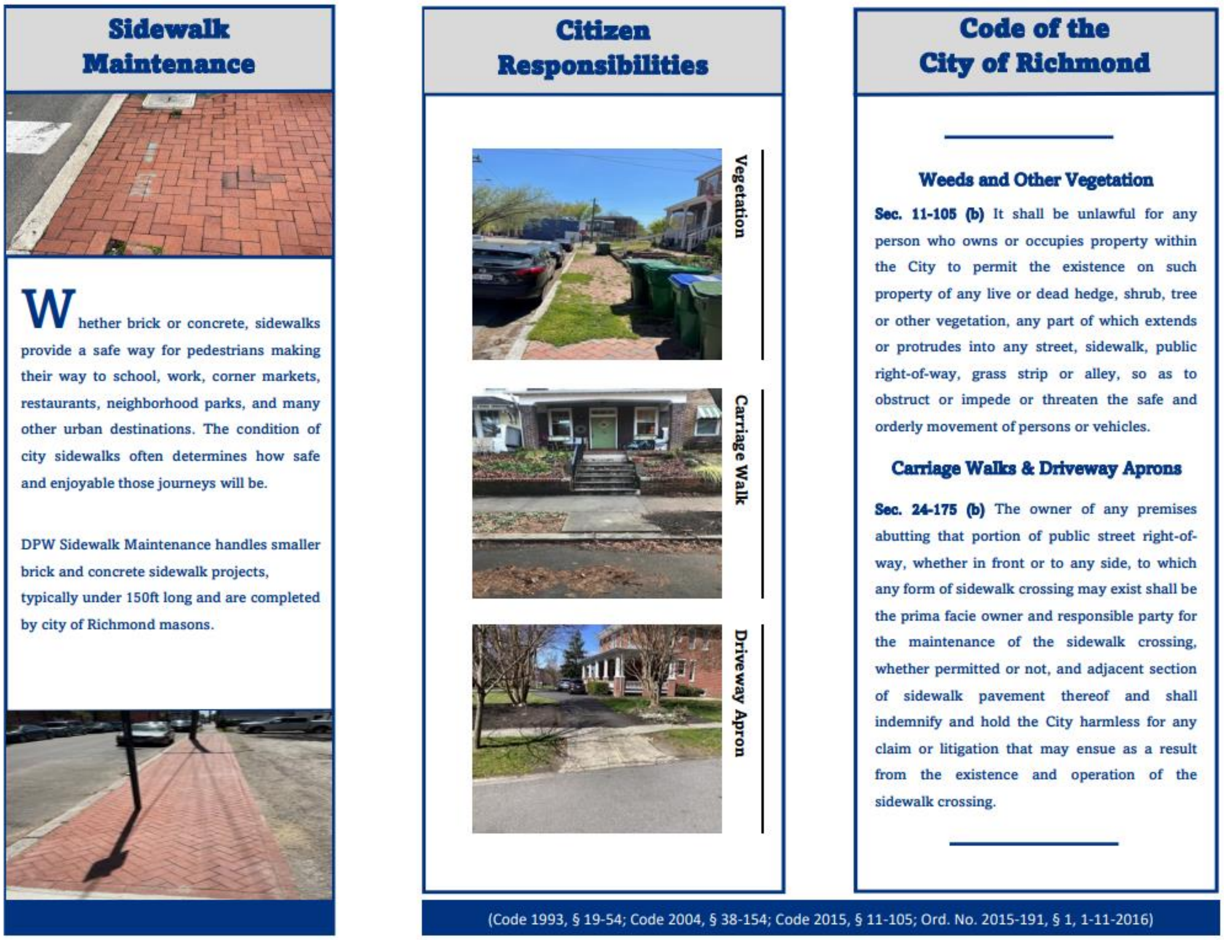


Figure 2: City of Richmond, Virginia sidewalk maintenance & capital improvement projects (CIP) information page.



Sidewalk Maintenance

Whether brick or concrete, sidewalks provide a safe way for pedestrians making their way to school, work, corner markets, restaurants, neighborhood parks, and many other urban destinations. The condition of city sidewalks often determines how safe and enjoyable those journeys will be.

DPW Sidewalk Maintenance handles smaller brick and concrete sidewalk projects, typically under 150ft long and are completed by city of Richmond masons.

Citizen Responsibilities

Vegetation

Carriage Walk

Driveway Apron

Code of the City of Richmond

Weeds and Other Vegetation

Sec. 11-105 (b) It shall be unlawful for any person who owns or occupies property within the City to permit the existence on such property of any live or dead hedge, shrub, tree or other vegetation, any part of which extends or protrudes into any street, sidewalk, public right-of-way, grass strip or alley, so as to obstruct or impede or threaten the safe and orderly movement of persons or vehicles.

Carriage Walks & Driveway Aprons

Sec. 24-175 (b) The owner of any premises abutting that portion of public street right-of-way, whether in front or to any side, to which any form of sidewalk crossing may exist shall be the prima facie owner and responsible party for the maintenance of the sidewalk crossing, whether permitted or not, and adjacent section of sidewalk pavement thereof and shall indemnify and hold the City harmless for any claim or litigation that may ensue as a result from the existence and operation of the sidewalk crossing.

(Code 1993, § 19-54; Code 2004, § 38-154; Code 2015, § 11-105; Ord. No. 2015-191, § 1, 1-11-2016)

Figure 3: City of Richmond, Virginia sidewalk maintenance brochure.

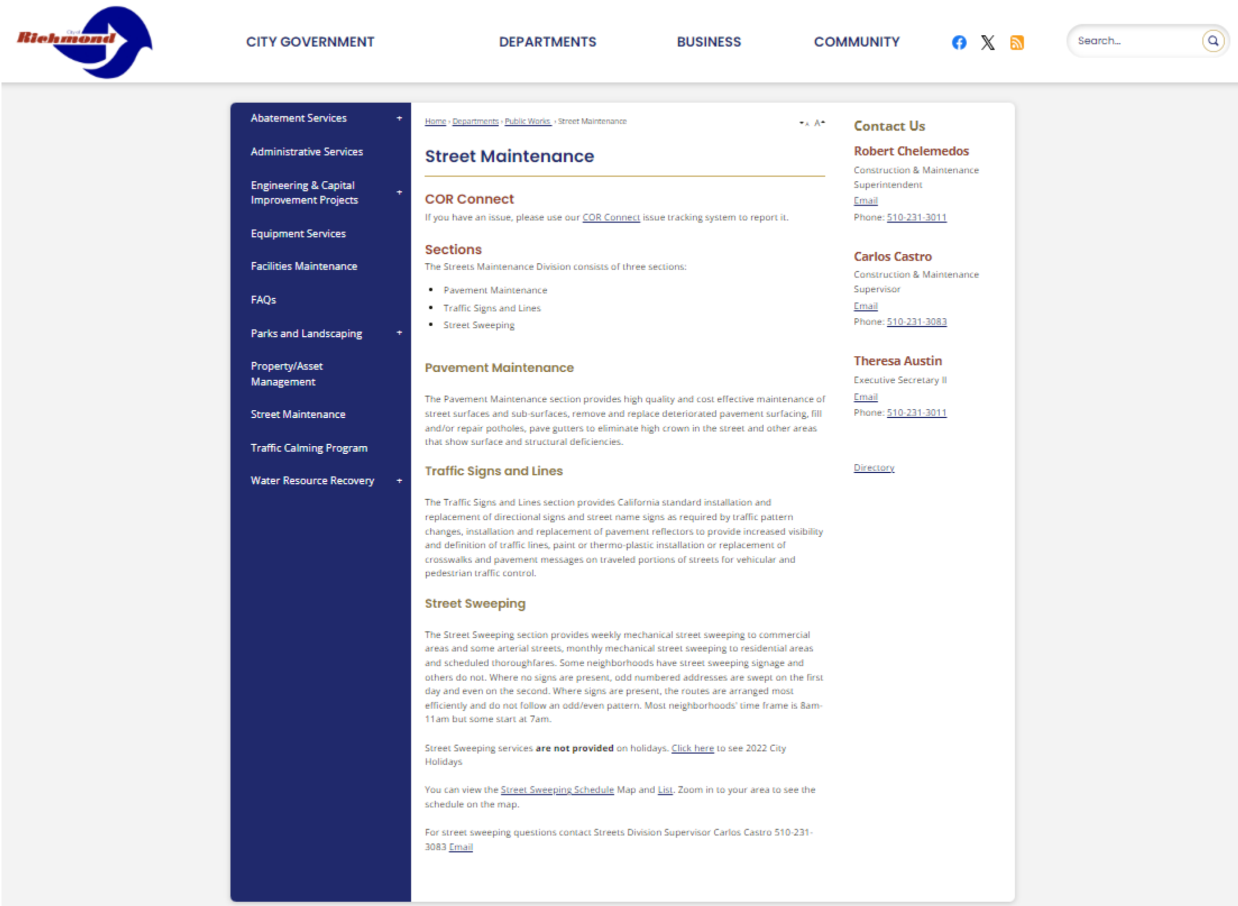


Figure 4: City of Richmond, Virginia street maintenance information page.

Green Alleys Project Approach, Milestones, and Deliverables

City of Richmond

Approach:

The City of Richmond has an existing green alley program, and 13 alleys were converted to green alleys between 2010-2021 (**Error! Reference source not found.**). While there is no formal definition of green alleys, the National Association of City Transportation Officials (NACTO) identified green alleys as alleyways that "uses sustainable materials, pervious pavement, and effective drainage to create inviting public space for people to walk, play, and interact." Past projects have experienced success in stormwater management and creating new community spaces, and a continuation of this project can expect to meet similar success.

The City of Richmond Department of Public Utilities and Department of Public Works/Transportation and Stormwater Division will be responsible for bidding out design and construction work. These departments will also be responsible for all major operations and maintenance of the green alleys. The City of Richmond DPU requires regular maintenance twice a year for the 13 existing green alleys. This regular maintenance ensures that that the green alley surfaces remain permeable and functional to reduce flooding as designed. The new green alleys would be added to the existing regular maintenance program.

Each project will be completed within a 3-year time period after the grant is awarded and accepted by the City of Richmond.

Milestones and Deliverables:

The green alley projects milestones timeline and deliverables are outlined in Table 1.

Table 1: Green Alleys Proposed Milestones

Milestones	Timeline	Deliverables
Green Alleys Projects receives NTP	Q1 2024	N/A
City of Richmond accepts Grant	Q1 2024	N/A
City of Richmond releases design RFP	Q1 2024	Design RPF by City
Design contract is awarded to preferred consultant	Q3 2024	Design RFP Response
Alternatives analysis submitted	Q3 2024	Alternatives Analysis
50% design submitted	Q4 2024	50% Design Package
90% design submitted	Q4 2024	90% Design Package
100% design submitted	Q4 2024	100% Design Package
City of Richmond releases construction RFP	Q1 2025	Construction RPF by City

Construction contract is awarded to preferred construction company	Q2 2025	Construction RFP Response
Construction begins	Q2 2025	Work Plan
Construction is completed	Q2 2026	Completed Project
Projects close out	Q2 2026	Completed Project

The final projects after construction completion and project close out will be two green alleys at Location 1 and 2 as described in the scope of work with permeable surfaces and green infrastructure elements designed to eliminate and reduce flooding and service the surrounding community.

N/A

N/A