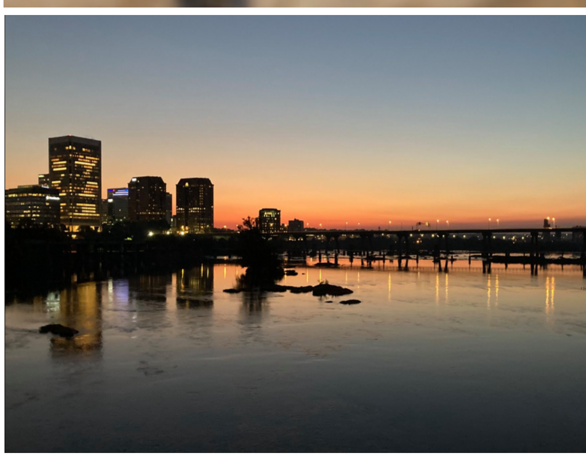
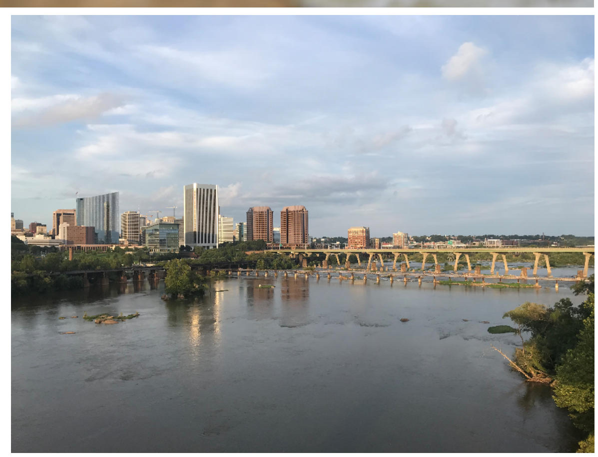
City of Richmond, Virginia
Department of Public Utilities
CSO Interim Plan Report

July 1, 2021





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List of Abbreviations

AACE	Association for the Advancement of Cost Engineering
Cfu	colony forming units
CSO	combined sewage overflow
CSS	combined sewer system
DEQ	Department of Environmental Quality
DPU	Department of Public Utilities
DUC	Dynamic Underflow Control
DWF	dry weather flow
DWO	dry weather overflow
I/I	inflow and infiltration
ILS	In-Line Storage
MG	million gallons
MGD	million gallons per day
MS4	Municipal Separate Storm Sewer System
NOAA	National Oceanic and Atmospheric Administration
NMC	nine minimum controls
RIC	Richmond International Airport
RT-DSS	Real Time-Decision Support System
SO	Special Order
SRB	Shockoe Retention Basin
WQS	Water Quality Standards
WWF	wet weather flow
WWTP	Richmond Wastewater Treatment Plant

SECTION 1

Executive Summary

1.1 Background

In 2020, the Virginia General Assembly enacted Senate Bill 1064 (2020 CSO Law). The 2020 CSO Law establishes specific timeframes for the development and implementation of Interim and Final Plans to address combined sewer overflows (CSOs). It applies to the owner or operator of any Combined Sewer System (CSS) east of Charlottesville that discharges into the James River watershed. As part of the Plan development process, amendments to any existing consent special orders issued by the Virginia Department of Environmental Quality (DEQ) pertaining to CSOs may be necessary.

As the owner and operator of a CSS located east of Charlottesville that discharges into the James River, the City of Richmond (City) has developed this Interim Plan. Additionally, an Amendment to the City's Special Order by Consent (2005 Order), was negotiated with the DEQ. The Amendment incorporates the deadlines specified in the 2020 CSO Law as reflected below.

	Due Date	Initiate Construction and Related Activities	Complete Construction and Related Activities
Interim Plan	July 1, 2021	July 1, 2022	July 1, 2027
Final Plan	July 1, 2024	July 1, 2025	July 1, 2035
TMDL Report	July 1, 2030	NA	NA

1.2 Interim Plan Purpose

The City's Interim Plan identifies projects with the most immediate benefits achievable in the required timeframe. These projects leverage state-of-the-art technology to optimize the use of existing infrastructure.

The Interim Plan Development process:

Project Identification › **Initial Screening** › **Project Evaluation** › **Final Screening** › **Project Selection**

1.3 Project Identification

In 2018, the City began studying potential opportunities to utilize Real Time Decision-Support System (RT-DSS) control technology to optimize the performance of their CSS.

The RT-DSS controls are informed by real-time system monitoring data and provide the ability for equipment to automatically adjust in response to wet weather, to optimize the use of existing infrastructure and facilities.

The projects identified in the Interim Plan are informed by the initial RT-DSS Study, and a systemwide evaluation that identified additional improvement opportunities. The Interim Plan Projects can be characterized into four groups:

In-Line Storage	Leverage existing large-diameter sewers (>72-inch diameter) to reduce overflow volume
Diversion	Replace the fixed controls with RT-DSS controlled mechanical equipment, that will better manage flow across the CSS and reduce overflows
Dynamic Underflow Control	Maximize flow sent downstream for treatment to prevent premature CSO overflows
Controls Update	Optimize the control strategy at several key CSO Management facilities to improve the performance of the CSS

1.4 Initial Screening

After the initial project identification, a screening process was executed to further investigate the feasibility and practicality of each project.

Screening Criteria

- Constructability
- Hydraulics/Flooding Risks
- Operability Risks

Project Identification
20 Projects

Initial Screening
18 Projects

1.5 Project Evaluation

Following the initial screening process, 18 Projects were selected and then evaluated to identify the most impactful, cost-effective solutions for the City.

Performance

The City's CSS Hydrologic and Hydraulic Model, and the Receiving Water Model (updated based on the collected 2019 system monitoring data), were used to evaluate performance improvements[1]

- Overflow Volume Reduction
- Overflow Event Reduction
- Remaining Local Overflow Events
- Bacteria Load Reduction
- % Improvement Towards compliance with WQS

Cost

Conceptual layouts for each project were developed and were used to develop AACE Class 5 cost estimates (Accuracy Range -50 to +100%)

- Construction Cost
- Annual Operation and Maintenance Cost
- Capital Cost

Schedule

Schedules were developed to estimate the required duration for each major phase of the project

- Design
- Permitting
- Procurement

Qualitative

A custom qualitative evaluation and scoring system was developed to evaluate additional benefits/impacts that are not captured in the cost and performance criteria

- Community
- Environmental
- Operational
- Adaptability

Cost-Effectiveness

Capital cost and performance metrics were utilized to identify the best "bang for the buck" projects

- $ / Overflow Volume Reduction
- $ / Overflow Event Reduction
- $ / Bacteria Reduction

1: Interim Plan projects were built into the CSS H&H model and were simulated under consistent rainfall conditions. The results were compared against the Baseline Scenario (described in Section 3) to quantify the performance improvements.

1.6 Final Screening

A final screening process was conducted to identify projects that provide meaningful overflow volume reduction and can be complete by the Interim Plan deadline of July 1, 2027.

Screening Criteria

- Overflow Volume Reduction > 2 MG
- Project Duration < 4 Years

Project Evaluation
18 Projects

Final Screening
10 Projects

1.7 Project Selection

10 projects, illustrated in Figure 1-1, were selected to be implemented in the Interim Plan. The benefits of the selected projects are summarized below:

<table>
<tr><td rowspan="3">Performance</td><td colspan="2">Overflow Volume Reduction</td><td>182.3 MG</td></tr>
<tr><td rowspan="2">Improvement (%) towards compliance with water quality standards (0%: Baseline Scenario – 100%: Full Compliance)</td><td>Geomean</td><td>4.1%</td></tr>
<tr><td>Statistical Threshold Value</td><td>21.4%</td></tr>
<tr><td>Cost</td><td colspan="2">Capital Cost</td><td>$33.3M</td></tr>
</table>

Utilizing RT-DSS control technology to optimize the use of the City's existing CSS infrastructure results in impactful, achievable projects that will provide a substantial reduction in CSO volume to the James River. Table 1-1 describes each selected project including: Cost, Performance, and Schedule details.

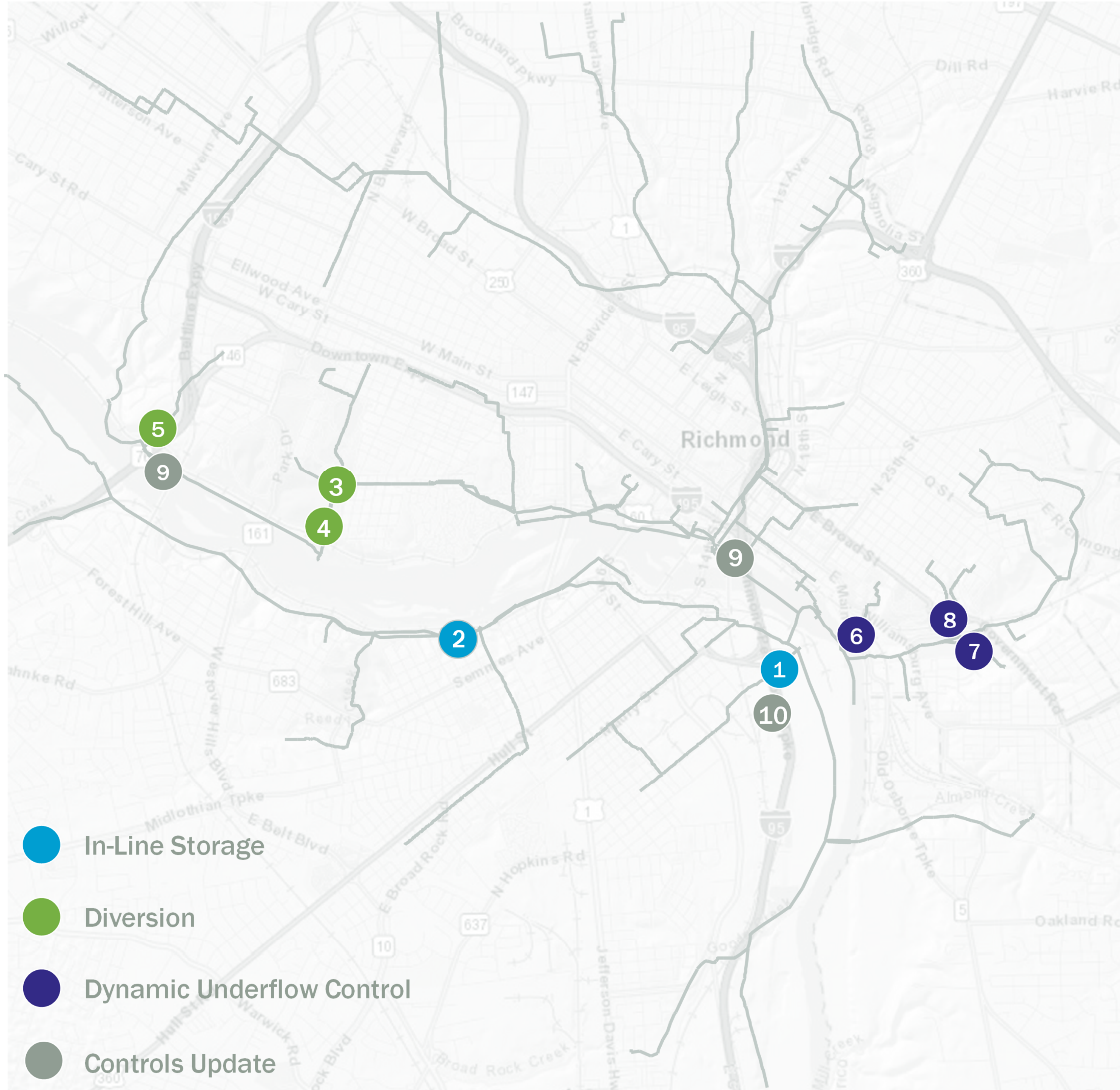


Figure 1-1: Selected Interim Plan Projects

Table 1-1. Summary of Selected Interim Plan Projects

PROJECT		PROJECT PURPOSE	Overflow Volume Reduction (MG)	Capital Cost ($M)	$/Gal Reduction	Construction Completion Date
In-Line Storage						
1	CSO 21	Replacement of the Regulator to utilize upstream in-line storage in the Gordon Avenue Sewer (approx. 1.5 MG of storage)	16.2	$5.4	$0.33	2025
2	CSO 40 #1	Installation of a new structure to utilize upstream in-line storage in the CSO 1/2 Pipeline (approx. 1.1 MG of storage)	12.3	$3.8	$0.31	2025
Diversion						
3	CSO 19A	Divert flow between the Hampton/McCloy Retention Tunnel and the Shockoe Retention Basin	10.3	$0.8	$0.08	2026
4	CSO 19B		2.2	$0.3	$0.14	2022
5	CSO 20		8.9	$0.8	$0.09	2026
Dynamic Underflow Control						
6	CSO 04	Relocation of the Regulator, to utilize upstream in-line storage and send additional flow to the Gillies Creek Interceptor	5.1	$8.7	$1.71	2024
7	CSO 24	Divert additional wet weather flow to the Gillies Creek Interceptor	3.8	$0.4	$0.11	2024
8	CSO 39		3.6	$0.8	$0.22	2024
Controls Updates						
9	Level 1 Controls	Automation of the drainage operation at the Shockoe Retention Basin and control improvements at the McCloy PS	78.7	$1.3	$0.02	2023
10	Level 2 Controls	Improvements of the WWTP Main Pumping Station to optimize the operation of the 65 MGD Wet Weather UV Disinfection Facility	41.2	$11.0	$0.27	2025
All Interim Plan Projects (10)			182.3 MG	$33.3M	$0.18/gal	

SECTION 2

Introduction

2.1 Combined Sewer System History

The original wastewater collection system, constructed in the late 1800's, was comprised of combined sewer pipes that carry both sanitary sewage and runoff from storms to the James River. In the 1940s the City began construction of an interceptor system, along the banks of the James River and its tributaries, to convey the combined sewage to the City of Richmond Wastewater Treatment Plant (WWTP), which was constructed in the 1950s. Regulator structures were installed at CSO outfalls to allow combined sewage to overflow to the James River when the capacity of the interceptor system was exceeded during rainfall events. Since its original construction the WWTP has undergone several significant expansions and upgrades.

For the past 60 years, the City has been proactively improving the CSS and the WWTP to reduce CSOs, and subsequently improve water quality in the James River. The City has invested approximately $350 million on the CSS improvements shown below:

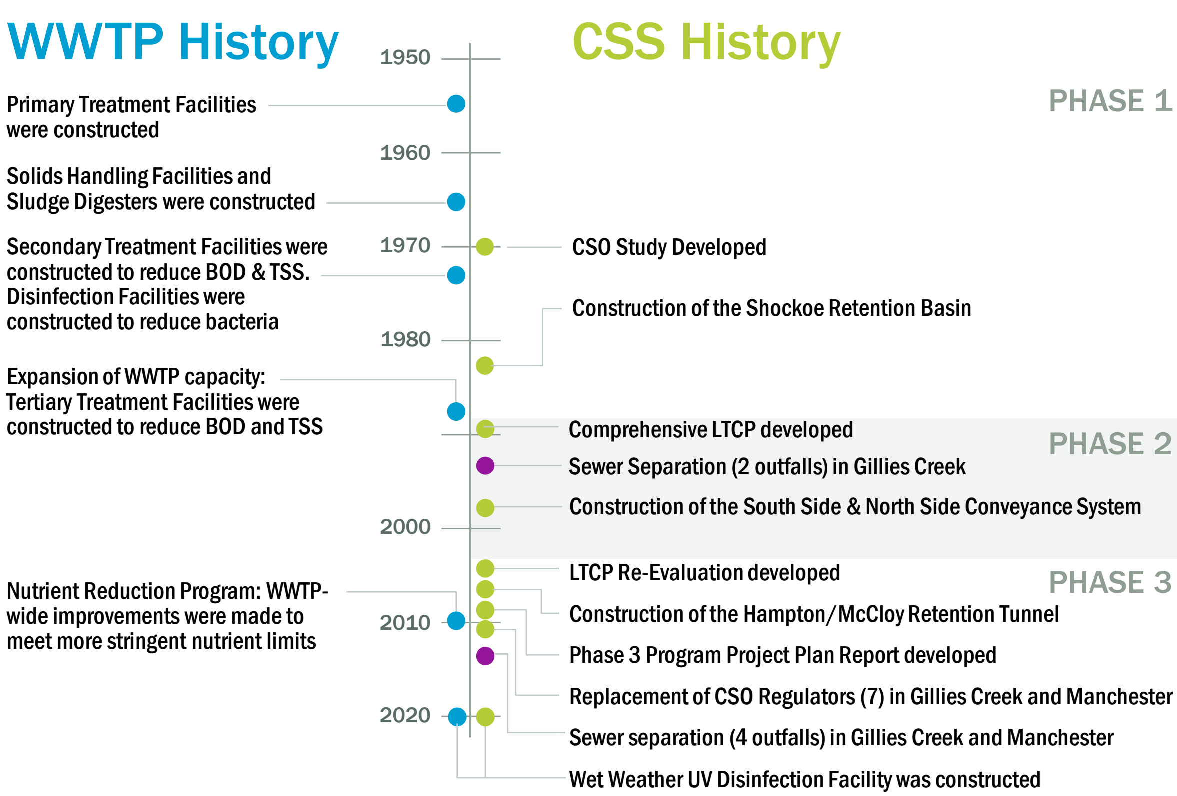


Figure 2-1: History of Richmond WWTP Upgrades and CSS Improvements

2.2 Amendment to the 2005 Special Order by Consent

The City has worked closely with the DEQ and the State Water Control Board to study and implement improvements to the CSS and WWTP.

In 2005, a Special Order by Consent (2005 Order) was issued between the State Water Control Board (Board) and the City to implement the improvements recommended in the 2002 Long Term Control Plan (LTCP). In 2020, the Virginia General Assembly passed, and the Governor signed into law, the 2020 CSO Law, that requires the owner or operator of any CSS east of Charlottesville that discharges into the James River watershed to submit to DEQ an Interim and Final Plan to address the requirements of any consent special order issued by the Board.

The 2020 CSO Law identifies the following dates and tasks for the owner or operator:

	Purpose	Due Date	Initiate Construction and Related Activities	Complete Construction and Related Activities
Interim Plan	Identify improvements that can be initiated in the short-term	July 1, 2021	July 1, 2022	July 1, 2027
Final Plan	Re-evaluates the remaining Special Order projects and identifies system-wide improvements	July 1, 2024	July 1, 2025	July 1, 2035
TMDL Report	Identify improvements to meet the requirements of the “James River – Richmond Tributaries Bacteria TMDL”	July 1, 2030	NA	NA

The 2005 Order was amended in 2020 in alignment with the 2020 CSO Law. The projects and improvements presented in the Interim and Final Plans will establish a prioritized list of projects that will provide the community with the most cost-effective solutions to complete the City’s obligations under the 2005 Order.

2.3 Interim Plan Purpose

The Interim Plan identifies opportunities to leverage state-of-the-art technology to optimize the use of existing infrastructure, to reduce overflows in the short-term.

The Interim Plan identifies short-term projects that will reduce the City's CSO volume and events and can be implemented quickly to comply with the construction initiation and completion deadlines.

The Interim Plan Development process:

Project Identification › **Initial Screening** › **Project Evaluation** › **Final Screening** › **Project Selection**

Each project selected for implementation in the Interim Plan includes:

- ✓ **Estimated Schedule**
- ✓ **Projected CSO Volume, Event, and Bacteria Discharge Reductions**
- ✓ **Projected Water Quality Improvements**
- ✓ **Estimated Cost**
- ✓ **Proposed Funding Sources**

SECTION 3

System Characterization

3.1 Combined Sewer System Description

The City of Richmond has a central area that is served by the CSS. The drainage area served by the CSS is approximately 12,000 acres and represents approximately a third of the City's total area. There are currently 25 active CSO outfalls that are grouped into seven (7) CSO districts.

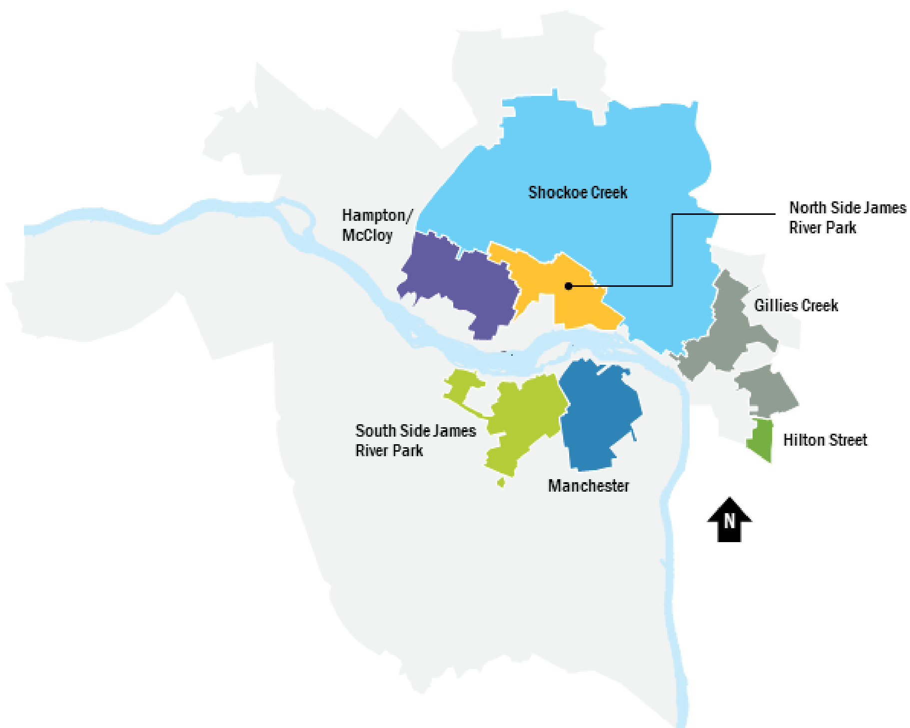


Figure 3-1: Richmond CSO Districts

Significant improvements have been made in each of the CSO districts to expand the conveyance and storage capacity of the system, reduce CSO volumes and activations, and improve receiving water quality. The following pages in Section 3 identify the existing key infrastructure assets in each of the CSO Districts, how the system is currently designed to operate, and the potential opportunities to optimize the performance of the system.

South Side James River Park

The 90" CSO 1/2 Pipeline could provide a significant storage volume in wet weather events. This additional storage could be utilized by installing new In-Line Storage structures on the pipe.

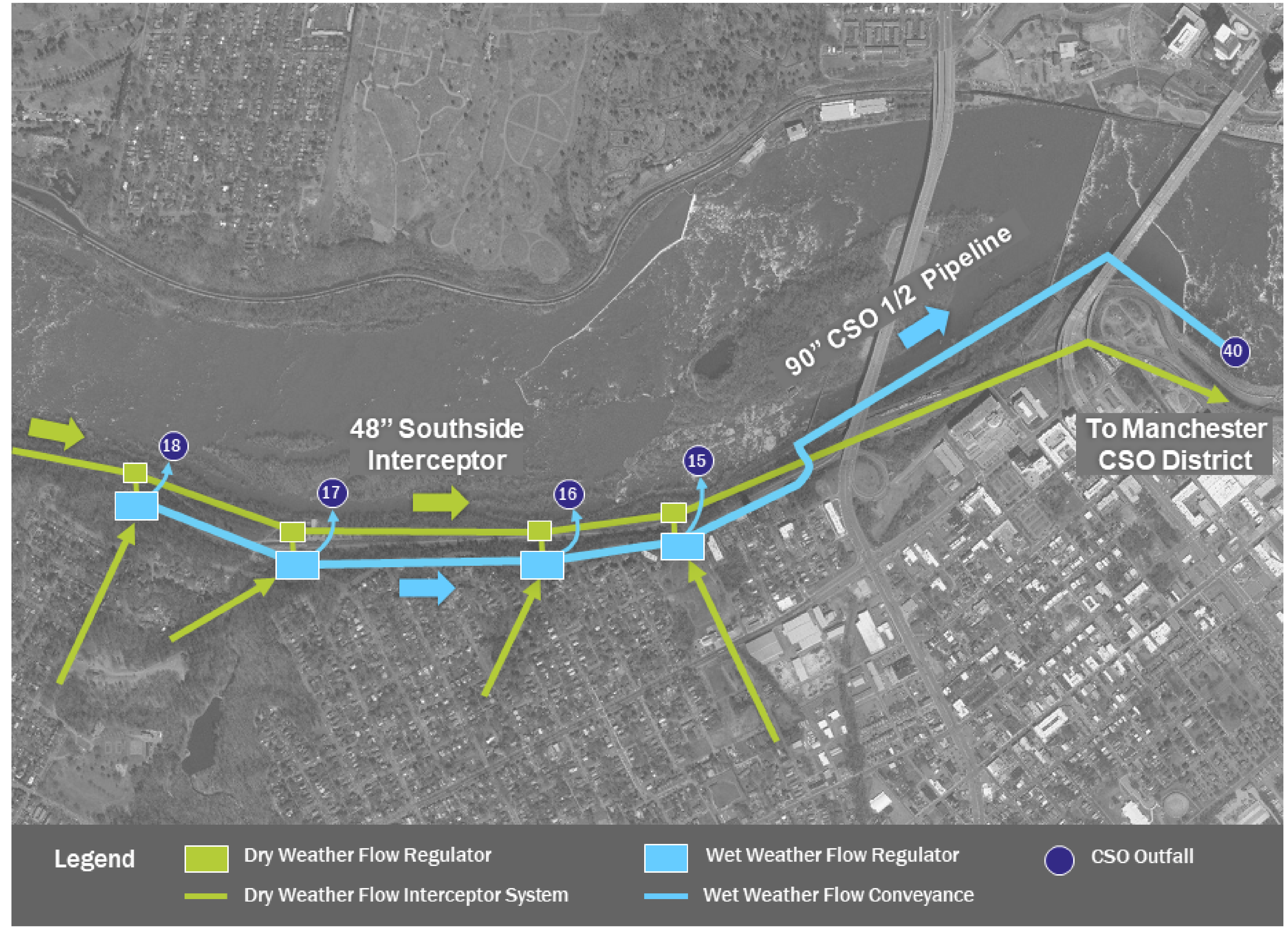
CSO CONTROL STRUCTURES: CSO Outfalls 15-18 each have two Regulator Control Structures:

- Dry Weather Flow (DWF) Regulator: Controls flow to the Interceptor System and to the WWF Regulators
- Wet Weather Flow (WWF) Regulator: Controls flow to the CSO 1/2 Conveyance Pipeline and to the local outfall

Flow from CSO 15-18 WWF Regulators is consolidated in the CSO 1/2 Pipeline and is conveyed downstream of the recreational area in the James River Park. During wet weather events, flow is discharged into the James River at the CSO 40 outfall, which is east of the 9th Street Bridge.

DWF CONDITIONS: Flow passes through the DWF Regulator static control devices and into the Southside Interceptor where it is conveyed to the Manchester CSO District.

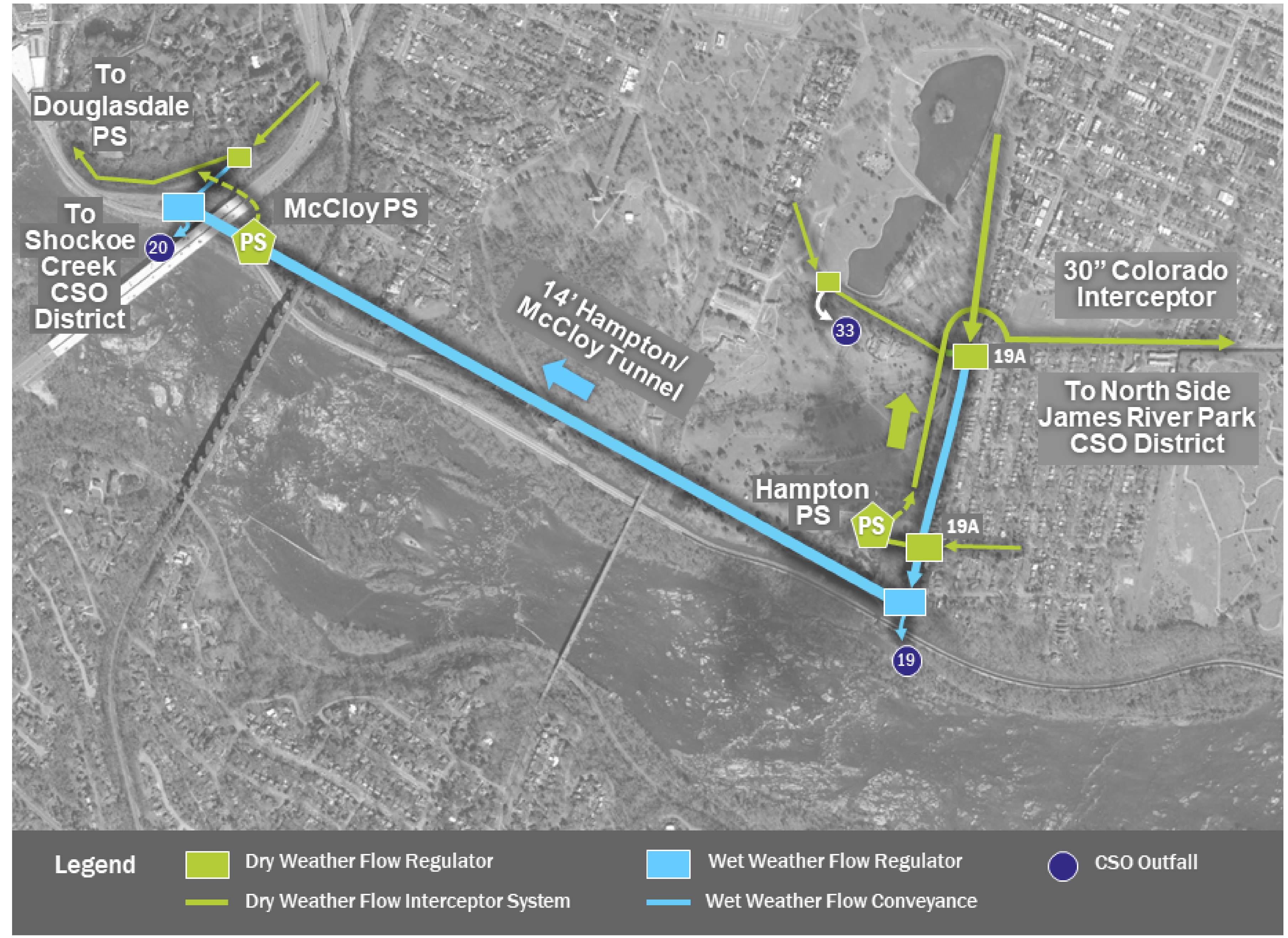
WWF CONDITIONS: Flow continues to the Southside Interceptor until its conveyance capacity or the capacity of the static control device in the DWF Regulator is exceeded. At that point, flow will begin to be sent to the CSO 1/2 Pipeline through the WWF Regulators. The CSO 1/2 pipeline conveys flow from the James River Park and discharges into the James River at CSO Outfall 40. In very large storm events, flow will overtop the static weirs in the WWF Regulators and will overflow at the local outfall in the James River Park. The WWF Regulators are designed to limit local outfall overflows (at Outfalls 15-18) to 2 or less per year.



CSO Outfall		2019 Reported Total Values[1]	
No.	Name	Overflow Volume (MG)	Overflow Activations (#)
15	Canoe Run	0	0
16	Woodland Heights	0	0
17	Reedy Creek	0	1
18	42nd Street	0	0
40	Diffuser	66.5	34

1: 2019 Discharge Monitoring Report Values

Hampton/McCloy



Additional flow can be diverted to the tunnel and away from the Shockoe Retention Basin (SRB), to better balance the flow distribution between the two storage facilities.

CSO CONTROL STRUCTURES: CSO Outfall 33 has one DWF Regulator Control Structure and CSO Outfalls 19 and 20 each have two types of Regulator Control Structures:

- DWF Regulator: Controls flow to the Interceptor System and to the local outfall/WWF Regulators. CSO 19 has two DWF Regulators (CSO 19A and CSO 19B).
- WWF Regulator – Controls flow to the Hampton/McCloy Retention Tunnel and to the local outfall

The Hampton/McCloy Retention Tunnel has a storage capacity of approximately 7.2 MG.

DWF CONDITIONS: Flow passes through the DWF Regulator static control device and into the Interceptor System where it is conveyed to either the North Side James River Park or Shockoe Creek CSO District.

WWF CONDITIONS: At CSO 33, flow continues to the Colorado Interceptor until its conveyance capacity or the capacity of the static control device in the DWF Regulator is exceeded. At that point, flow will enter an overflow pipe and overflow at the local outfall in Maymont Park. This outfall has a relatively small drainage area with infrequent overflow events (0-2 per year). At CSO 19A, 19B and 20, flow continues to the Interceptor System until conveyance and/or pumping capacity is limited or the capacity of the static control device in the DWF Regulator is limited. At that point, flow will begin to be sent to the downstream WWF Regulator. The WWF Regulators send flow to be stored in the Hampton/McCloy Retention Tunnel. Once the wet weather event has concluded, and the WWTP has available capacity, the tunnel is dewatered via the McCloy Pumping Station (PS) where flow is sent to the Douglasdale PS. Flow is then pumped from the Douglasdale PS to the Bacons Quarter Interceptor in the Shockoe Creek drainage area. In very large storm events, flow will overtop a static weir in the WWF Regulators and will overflow at the local outfalls. The operation of the Hampton/McCloy Retention Tunnel and the WWF Regulators are designed to limit local outfall overflows to 4 or less per year.

CSO Outfall		2019 Reported Total Values[1]	
No.	Name	Overflow Volume (MG)	Overflow Activations (#)
19	Hampton Street	0.49	2
20	McCloy Street	0.10	1
33	Shields Lake	0.07	2

1: 2019 Discharge Monitoring Report Values

North Side James River Park

Additional flow can be potentially diverted to the Hollywood Interceptor and away from the CSO 3 Pipeline, to better balance the flow between the two pipes.

CSO CONTROL STRUCTURES: CSO Outfalls 7 and 11 each have two types of Regulator Control Structures:

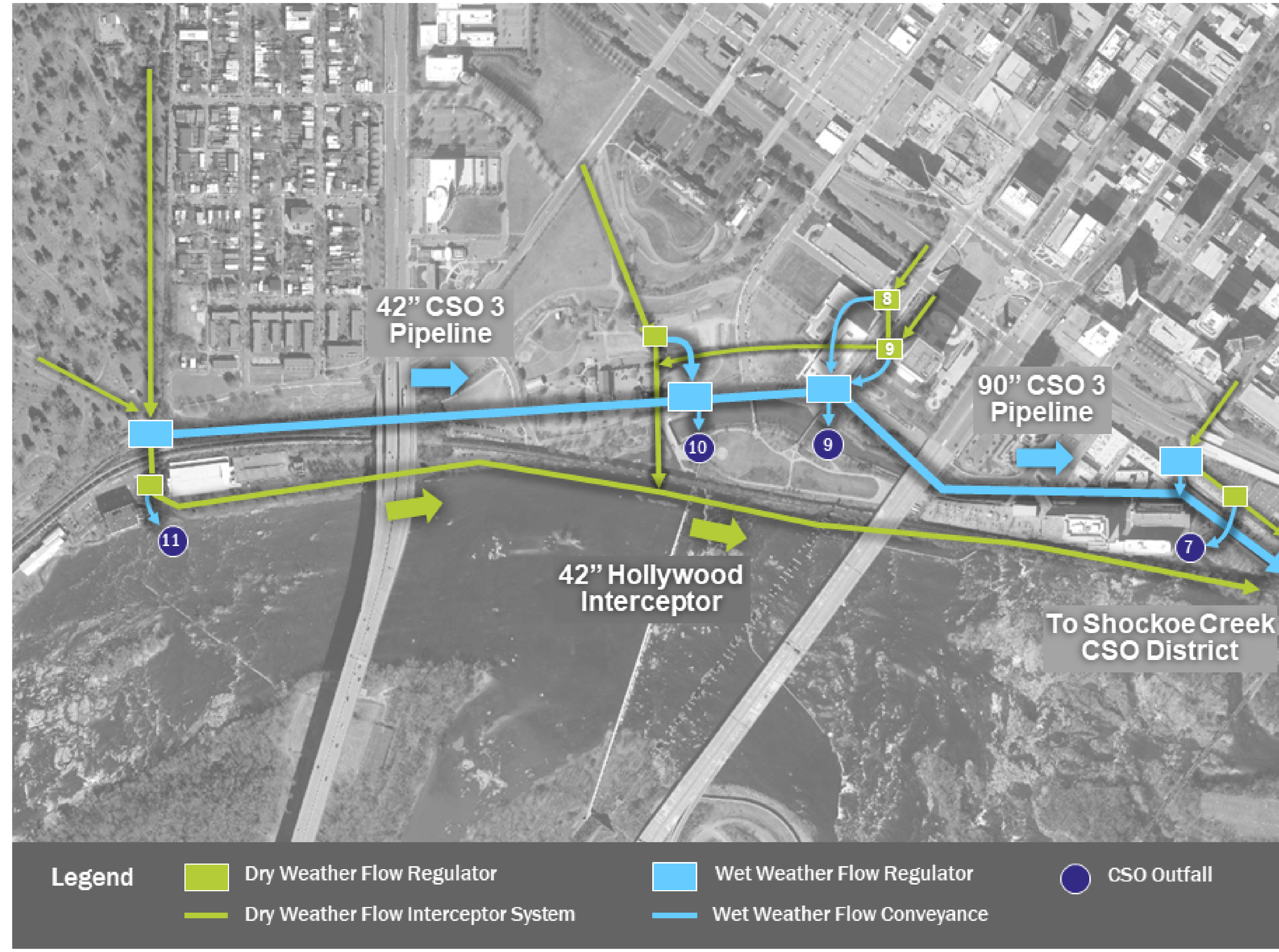
- WWF Regulator – Controls flow to the CSO 3 Conveyance Pipeline and to the DWF Regulators
- DWF Regulator – Controls flow to the Interceptor System and to the local outfall

CSO Outfalls 9 and 10 each have two types of Regulator Control Structures:

- DWF Regulator – Controls flow to the Interceptor System and to the WWF Regulators. CSO 09 has two DWF Regulators (CSO 08 and CSO 09).
- WWF Regulator – Controls flow to the CSO 3 Conveyance Pipeline and to the local outfall

DWF CONDITIONS: At CSO 7 and 10, flow passes through the DWF Regulator static control devices and into the Hollywood Interceptor where it is conveyed to the Shockoe Creek CSO District. At CSO 9, flow is diverted at the DWF Regulator into the CSO 3 Conveyance Pipeline where it is conveyed to the Shockoe Creek CSO District. At CSO 11, flow is diverted at WWF Regulator into the CSO 3 Conveyance Pipeline where it is conveyed to the Shockoe Creek CSO District.

WWF CONDITIONS: At CSO 7, flow continues to be sent to the Hollywood Interceptor until its conveyance capacity is exceeded. At that point, flow will overtop a weir in the WWF Regulator and will be sent to the CSO 3 Conveyance Pipeline. In large events, flow will enter an overflow pipe at the CSO 07 DWF Regulator and will overflow at the local outfall. At CSO 9, flow continues to be sent to the CSO 3 Conveyance Pipeline through the WWF Regulator. In very large events, flow will overtop a weir in the WWF Regulator and will overflow at the local outfall. At CSO 10, flow continues to be sent to the Hollywood Interceptor until its conveyance capacity is exceeded. At that point, flow will overtop a weir in the WWF Regulator and will be sent to the CSO 3 Conveyance Pipeline. In very large events, flow will overtop a weir in the WWF Regulator and will overflow at the local outfall. At CSO 11, flow continues to be sent to the CSO 3 Conveyance Pipeline until the capacity through the diversion control creates surcharging in the CSO 11 WWF Regulator. Flow will then overtop a weir and be sent to the CSO 11 DWF Regulator, where the flow will be sent to the Hollywood Interceptor. In large events when capacity is limited in the Hollywood Interceptor, flow will overtop a weir in the CSO 11 DWF Regulator and will overflow at the local outfall.



CSO Outfall		2019 Reported Total Values[1]	
No.	Name	Overflow Volume (MG)	Overflow Activations (#)
7	Byrd Street	2.10	6
9	6th and 7th Streets	0.81	4
10	Gambles Hill	4.17	3
11	Park Hydro	31.90	26

1: 2019 Discharge Monitoring Report Values

Shockoe Creek

The drainage operation of the SRB could be optimized by automating the drain gates and leveraging RT-DSS controls. The SRB needs to be drained quickly so the 35 MG storage volume can be available for the next storm.

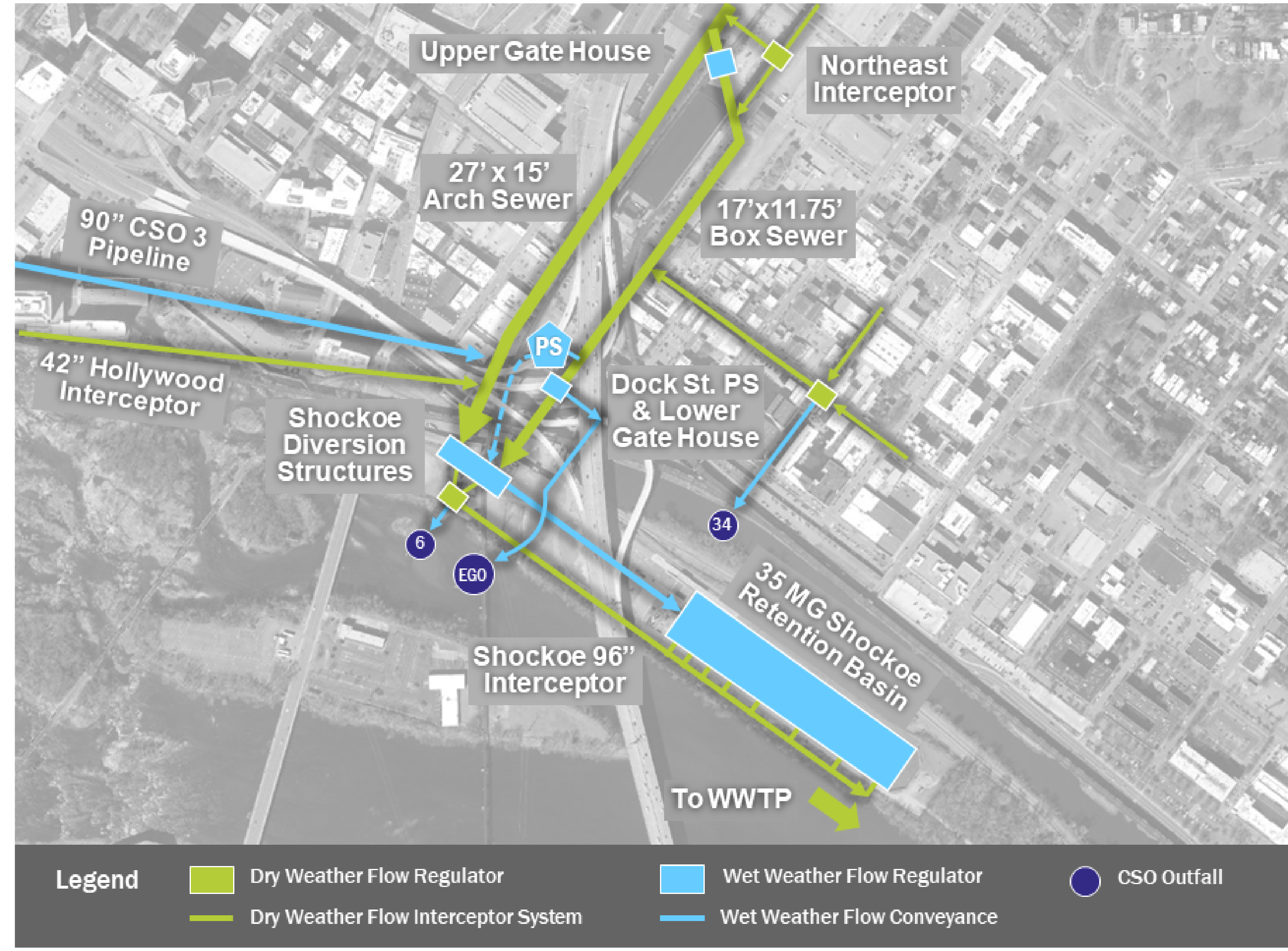
CSO CONTROL STRUCTURES: CSO Outfalls 06 and 34 each have one Regulator Control Structure:

- DWF Regulator – Controls flow to the Interceptor System and to the local outfall.

Several major upgrades have been made to improve the performance of the system and to improve the Shockoe area drainage and mitigate the local flooding. The Arch Sewer is 27'x15' sewer that conveys flow from the entire Shockoe Creek drainage area. The gate in the Upper Gate House was closed in the late 2000s to isolate the Arch Sewer from the Box Sewer. The Box Sewer is currently dedicated to receiving flow from the local Shockoe area to prevent local flooding. The Shockoe Diversion Structures divert flow from the Arch and Box Sewer, in wet weather to the 35 MG Shockoe Retention Basin (SRB). Gates in the Diversion Structures are also utilized to create an additional 15 MG of in-line storage in the Arch and Box Sewer. The flow in the Box Sewer needs to be pumped by the Dock Street PS (110 mgd capacity) to the Shockoe Diversion Structures in wet weather events. In order to prevent exceeding the capacity of the PS, the Northeast Interceptor was installed, to allow flow from the upstream drainage area to be conveyed to the Arch Sewer. The East Gravity Outlet (EGO) outfall is a stormwater outlet, that allows stormwater to be conveyed underneath the floodwall to the James River. The conduit was connected to the Box Sewer with a static and dynamic control device, to protect against upstream local flooding. If the level in the Box Sewer rises too high, flow may overtop a weir or pass through a gate and overflow at the EGO.

DWF CONDITIONS: Flow passes through the DWF Regulator static control device and into the Interceptor System where it is conveyed to the WWTP.

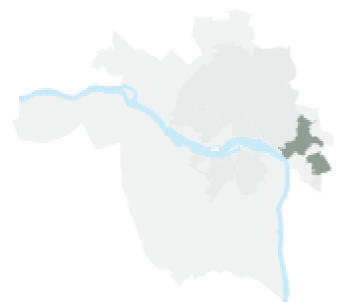
WWF CONDITIONS: At CSO 34, flow continues to the Box Sewer until its capacity is exceeded or the capacity of the static control device in the DWF Regulator is limited. At that point, flow will begin to be sent to the local outfall. At CSO 6, flow continues to the Shockoe 96" Interceptor until its conveyance capacity or the capacity of the static control device in the DWF Regulator is limited. At that point, gates in the Shockoe Diversion Structures will send flow to the SRB for storage and begin to utilize the upstream In-line storage. In large wet weather events, the storage capacity will be exceeded, and flow will overflow at the local outfall. Once the event has concluded, the in-line storage and SRB are emptied through drain gates, based on the capacity of the Shockoe 96" Interceptor and the WWTP.



CSO Outfall		2019 Reported Total Values[1]	
No.	Name	Overflow Volume (MG)	Overflow Activations (#)
6	Shockoe	1444.7	29
34	19th Street	1.21	6

1: 2019 Discharge Monitoring Report Values

Gillies Creek



Modifications to the Regulator structures would allow additional flow to the Gillies Creek Interceptor to potentially mitigate small overflow events. The CSO 04 regulator is also aging and could be optimized to take advantage of upstream in-line storage.

CSO CONTROL STRUCTURES: CSO Outfalls 04, 05, 24, 25, 26, 31 and 39 have one Regulator Control Structure:

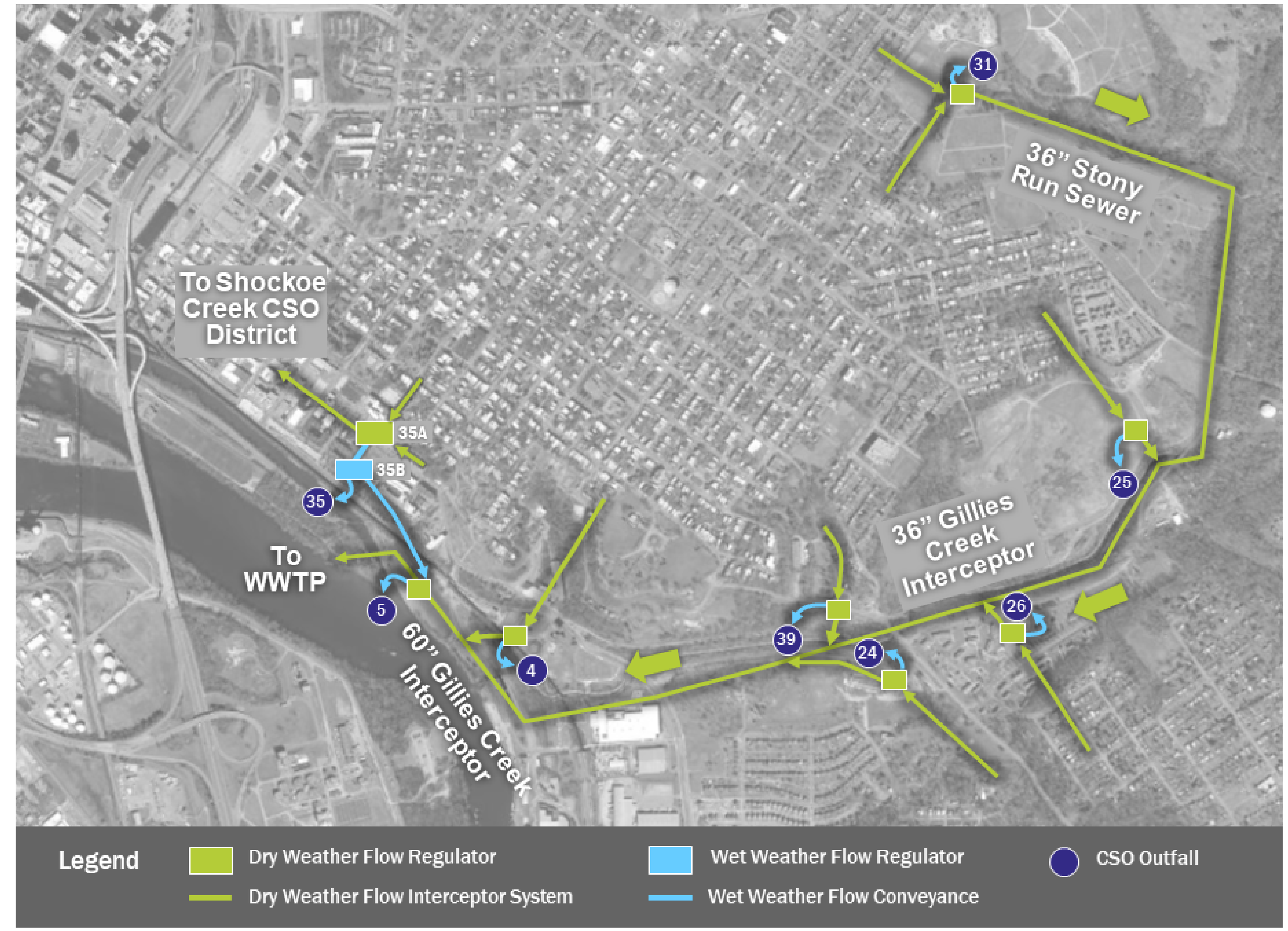
- DWF Regulator – Controls flow to the Interceptor System and to the local outfall

CSO Outfall 35 has two Regulator Control Structures:

- DWF Regulator (35A) – Controls flow to the Interceptor System in the Shockoe Creek CSO District
- WWF Regulator (35B) – Controls flow to the CSO 05 DWF Regulator and to the local outfall

DWF CONDITIONS: Flow passes through the CSO 04, 05, 24, 25, 26, 31 and 39 DWF Regulator static control devices and into the Gillies Creek Interceptor where it is conveyed to the WWTP. Flow passes through the CSO 35A DWF Regulator static control device to the Shockoe Box Sewer in the Shockoe Creek CSO District.

WWF CONDITIONS: At CSO 4, 5, 25, 26, 31, and 39, flow continues to be sent to the Gillies Creek Interceptor until its conveyance capacity or the capacity of the static control device in the DWF Regulator is limited. At that point, flow will pass through a bar rack (which screens out floatables), overtop a static weir in the DWF Regulator, and overflow at the local outfall, into Gillies Creek.
At CSO 35, flow continues to be sent to the Shockoe Box Sewer until its conveyance capacity or the capacity of the static control device in the 35A DWF Regulator is limited. At that point, flow will be conveyed to the 35B WWF Regulator through an overflow pipe. The 35B WWF Regulator will convey the flow to the CSO 05 DWF Regulator, or in large events, flow will overtop a weir and will be sent to a local outfall.



CSO Outfall		2019 Reported Total Values[1]	
No.	Name	Overflow Volume (MG)	Overflow Activations (#)
4	Bloody Run	13.57	43
5	Peach Street	7.28	20
24	Varina Street	7.31	16
25	Briel Street	2.38	12
26	Government Road	0	0
31	Oakwood Cemetery	6.65	13
35	29th and Dock Streets	1.22	15
39	Government Road	11.41	37

1: 2019 Discharge Monitoring Report Values

Manchester

The CSO 21 regulator is aging and could be optimized to take advantage of the available 1.5 MG upstream in-line storage.

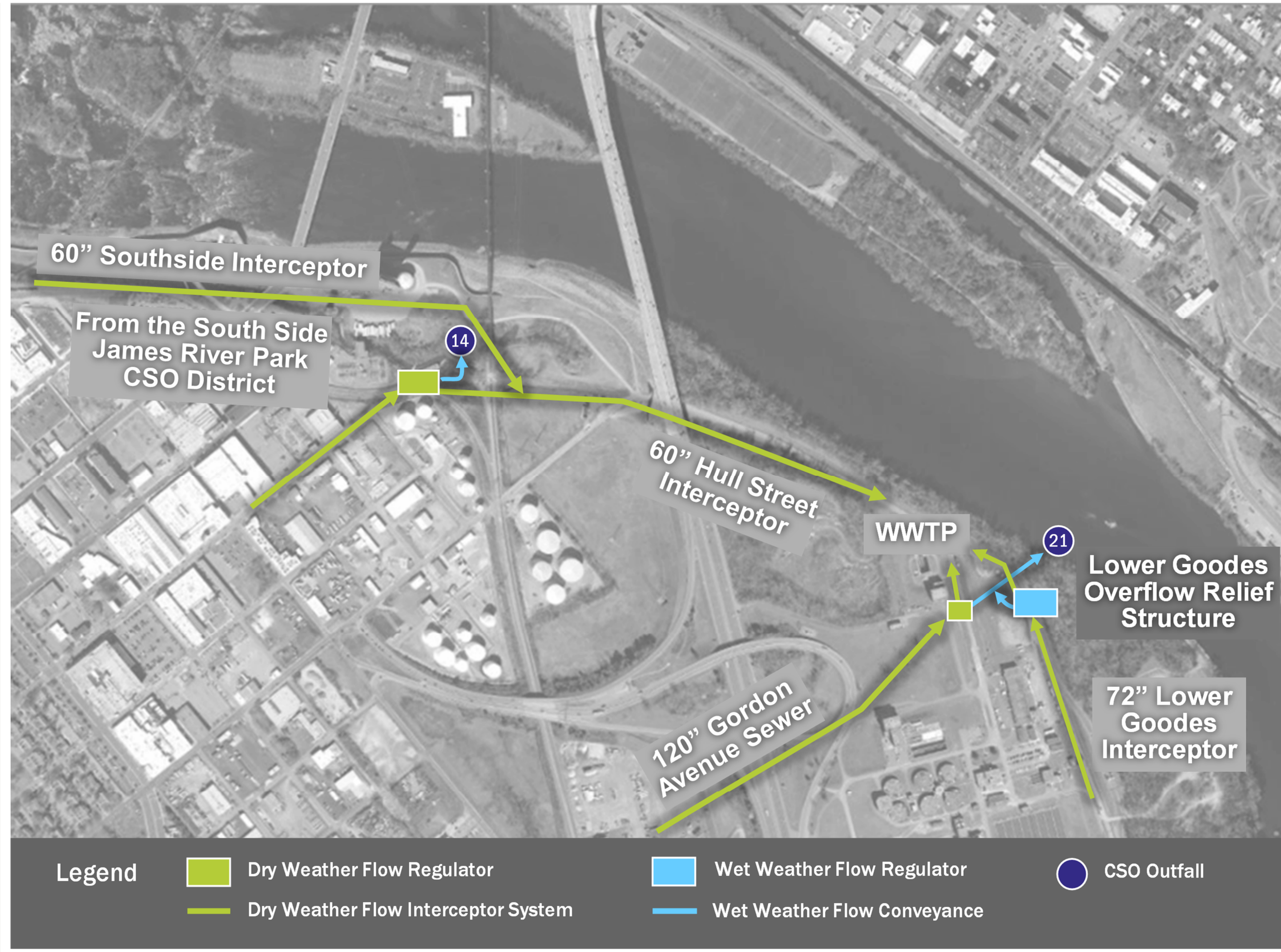
CSO CONTROL STRUCTURES: CSO Outfalls 14 and 21 each have one Regulator Control Structure:

- DWF Regulator – Controls flow to the Interceptor System and to the local outfall

The 72-inch Lower Goodes Interceptor may overflow into the CSO 21 outfall pipe through the Lower Goodes Overflow Relief Structure.

DWF CONDITIONS: Flow passes through the DWF Regulator static control device and into the Interceptor System where it is conveyed to the WWTP.

WWF CONDITIONS: At CSO 14, flow continues to be sent to the Hull Street Interceptor until its conveyance capacity or the capacity of the static control device in the DWF Regulator is limited. At that point, flow will pass through a bar rack (which screens out floatables), overtop a static weir in the DWF Regulator, and overflow at the local outfall, into the Manchester Canal. At CSO 21, flow continues to be sent to the WWTP until its conveyance capacity or the capacity of the static control device in the DWF Regulator is limited. At that point, flow will overtop a static weir in the DWF Regulator and will overflow at the local outfall. If the water level in the Interceptor System continues to rise in a wet weather event, flow may overtop a static control device in the Lower Goodes Overflow Relief Structure and overflow at the local outfall through the CSO 21 outfall pipe. This structure is key to ensure that upstream flooding in the interceptor system is minimized.



CSO Outfall		2019 Reported Total Values[1]	
No.	Name	Overflow Volume (MG)	Overflow Activations (#)
14	Stockon Street	74.71	38
21	Gordon Avenue	168.97	43

1: 2019 Discharge Monitoring Report Values

Hilton Street

This remote District is already optimized and will require a more extensive control project in the Final Plan.

CSO CONTROL STRUCTURES: CSO Outfall 12 has one Regulator Control Structure:

- DWF Regulator – Controls flow to the Interceptor System and to the local outfall

DWF CONDITIONS: Flow passes through the DWF Regulator static control device and into the Almond Creek Interceptor where it is conveyed to the Lower Goodes Interceptor.

WWF CONDITIONS: Flow continues to the Almond Creek Interceptor until its conveyance capacity or the capacity of the static control device in the DWF Regulator is limited. At that point, flow will pass through a bar rack (which screens out floatables), overtop a static weir in the DWF Regulator, and overflow at the local outfall, into Almond Creek.

CSO Outfall		2019 Reported Total Values[1]	
No.	Name	Overflow Volume (MG)	Overflow Activations (#)
12	Hilton Street	9.30	37

1: 2019 Discharge Monitoring Report Values

3.2 System Monitoring Data

The City has had a metering system for the past 30 years (which was updated through the years to ultimately include six rain gauges and 19 flow meters) to better understand how their CSS is operating and where potential improvements could be made.

In 2018, the City expanded their CSS metering system to collect additional system data. The expansion, shown in Figure 3-2, included the following additional equipment:

- 4 Rain Gauges (10 in total) – Distributed spatially throughout the City
- 5 Flow Meters (24 in total) – Distributed spatially throughout the critical sewer interceptors
- 26 Level Sensors (26 in total) – Installed primarily in CSO Regulator Control Structures

Rainfall, flow, and level data provided meaningful insight into how the CSS was operating during wet weather events and allowed the identification of potential improvements to optimize/maximize the use of the existing infrastructure.

The data collected from January-December 2019 were also utilized to update the City's CSS Hydrologic and Hydraulic (H&H) model, so that it could better serve as a performance evaluation tool for the Interim Plan.

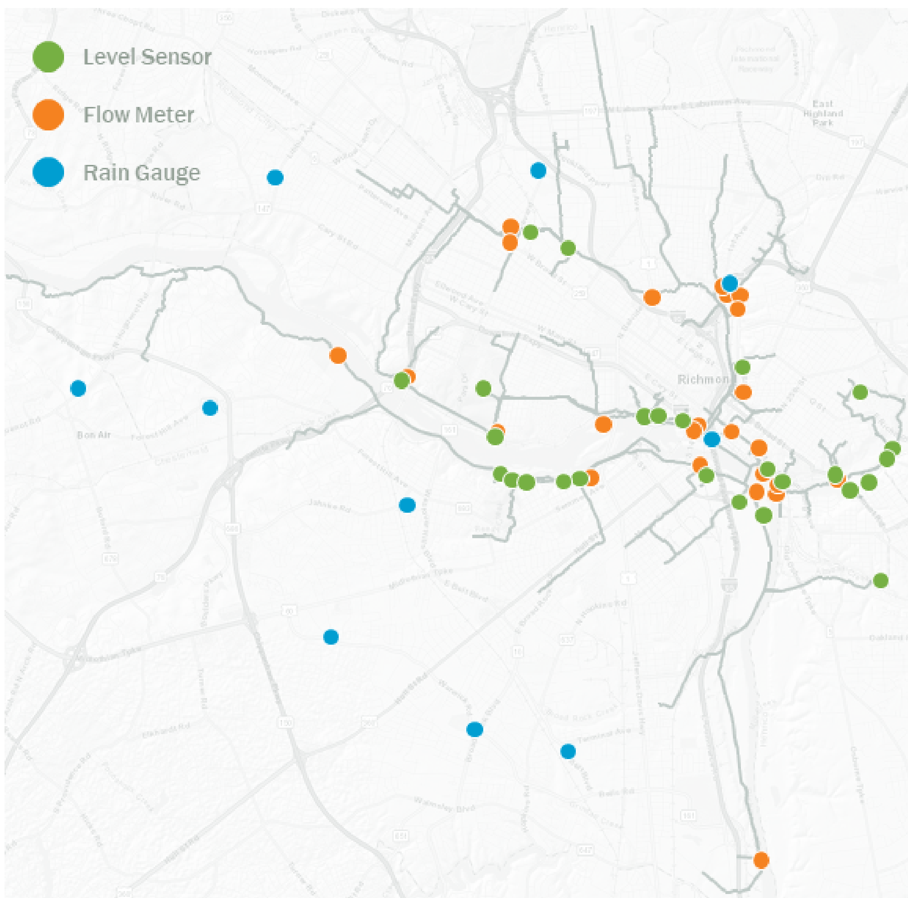


Figure 3-2: CSS Monitoring System

3.2.1 Rainfall Data

The City's rainfall distribution is highly variable. To better characterize the rainfall distribution throughout the system ten (10) rain gauges were installed throughout the City. Rainfall data from the NOAA Richmond International Airport (RIC) were also collected to augment any potential data gaps from the 10 system rain gauges.

Data Summary:

- Six (6) rain gauges were out of service for prolonged periods of time and were not utilized in the CSS H&H model update
- The RIC rain gauge provided continuous data throughout the 2019 year
- M-07 (the rain gauge installed in Shockoe) was out of service for prolonged periods of time. While it was in service it tracked very closely with the RIC rain gauge. Therefore, the RIC rain gauge was identified as a suitable replacement for the M-07 rain gauge, for the 2019 evaluation period.
- The remaining four (4) rain gauges: FS-19, FS-22, FS-23, and FS-24, contained sporadic data gaps that were augmented using data from the RIC rain gauge.

The augmented rain gauge data were then assigned to the CSS H&H model subcatchments to better represent the City's variable rainfall distribution. The NOAA RIC rain gauge (substitute for the rain gauge located in Shockoe) was assigned to the City's northeastern subcatchments in the CSS H&H model.

Figure 3-3 shows the five (5) rain gauges: FS-19, FS-22, FS-23, FS-24, and the NOAA RIC, distributed throughout the CSS H&H model.

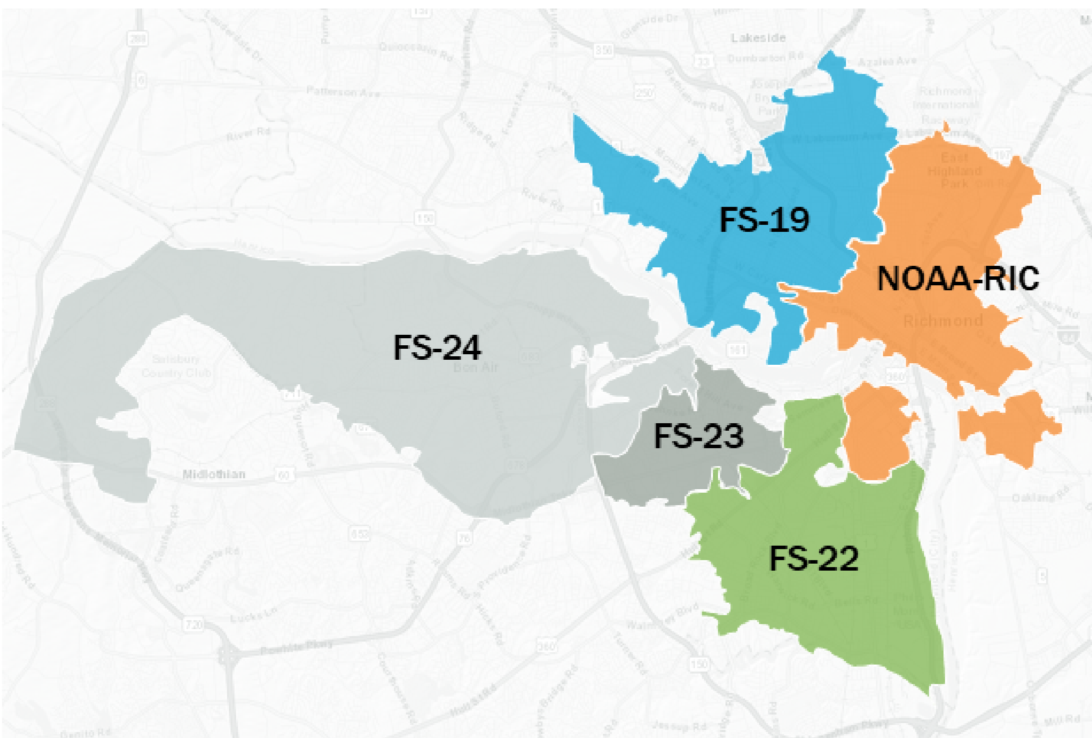


Figure 3-3: CSS H&H Model Rain Gauge Distribution

3.2.2 Flow and Level Data

Collected data were used to support model updates to improve its use as an evaluation tool.

As referenced in Section 3.2, five additional flow meters and 26 level sensors were installed throughout the City's CSS to expand their monitoring program and collect level and flow data.

The collected data were compared to the CSS H&H model results and were used to support further modifications and adjustments to the model. Figure 3-4 shows an example of the modifications made in the South Side James River Park CSO District.

Data Summary:

- Several of the flow meters had significant data gaps
- Level sensors were installed in critical CSO Control Structures, typically upstream of overflow weirs and provided fairly complete data sets
- Data sets for the flow meters and level sensors were edited to adjust for minor gaps. At several locations the flow meter data were unusable due to large missing data gaps (meter dropouts) and data instabilities.

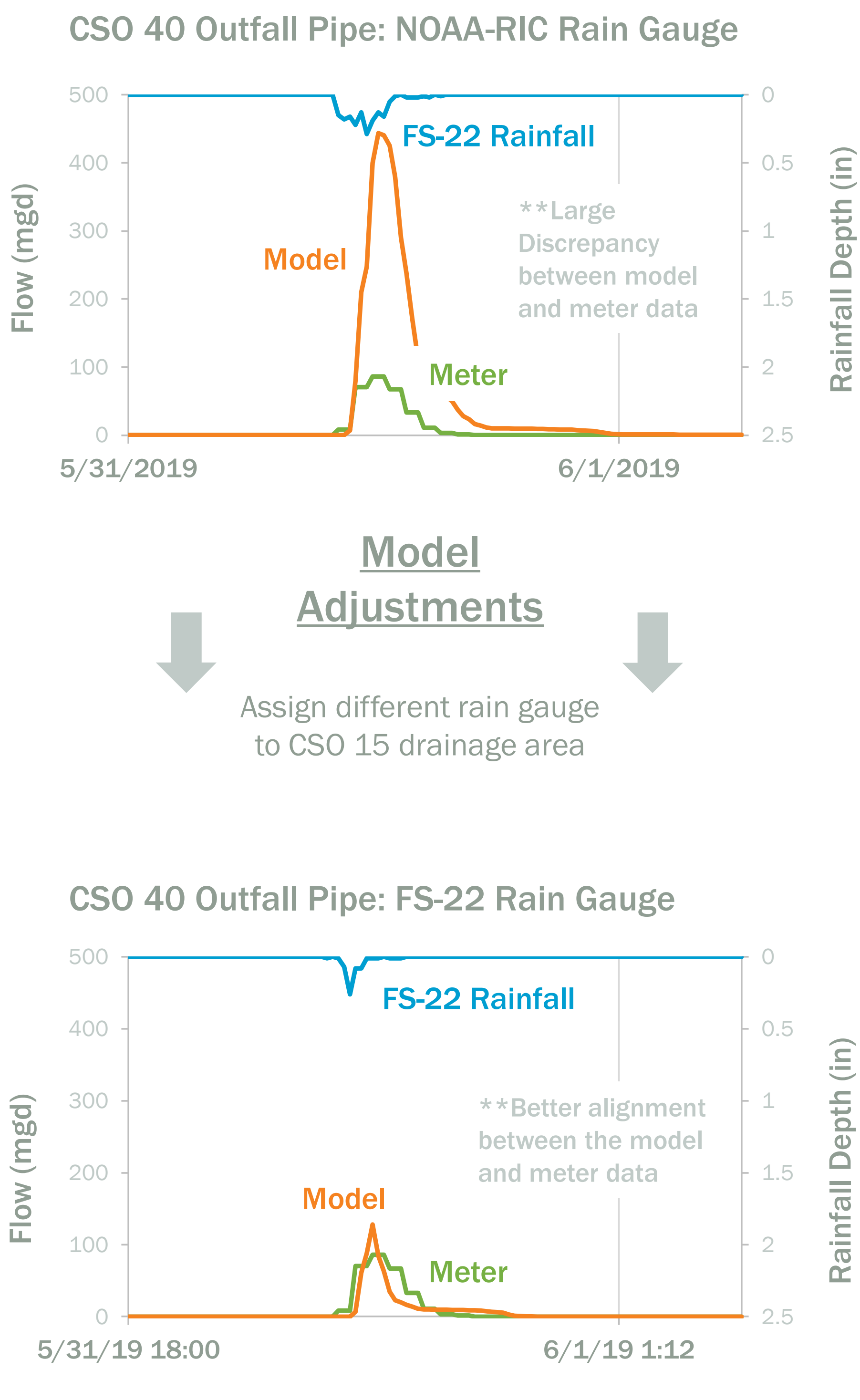


Figure 3-4: Model Adjustments in South Side James River Park CSO District

3.3 CSS Hydrologic and Hydraulic Modeling

The updated CSS H&H model, informed by the system monitoring data, was used as an evaluation tool for the Interim Plan. The evaluation period for the Interim Plan Projects and other additional modeling scenarios was January 2019 through December 2019, to make best use of the recently collected system data.

Volume and frequency of CSO discharge at individual CSO outfalls were the principal model results assessed to quantify performance of the CSS Improvements.

3.3.1 Model Updates

Due to the time constraints of the Interim Plan, the CSS H&H model was not fully re-calibrated. Instead, known areas of potential Interim Plan Projects were updated in the model. Work to be conducted for the Final Plan will involve a more thorough model recalibration effort. The model network and control areas were reviewed in key areas and several adjustments were made to:

- The model pipe network to be consistent with Record Drawings and/or current conditions
- The control rules to better reflect current operational protocols followed by the City
- The subcatchment hydrologic parameters to allow for better convergence of the modeling results with the collected system data
- The subcatchment rain gauge assignments to better account for rainfall variability

A detailed description of the CSS H&H model updates is included in Appendix B.

3.3.2 Existing Conditions

The Existing Conditions Modeling Scenario was developed to represent the City's CSS during the evaluation period, 2019. The Existing Conditions Scenario informed adjustments in the model to better align the modeling results with the collected system data.

3.3.3 Baseline Scenario

The Baseline Condition Scenario represents the Existing Condition, including projects that are scheduled to be complete before the required initiation of the Interim Plan Projects (July 1, 2022).

The projects currently in progress, and included in the Baseline Scenario, are:

- WWTP wet weather treatment up to 140 mgd
- Replacement/repair of the tide gates at CSO Outfalls 04, 05 and 21
- Cleaning of the Shockoe 96-inch Interceptor
- Cleaning of the Twin 66-inch Siphons

The Baseline Scenario will be used as a reference point for comparison against all other modeling results.

The Baseline Scenario, under the 2019 reported rainfall conditions produced a simulated overflow volume of 800.5 MG.

3.4 Receiving Water Data

Receiving water monitoring data have been collected by the City, in a partnership with the Virginia Commonwealth University (VCU), and the James River Association (JRA) since 2010.

The eight (8) monitoring stations and their sampling frequency are shown in Figure 3-5:

Figure 3-5: Monitoring stations

An evaluation of the data showed that *E. coli* concentrations are the lowest at the upstream boundary (Huguenot station) and are elevated at larger CSO Outfalls (CSO-40, CSO-06, and in Gillies Creek).

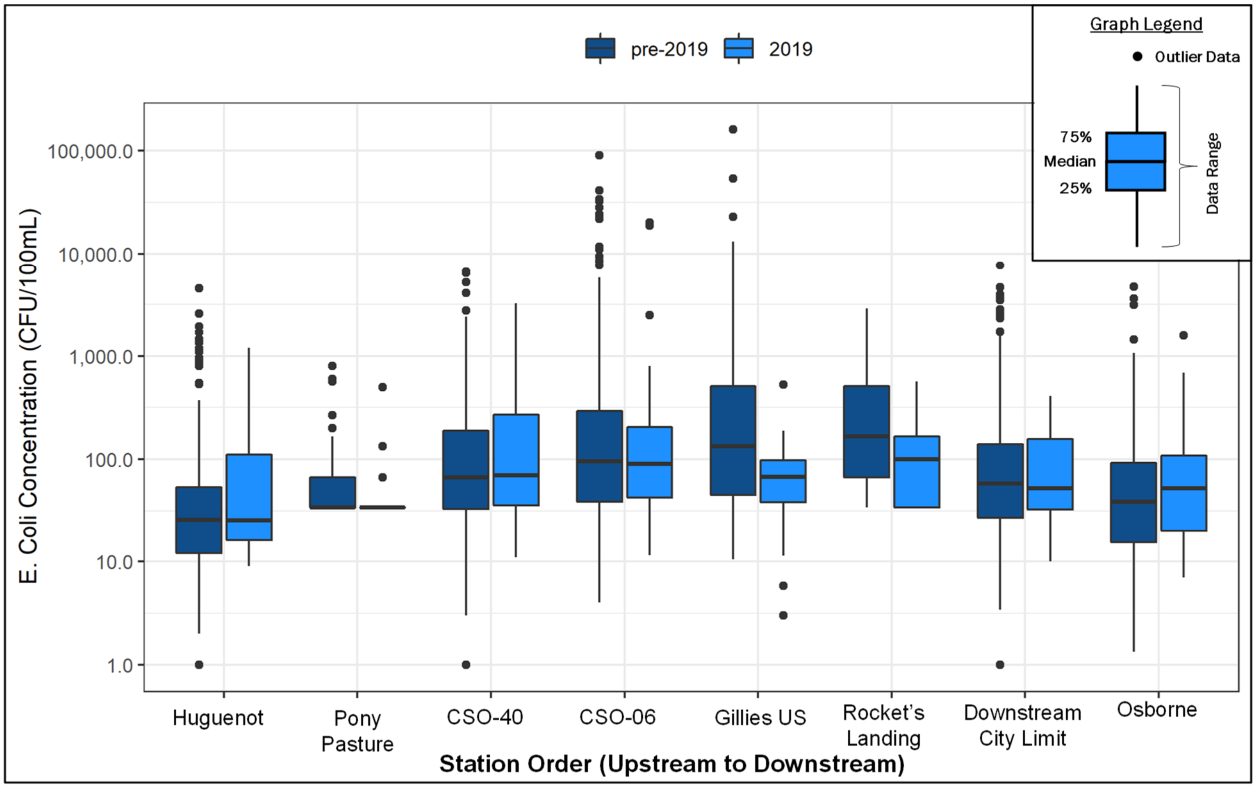


Figure 3-6: E. coli concentrations along the James River

The Virginia Water Quality Standards (WQS) state that in freshwater, *E. coli* bacteria concentrations shall not:

1. Exceed a geometric mean of 126 counts/100ml, over a rolling 90-day period
2. Exceed a 10% excursion frequency of a statistical threshold value (STV) of 410 counts/100 ml, over a rolling 90-day period

Exceedance of *E. coli* water quality standards occur at each of the (8) monitoring locations. Exceedances of the STV standard occur more frequently than exceedances of the geomean standard. The variability from station to station is likely influenced as much by the limited number of samples as it is by the actual *E. coli* sources.

3.5 Water Quality Modeling

Bacteria load reduction and improvement towards Water Quality Standards compliance, were the principal model results assessed to quantify the benefits associated with potential CSS Improvements.

3.5.1 Model Updates

The water quality model developed to support the City's 2017 Clean Water Plan was updated to evaluate potential CSS Improvements over the 2019 calendar year. The major updates to the model include:

- James River upstream flow inputs, and tidal water levels to represent the 2019 flow conditions.
- James River upstream *E. coli* concentration inputs, based on collected 2019 data
- Richmond MS4 and CSO flows and *E. coli* source inputs to represent the 2019 conditions

3.5.2 Existing Conditions

The Existing Conditions Modeling Scenario was developed to represent the James River *E. coli* concentrations during the 2019 evaluation period. The modeled *E. coli* concentrations were compared to observed concentrations at the (8) locations along the James River.

- The water quality model captures the variability and magnitude of the upstream *E. coli* concentrations entering the City.
- The water quality model captures the variability and magnitude in *E. coli* concentrations that are driven by CSO volume. This is particularly noticeable during local rain events throughout the year. These events result in short, high spikes in *E. coli* concentrations in the James River, particularly at major CSO discharge points, like CSO-06.
- The two largest contributors to exceedances of the Water Quality Standards are upstream sources and CSO volume.

A detailed description of the Existing Conditions Model Scenario and the water quality modeling results are included in Appendix C.

3.5.3 Baseline Scenario

The Baseline Condition Scenario represents the Existing Condition and includes projects that are identified in Section 3.3.3.

The Baseline Scenario, simulated based on 2019 conditions, improved the compliance with WQS.

The Baseline Scenario will be used as a reference point to compare all other modeling results against.

Table 3-1. Baseline Scenario Water Quality Improvement

Improvement (%) towards compliance with water quality standards (0%: Existing Scenario – 100%: Full Compliance)	
Geomean WQS	STV WQS
0.4%	10.8%

SECTION 4

Project Identification

In 2018, the City began studying the potential opportunities to utilize Real Time Decision-Support System (RT-DSS) control technology to optimize the performance of their CSS. The projects identified in the Interim Plan are informed by the initial RT-DSS Study, and an additional systemwide evaluation that identified additional improvement opportunities.

4.1 RT-DSS Controls

RT-DSS control technology is an effective option for optimizing infrastructure performance. The controls are informed by real time system monitoring data and provide the ability for equipment to automatically adjust in response to wet weather based on current system operating conditions. These adjustments can optimize the use of the existing infrastructure and facilities, in order to increase the performance of the system in a more cost-effective manner than building new infrastructure. Such facilities are only feasible in certain locations and up to certain locations and up to certain levels of performance.

4.2 Project Types

The projects identified in the Interim Plan leverage the use of the RT-DSS control technology to better balance the flow between the CSO districts and optimize the use of the existing infrastructure. These projects can be characterized into four groups and are further described in the following sections:

In-Line Storage	Leverage existing large-diameter sewers (>72-inch diameter) to reduce overflow volume
Diversion	Replace the fixed controls with RT-DSS controlled mechanical equipment, that will better manage flow across the CSS and reduce overflows
Dynamic Underflow Control	Maximize flow sent downstream for treatment to prevent premature CSO overflows
Controls Update	Optimize the control strategy at several key CSO Management facilities to improve the performance of the CSS

4.2.1 In-Line Storage

The City's CSS includes many large diameter sewers (>72-inch diameter), which are utilized for the conveyance of combined sewage. The purpose of an in-line storage project is to use a large diameter sewer as a linear storage facility in wet weather events, which allows unused conveyance capacity to be used as storage, reducing downstream peak flows and overflow volume. This strategy is particularly useful in a large CSS that experiences geographically variable rainfall. In order for a sewer to be considered as a potential in-line storage candidate, it must meet the following key criteria:

- Large potential storage volume (large diameter, long length, and relatively flat slope)
- No adverse hydraulic upstream impacts (storage in the pipe does not cause surface flooding or basement backups)

A new hydraulic control structure must be installed on the existing sewer to achieve the upstream in-line storage. An example of this control structure is shown in Figure 4-1.

In-Line Storage **In-Line Storage projects will leverage EXISTING infrastructure to reduce overflow volume.**

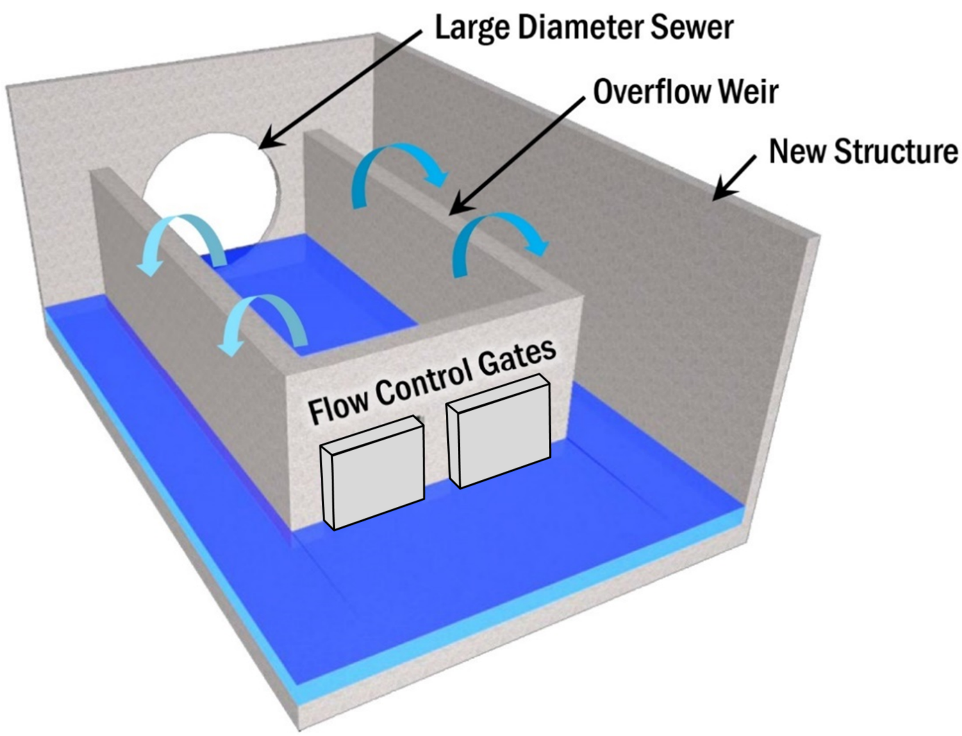


Figure 4-1: Example In-Line Storage Control Structure Project (Xylem)

In normal dry weather conditions, flow will enter the structure and pass through the open flow control gates and continue downstream through the interceptor system.

In wet weather conditions, the flow control gates will be closed or lowered, and flow will begin to be stored upstream in the sewer. Once the storage capacity in the upstream sewer has been reached, and the in-line storage structure fills up, the excess flow will overtop the weir and travel downstream. The overflow weir is designed to prevent upstream flooding and surcharging conditions. Once the wet weather event is over, the flow control gates will be opened to allow the stored flow to travel downstream through the interceptor system.

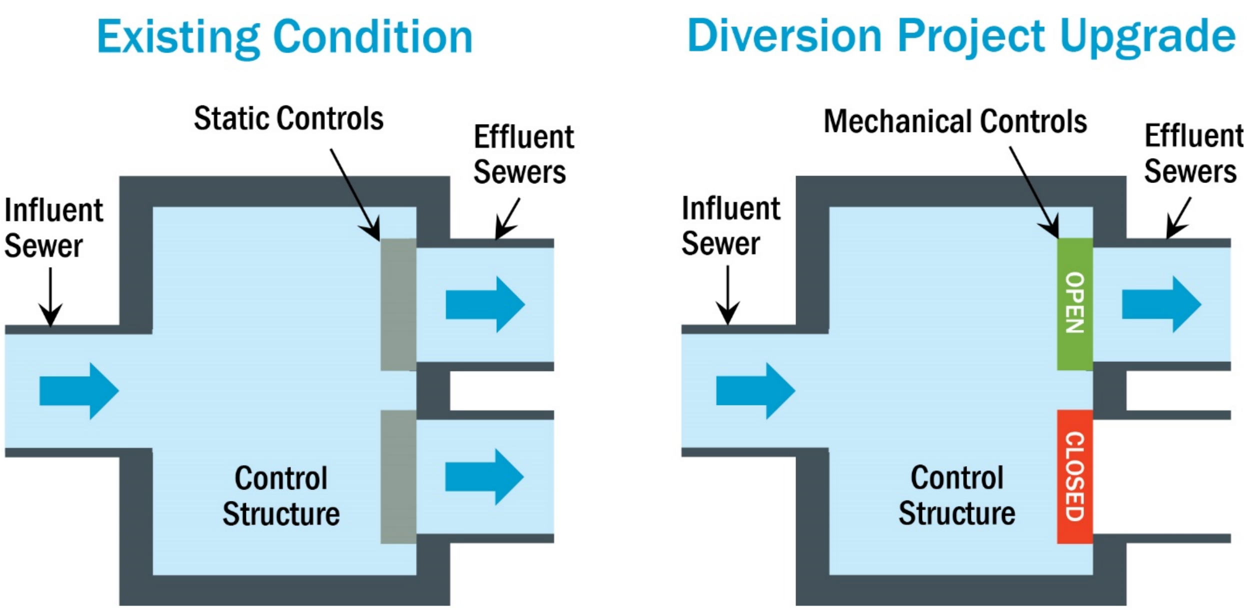
4.2.2 Diversion

The City's CSS contains many structures, which are utilized to control the flow direction of the combined sewage through the interceptor system. These structures currently use static controls (weirs, orifices, etc.) to control the flow direction, which are governed by local hydraulic conditions.

A Diversion Project replaces the static controls with RT-DSS controlled modulating mechanical equipment. The RT-DSS controls will evaluate current system capacity conditions and make an informed decision on where flow should be diverted. These improvements will serve to better balance the flow between CSO districts and maximize the use of the existing infrastructure.

An example of a Diversion Project upgrade is shown in Figure 4-2.

Diversion — **With a Diversion Project upgrade, RT-DSS controls evaluate the capacity of CSS infrastructure and divert flow to underutilized infrastructure.**



Static controls are governed by local hydraulic conditions.

RT-DSS controls make an informed decision on where flow should be diverted based on available capacity.

Figure 4-2: Example Diversion Project

4.2.3 Dynamic Underflow Control

The City's CSS includes regulator control structures installed at each outfall. In wet weather events, these structures are designed to send a specific flowrate to the downstream interceptor, and any excess flow is designed to overflow at the outfall to prevent flooding in the upstream sewer system. The structures utilize static controls (weirs, orifices, etc.) to control the flow to the interceptor and to the outfall.

Due to the City's variable rainfall, intense storm events could occur that affect small portions of a CSO District, while the rest of the area is unaffected. In these events, this could lead to the overwhelming of one or several regulator control structures while the downstream system has available capacity. The affected regulator control structures do not have the capability to send any additional flow to the downstream interceptor through the existing control devices, despite there being available capacity, so the excess flow is sent to the local outfall to prevent upstream flooding.

A Dynamic Underflow Control Project provides an additional mechanically controlled device in the structure, which is controlled by the RT-DSS. The RT-DSS controls will evaluate the capacity of the downstream interceptor and will modulate the new control device to send more or less flow downstream as capacity allows. These improvements will allow the Interceptor System capacity to be maximized before an overflow occurs.

An example of a Diversion Project upgrade is shown in Figure 4-3.

Dynamic Underflow Control — **Dynamic Underflow Control will maximize the use of the downstream infrastructure to prevent premature CSO overflows.**

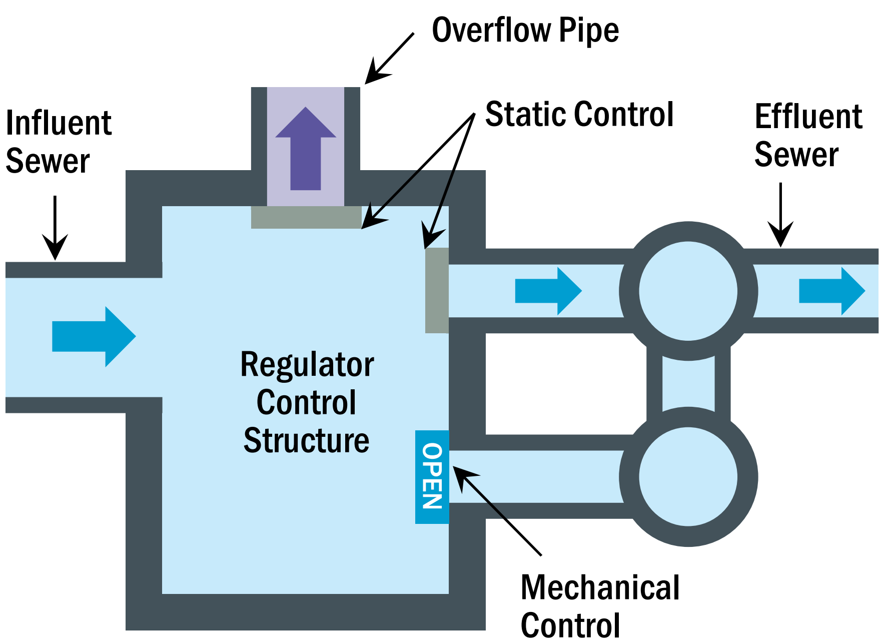


Figure 4-3: Example Dynamic Underflow Control Project

4.2.4 Controls Update

The City's CSS includes several key facilities:

- Shockoe Storage System
  - SRB (35 MG of Storage)
  - Shockoe In-line Storage (15 MG of Storage)
- Hampton/McCloy Tunnel (7.2 MG of Storage)
- WWTP
  - Full Treatment (75 MGD)
  - Wet Weather UV Disinfection Facility (additional 65 MGD peak flow rate after primary treatment)

The large capacity of these facilities makes their operation critical to the overall performance of the City's CSS.

Prior to wet weather events, it is key that storage facilities have been emptied to the fullest practical extent, so that the full storage capacity may be utilized. If these facilities are not drained adequately, the available storage capacity may be limited which would inhibit the performance of the system and increase overflow volume. The RT-DSS controls will evaluate current system capacity conditions and make an informed decision on when the storage facilities should be drained and at what flowrate.

In wet weather events, it is also key that the WWTP has the capability to make full use of its 140 MGD treatment capacity, and that the operation of the new Wet Weather UV (WWUV) is optimized. The RT-DSS controls will evaluate current system flow and level conditions and make an informed decision on when the WWUV Facility should be brought on-line. Any such operations would need to be consistent with the City's WWTP discharge permit.

4.3 Initial Project Screening

The City's CSS was evaluated for opportunities to utilize RT-DSS technology controls to maximize the use of the existing infrastructure. After an initial assessment, 20 potential projects were identified.

Once the initial 20 projects were identified, a screening process was followed to further investigate the feasibility and practicality of each project. The initial screening process included an evaluation of the following:

- Constructability
- Hydraulics/Flooding Risks
- Operability

Through the screening process, several projects were modified due to constructability and operability concerns. Two (2) projects were eliminated from further consideration due to hydraulic and operability concerns.

At the conclusion of the screening process, 18 projects remained for further evaluation. These projects are illustrated in Figure 4-4. A detailed description of each of the identified projects is available in Appendix D.

Figure 4-4 Identified Projects

Table 4-1. Summary of Identified Projects

	PROJECT	PROJECT DESCRIPTION
In-Line Storage		
1	BQ-ILS1	Installation of two new in-line storage structures in an upstream reach of the Bacon's Quarter Sewer (approx. 1.0 MG of storage)
2	CSO 21	Relocation of the Regulator to store CSO in the Gordon Avenue Sewer (approx. 1.5 MG of storage)
3	CSO 40 #1	Installation of new in-line storage structure on the CSO 1/2 Pipeline near the CSO 15 Regulator (approx. 1.1 MG of storage)
4	CSO 40 #2	Installation of new in-line storage structure and pumping station on the CSO 1/2 Pipeline at the CSO 40 outfall (approx. 1.6 MG of storage)
Diversion		
5	CSO 11	Replacement of an existing gate with mechanical control to be able to divert flow between the Hollywood Interceptor and the CSO 3 Pipeline
6	CSO 19A	Installation of mechanical control to be able to divert flow between the Hampton/McCloy Retention Tunnel and the Colorado Interceptor (conveys flow to North Side James River Park CSO District)
7	CSO 19B	Installation of mechanical control to be able to divert flow between the Hampton/McCloy Retention Tunnel and the Hampton PS (conveys flow to the North Side James River Park CSO District)
8	CSO 20	Installation of mechanical control to be able to divert flow between the Hampton/McCloy Retention Tunnel and the Douglasdale PS
9	NE-G11	Installation of mechanical control to be able to divert flow between the Shockoe Arch Sewer and the Shockoe Box Sewer
10	NE-G14	Installation of mechanical control to be able to divert flow between the Shockoe Arch Sewer and the Shockoe Box Sewer
Dynamic Underflow Control		
11	CSO 04	Relocation of the Regulator, to provide upstream in-line storage and the installation of a secondary mechanical control to send additional flow to the Gillies Creek Interceptor as capacity allows
12	CSO 05	Installation of secondary mechanical control to send additional flow to the Gillies Creek Interceptor as capacity allows
13	CSO 15	Installation of secondary mechanical control to send additional flow to the Southside Interceptor as capacity allows
14	CSO 24	Installation of secondary mechanical control and small diameter sewer to send additional flow to the Gillies Creek Interceptor as capacity allows
15	CSO 31	Installation of secondary mechanical control and small diameter sewer to send additional flow to the Gillies Creek Interceptor as capacity allows
16	CSO 39	Installation of secondary mechanical control and small diameter sewer to send additional flow to the Gillies Creek Interceptor as capacity allows
Controls Updates		
17	Level 1 Controls	Automation of the drainage operation at the Shockoe Retention Basin and reduced dewatering flowrates at the Hampton/McCloy Retention Basin to give priority to the drainage of the Shockoe Retention Basin
18	Level 2 Controls	Improvements of the WWTP Main Pumping Station to optimize the operation of the 65 MGD Wet Weather UV Disinfection Facility

SECTION 5

Project Evaluation

Following the initial screening, the 18 identified projects were evaluated for performance, schedule, and other qualitative benefits/impacts to identify the most impactful, cost-effective solutions.

5.1 Performance Evaluation

5.1.1 CSS H&H Model Results

The 18 identified projects were built into the CSS H&H model, and model simulations were run for each individual project. The model results were then compared back to the Baseline Modeling scenario (Section 3.3.3 and Appendix B) to quantify improvements to the following performance metrics:

Overflow Volume Reduction (MG)	The projects have system-wide impacts, so the system-wide overflow volume reduction was evaluated
Overflow Event Reduction (#)	The projects have system-wide impacts, so the system-wide overflow event reduction was evaluated
Remaining Local Overflow Events (#)	Some of the projects can be attributed to a specific outfall. For these projects, the remaining overflow events after project completion were evaluated to determine which projects would result in very few remaining overflows
Bacteria Load Reduction (Billion cfu/year)	Bacteria loads were calculated using the *E. Coli* CSO Event Mean Concentrations (EMCs) that were utilized in the *2017 RVA Clean Water Plan*.

Table 5-1 summarizes improvements to these performance metrics, as compared to the Baseline Modeling Scenario.

Table 5-1. Project Performance Evaluation Summary

PROJECT		PERFORMANCE			
		Overflow Volume Reduction (MG)	Overflow Event Reductions (#)	Remaining Local Overflow Events (#)	Bacteria Load Reduction (Billion CFU/year)
In-Line Storage					
1	BQ-ILS1	8.5	2	15	35,000
2	CSO 21	16.2	17	36	24,000
3	CSO 40 #1	12.3	1	40	162,000
4	CSO 40 #2	42.7	27	15	507,000
Diversion					
5	CSO 11	0.1	2	10	0
6	CSO 19A	10.3	2	1	39,000
7	CSO 19B	2.2	2	1	9,000
8	CSO 20	8.9	1	0	34,000
9	NE-G11	1.2	-1[A]	15	2,000
10	NE-G14	0.3	2	15	2,000
Dynamic Underflow Control					
11	CSO 04	5.1	48	5	62,000
12	CSO 05	0.5	2	12	2,000
13	CSO 15	0.0	0	40	4,000
14	CSO 24	3.8	26	21	45,000
15	CSO 31	1.1	2	15	6,000
16	CSO 39	3.6	13	41	27,000
Controls Updates					
17	Level 1 Controls	78.7	7	NA[B]	323,000
18	Level 2 Controls	41.2	7	NA[B]	155,000

A: Negative value represents an increase in the number of systemwide overflow events

B: Control Update Projects have systemwide improvements and are not tied to a local outfall

A review of the performance evaluation is summarized below:

In-Line Storage	All of these projects provide a moderate to high overflow volume reduction. The CSO 21 and CSO 40 #2 projects provide substantial reductions in overflow events. The projects in the South Side James River Park CSO District (CSO 40 #1 and CSO 40 #2) provide a substantial reduction in bacteria load discharged to the waterbody due the higher strength waste load characterized in the EMC data.
Diversion	Projects that divert flow from the Shockoe Creek CSO District to the Hampton/McCloy Retention Tunnel (CSO 19A, CSO 19B, and CSO 20) provide moderate overflow volume reduction. This suggests that the use of the Hampton/McCloy Tunnel could be optimized to handle additional flow in most storm events.
Dynamic Underflow Control	Several of the projects in the Gillies Creek area (CSO 04, CSO 24 and CSO 39) provide a low to moderate overflow volume reduction. Importantly, these projects also provide a substantial reduction in overflow events. The results show that the implementation of the CSO 04 project alone would reduce the overflow events at this outfall to five (5) under 2019 rainfall conditions.
Controls Update	Both of the Control Updates provide a high-volume reduction. This suggests that the operation of several key facilities can be optimized to maximize the CSS performance.

5.1.2 Receiving Water Quality Model Results

Only seven (7) individual projects and two (2) combinations of grouped projects were evaluated using the water quality model, due to the time constraints of the Interim Plan development. Model simulations were run, and compared back to the Baseline Modeling scenario (Section 3.5.3 and Appendix C) to quantify improvements to the following performance metrics:

Reduction in Bacteria Load (%)	Bacteria loads were calculated using the *E. Coli* CSO Event Mean Concentrations (EMCs) that were utilized in the *2017 RVA Clean Water Plan*. The reduction in bacteria load was calculated by comparing to the Baseline Modeling Scenario.
Improvement Towards Compliance with WQS (%)	0% - Baseline Scenario water quality standard compliance 100% - Full compliance with the water quality standards at the DS city limit

Table 5-2 summarizes improvements to the performance metrics for the seven (7) modeled individual projects and the two (2) grouped project combinations, as compared to the Baseline Modeling Scenario.

Table 5-2. Water Quality Modeling Evaluation Summary

PROJECT	PERFORMANCE		
	% Reduction in Bacteria Load	Improvement (%) towards compliance with water quality standards (0%:-Baseline Scenario – 100%: Full Compliance)	
		Geomean	STV
Diversion			
CSO 19A	Small[1]	Negligible[2]	Negligible[2]
CSO 19B	Small[1]	Negligible[2]	Negligible[2]
CSO 20	Small[1]	Negligible[2]	Negligible[2]
Dynamic Underflow Control			
CSO 24	Small[1]	Negligible[2]	Negligible[2]
CSO 39	Small[1]	Negligible[2]	Negligible[2]
Controls Update			
Level 1 Controls	7.8%	1.7%	0.8%
Level 2 Controls	Small[1]	Negligible[2]	Negligible[2]
Total			
Project Group #1: CSO 19A, 19B, 20, 24, 39 and Level 1/2 Controls	14.4%	3.5%	17.9%
Project Group #2: CSO 04, 19A, 19B, 20, 21 24, 39, 40 #1, and Level 1/2 Controls	20.6%	4.1%	21.4%

1: These projects have small overall volume or bacteria load reductions that fall within the model's bounds of uncertainty

2: Water Quality impacts are negligible or not discernable within the model's bounds of uncertainty

The majority of these projects reveal very small or negligible improvements to receiving water quality due to the relatively small overflow volume reductions. However, the two grouped project combinations provide a noticeable improvement in compliance with the geomean and STV water quality standards.

5.2 Qualitative Evaluation

Each identified project will have additional qualitative, community, environmental, and operational benefits and impacts that are not considered in the performance and cost evaluations.

The following qualitative project impacts and benefits were evaluated for each project:

Table 5-3. Qualitative Evaluation Criteria

Category	Topic
Constructability	Estimated Project Schedule Duration (Design, Permitting, Procurement, Construction)
	Conflicts with aboveground and/or subsurface features/utilities
	Improvements to existing assets identified in CIP
Operation and Maintenance	Mechanical Equipment Failure Risks
	Vulnerability to equipment failures
	Accessibility to I&C equipment
Adaptability	Ability to support and work in coordination with future Final Plan Improvements
Land Use and Permitting	Required land acquisition or construction easements
Community	Opportunities to Coordinate with Future Development
	Required Fed/State Permits/Coordination
	Project located in Environmentally sensitive areas
	Opportunities for Water Quality Improvements in Social Vulnerability Areas
	Disruption/Impacts to community during construction
	Aesthetics (new above ground features and/or noise impacts to neighbors during/after construction)
	Potential increased community exposure to nuisance-level odors

A scoring system was developed to quantify this evaluation and assign a Qualitative Benefit Score for each project, to better summarize potential project benefits outside of the developed performance metrics. A higher score indicates a greater Qualitative Benefit. The highest score that can be achieved in the scoring system is a 94.

Another critical item that required consideration is the estimated project duration. Projects must be complete by July 1, 2027 pursuant to the Interim Plan; therefore, project durations were taken into account.

The qualitative benefit scores and estimated project durations are summarized in Table 5-4, and a detailed breakdown is provided in Appendix D.

Table 5-4. Project Qualitative Assessment Summary

PROJECT		QUALITATIVE ASSESSMENT	
		Benefit Score	Estimated Project Duration (Months)
In-Line Storage			
1	BQ-ILS1	29	57
2	CSO 21	76	45
3	CSO 40 #1	52	45
4	CSO 40 #2	40	72
Diversion			
5	CSO 11	54	15
6	CSO 19A	75	21
7	CSO 19B	92	15
8	CSO 20	55	33
9	NE-G11	37	24
10	NE-G14	65	21
Dynamic Underflow Control			
11	CSO 04	57	36
12	CSO 05	52	30
13	CSO 15	63	20
14	CSO 24	68	18
15	CSO 31	66	18
16	CSO 39	61	18
Controls Updates			
17	Level 1 Controls	69	30
18	Level 2 Controls	81	45

A review of the qualitative scores and project durations are summarized below:

In-Line Storage	These projects have fairly consistently low Qualitative Benefit Scores, due to their construction impacts and their likely need for extensive permitting. These projects also have the longest project durations, which could present a risk to meeting the Interim Plan construction completion deadline.
Diversion	These projects have a wide array of Qualitative Benefit Scores, as some projects have a larger construction impact and may become obsolete after the Final Plan Improvements are implemented. These projects have relatively short project durations and have flexibility on when they could be implemented to meet the Interim Plan construction completion deadline.
Dynamic Underflow Control	These projects have moderate Qualitative Benefit Scores, due to their minimal construction impacts and community benefits. These projects have relatively short project durations and have flexibility on when they could be implemented to meet the Interim Plan construction completion deadline.
Controls Update	Both of these projects have high Qualitative Benefit Scores, due to minimal construction and land use/permitting impacts These projects have short project durations and have flexibility on when they could be implemented to meet the Interim Plan construction completion deadline.

5.3 Cost Estimates

Conceptual construction costs, annual operations and maintenance (O&M) costs, and 30-year life cycle costs were developed for each project.

These cost estimates are considered Class 5 estimates as defined by the Association for the Advancement of Cost Engineering (AACE). The accuracy range for Class 5 estimates is -50 percent to +100 percent.

In order to develop the estimates, a conceptual layout with initial design criteria was developed for each project. The conceptual layouts and design criteria are further detailed in Appendix D.

The following items were considered while developing the cost estimates for each project:

Construction Cost

Demolition

Structural Improvements

Civil Improvements

Mechanical Improvements

Erosion and Sediment Control and other Site Improvements

Contingencies

- Wet Weather Coordination Contingency (several of the projects will require work in structures or facilities that may not be taken out of service during wet weather events)
- Existing Infrastructure Improvements (several of the projects may require additional infrastructure improvements that have not yet been identified)
- Railroad Coordination Contingency (several of the projects are near or cross active railroads, which may require special construction provisions that could increase cost)
- Construction Contingency (it is likely that additional improvements will be identified as the conceptual designs are progressed)

Annual O&M Cost

Labor: Inspections, Cleaning, etc.

Maintenance of new Assets

Operating Costs of new Pump Stations

Contingency (it is likely that additional O&M requirements will be identified as the projects are progressed)

30-Year Lifecycle Cost

Expected future project costs that may be incurred within the 30-Year Life Cycle period

- It was assumed that Electrical and Instrumentation and Control equipment will need to be replaced after 15 years

Table 5-5 summarizes the cost estimates, and a detailed breakdown is provided in Appendix D.

Table 5-5. Project Cost Estimate Summary

PROJECT		AACE CLASS 5 COST ESTIMATES				
		Construction ($M)	Capital ($M)[1]	O&M ($M)	15-Year Improvements ($M)	30-Year Life Cycle Cost ($M)
In-Line Storage						
1	BQ-ILS1	$4.8	$7.2	$0.08	$0.3	$9.9
2	CSO 21	$3.6	$5.4	$0.06	$0.1	$7.4
3	CSO 40 #1	$2.6	$3.8	$0.06	$0.1	$5.7
4	CSO 40 #2	$8.9	$13.3	$0.07	$0.2	$15.7
Diversion						
5	CSO 11	$0.2	$0.3	$0.05	$0.1	$1.9
6	CSO 19A	$0.5	$0.8	$0.05	$0.1	$2.4
7	CSO 19B	$0.2	$0.3	$0.05	$0.1	$1.8
8	CSO 20	$0.5	$0.8	$0.05	$0.1	$2.4
9	NE-G11	$1.0	$1.5	$0.06	$0.1	$3.4
10	NE-G14	$0.6	$0.9	$0.05	$0.1	$2.6
Dynamic Underflow Control						
11	CSO 04	$5.6	$8.7	$0.07	$0.1	$10.8
12	CSO 05	$0.7	$1.1	$0.05	$0.1	$2.7
13	CSO 15	$0.9	$1.3	$0.05	$0.1	$2.9
14	CSO 24	$0.3	$0.4	$0.02	$0.0	$0.9
15	CSO 31	$0.6	$0.9	$0.05	$0.1	$2.5
16	CSO 39	$0.5	$0.8	$0.05	$0.1	$2.4
Controls Updates						
17	Level 1 Controls	$0.9	$1.3	$0.03	$0.2	$2.5
18	Level 2 Controls	$7.3	$11.0	$0.02	$1.2	$12.8
TOTALS		$39.8	$59.9	$1.0	$4.8	$94.1

1: The City of Richmond standard multiplier of 1.5 was applied to the construction cost estimates to develop the Capital Cost estimate. This multiplier comprises the design and construction/administration services.

A review of the cost estimates is summarized below:

In-Line Storage	These projects include new, large hydraulic control structures and therefore have the largest construction and annual O&M cost estimates. CSO 40 #2 includes the installation of new deep structure, pumping station and a large diameter sewer in the James River, which makes it most expensive estimated project cost.
Diversion	These projects are relatively inexpensive, with minor to moderate structural improvements to the existing control structures to improve access for O&M and new mechanical control equipment.
Dynamic Underflow Control	These projects are relatively inexpensive, with the exception of the CSO 04 project, and are able to be implemented with minor to moderate structural improvements to the existing regulator structures (similar to the Diversion Projects). The CSO 04 project includes the relocation of the CSO 04 regulator and the installation of large diameter sewers to the new regulator and downstream connection to the existing interceptor.
Controls Update	The Level 1 Controls Project includes the replacement and automation of the eight (8) drain gates in the Shockoe Retention Basin. The Level 2 Controls Project is more expensive because it includes the replacement of the existing pumps and electrical equipment in the Main Pumping Station to ensure the reliability and redundancy to pump 140 MGD in wet weather.

5.4 Cost Effectiveness Evaluation

The conceptual capital cost estimates (Table 5-5) and estimated project performance improvements (Table 5-1) were utilized to evaluate the cost effectiveness of each project with respect to: Volume Reduction, Overflow Event Reduction, and Bacteria Load Reduction.

The cost effectiveness metrics for each project are summarized below in Table 5-6.

Table 5-6. Project Cost Effectiveness Summary

PROJECT		COST EFFECTIVENESS		
		$/Gal Reduction	$M/Event Reduction	$/Billion CFU Reduction
In-Line Storage				
1	BQ-ILS1	$0.85	$3.60	$206
2	CSO 21	$0.33	$0.32	$225
3	CSO 40 #1	$0.31	$3.80	$23
4	CSO 40 #2	$0.31	$0.49	$26
Diversion				
5	CSO 11	$3.00	$0.15	NA
6	CSO 19A	$0.08	$0.40	$21
7	CSO 19B	$0.14	$0.15	$33
8	CSO 20	$0.09	$0.80	$24
9	NE-G11	$1.25	NA	$750
10	NE-G14	$3.00	$0.45	$450
Dynamic Underflow Control				
11	CSO 04	$1.71	$0.18	$140
12	CSO 05	$2.20	$0.55	$550
13	CSO 15	NA	NA	$325
14	CSO 24	$0.11	$0.02	$9
15	CSO 31	$0.82	$0.45	$150
16	CSO 39	$0.22	$0.06	$30
Controls Updates				
17	Level 1 Controls	$0.02	$0.19	$4
18	Level 2 Controls	$0.27	$1.57	$71

A review of the cost effectiveness metrics is summarized below:

In-Line Storage	These projects are moderately cost effective from a volume standpoint. The CSO 40 #1 and #2 projects are very cost effective in bacteria removal, as the bacteria concentration at the CSO 40 outfall is higher than others based on historical data.
Diversion	These projects have a wide range of cost effectiveness values. The projects (CSO 19A, CSO 19B, and CSO 20) that aim to divert more flow to the Hampton/McCloy Tunnel are very cost effective from a volume, event, and bacteria standpoint. The projects (NE-G11 and NE-G14) that aim to divert more flow to the Box Sewer are shown to have very little performance improvements and therefore are not cost-effective solutions.
Dynamic Underflow Control	These projects have a wide array of cost effectiveness values. Projects CSO 24 and CSO 39 are very cost effective from a volume and event standpoint. Projects at CSO 05, CSO 15, and CSO 31 are shown to have very little performance improvements and therefore are not cost-effective solutions. CSO 04 is a very cost-effective project to reduce overflow events.
Controls Update	Both of these projects have very favorable cost effectiveness values from a volume and bacteria standpoint. Both of these projects are shown to have large performance improvements at minimal cost, as they centered around maximizing the use of existing key CSS facilities.

5.5 Project Evaluation Summary

The data developed from the performance, cost, qualitative, and cost effectiveness evaluations is summarized for each project below in Table 5-7:

Table 5-7. Project Evaluation Summary

	PROJECT	PERFORMANCE				AACE CLASS 5 COST ESTIMATES					QUALITATIVE ASSESSMENT		COST EFFECTIVENESS		
		Overflow Volume Reduction (MG)	Overflow Event Reductions (#)	Remaining Local Overflow Events (#)	Bacteria Load Reduction (Billion CFU/year)	Construction ($M)	Capital ($M)	O&M ($M)	15-Year Improvements ($M)	30-Year Life Cycle Cost ($M)	Benefit Score	Estimated Project Duration (Months)	$/Gal Reduction	$M/Event Reduction	$/Billion CFU Reduction
In-Line Storage															
1	BQ-ILS1	8.5	2	15	35,000	$4.8	$7.2	$0.08	$0.3	$9.9	29	57	$0.85	$3.60	$206
2	CSO 21	16.2	17	36	24,000	$3.6	$5.4	$0.06	$0.1	$7.4	76	45	$0.33	$0.32	$225
3	CSO 40 #1	12.3	1	40	162,000	$2.6	$3.8	$0.06	$0.1	$5.7	52	45	$0.31	$3.80	$23
4	CSO 40 #2	42.7	27	15	507,000	$8.9	$13.3	$0.07	$0.2	$15.7	40	72	$0.31	$0.49	$26
Diversion															
5	CSO 11	0.1	2	10	0	$0.2	$0.3	$0.05	$0.1	$1.9	54	15	$3.00	$0.15	NA
6	CSO 19A	10.3	2	1	39,000	$0.5	$0.8	$0.05	$0.1	$2.4	75	21	$0.08	$0.40	$21
7	CSO 19B	2.2	2	1	9,000	$0.2	$0.3	$0.05	$0.1	$1.8	92	15	$0.14	$0.15	$33
8	CSO 20	8.9	1	0	34,000	$0.5	$0.8	$0.05	$0.1	$2.4	55	33	$0.09	$0.80	$24
9	NE-G11	1.2	-1	15	2,000	$1.0	$1.5	$0.06	$0.1	$3.4	37	24	$1.25	NA	$750
10	NE-G14	0.3	2	15	2,000	$0.6	$0.9	$0.05	$0.1	$2.6	65	21	$3.00	$0.45	$450
Dynamic Underflow Control															
11	CSO 04	5.1	48	5	62,000	$5.6	$8.7	$0.07	$0.1	$10.8	57	36	$1.71	$0.18	$140
12	CSO 05	0.5	2	12	2,000	$0.7	$1.1	$0.05	$0.1	$2.7	52	30	$2.20	$0.55	$550
13	CSO 15	0.0	0	40	4,000	$0.9	$1.3	$0.05	$0.1	$2.9	63	20	NA	NA	$325
14	CSO 24	3.8	26	21	45,000	$0.3	$0.4	$0.02	$0.0	$0.9	68	18	$0.11	$0.02	$9
15	CSO 31	1.1	2	15	6,000	$0.6	$0.9	$0.05	$0.1	$2.5	66	18	$0.82	$0.45	$150
16	CSO 39	3.6	13	41	27,000	$0.5	$0.8	$0.05	$0.1	$2.4	61	18	$0.22	$0.06	$30
Controls Updates															
17	Level 1 Controls	78.7	7	NA	323,000	$0.9	$1.3	$0.03	$0.2	$2.5	69	30	$0.02	$0.19	$4
18	Level 2 Controls	41.2	7	NA	155,000	$7.3	$11.0	$0.02	$1.2	$12.8	81	45	$0.27	$1.57	$71

SECTION 6

Project Selection

Utilizing the evaluation data, the 18 projects underwent a final screening process. Projects that met overflow volume reduction and project duration criteria were selected for implementation within the Interim Plan.

6.1 Selected Interim Plan Projects

Projects that met both of the following criteria were selected to be implemented within the Interim Plan:

Overflow Volume Reduction	**Annual Overflow Volume Reduction > 2 MG**
Project Duration	**Project Duration < 4 Years** Projects with durations of greater than four (4) years are large construction projects that pose greater risk of future schedule delays, with potential for the City to miss the Interim Plan construction completion deadline of July 1, 2027.

At the conclusion of the screening process, 10 projects were selected for implementation.

10 of the 18 evaluated projects meet the criteria identified above and have been selected to be implemented in the Interim Plan. These 10 projects, along with their expected cost and performance improvements, are summarized in Table 6-1.

Selected Interim Plan Projects are expected to reduce approximately 182 MG of annual CSO volume at a cost efficiency of $0.18/gallon.

Table 6-1. Selected Interim Plan Projects

PROJECT	PERFORMANCE	AACE CLASS 5 COST ESTIMATES	COST EFFECTIVENESS
	Overflow Volume Reduction (MG)	Capital ($M)	$/Gal Reduction
In-Line Storage			
CSO 21	16.2	$5.4	$0.33
CSO 40 #1	12.3	$3.8	$0.31
Diversion			
CSO 19A	10.3	$0.8	$0.08
CSO 19B	2.2	$0.3	$0.14
CSO 20	8.9	$0.8	$0.09
Dynamic Underflow Control			
CSO 04	5.1	$8.7	$1.71
CSO 24	3.8	$0.4	$0.11
CSO 39	3.6	$0.8	$0.22
Controls Updates			
Level 1 Controls	78.7	$1.3	$0.02
Level 2 Controls	41.2	$11.0	$0.27
TOTALS	182.3 MG Reduced	$33.3M	$0.18 / Gal Reduced

The City's selection of the 10 projects for the Interim Plan for July 1, 2027 completion, represents an ambitious undertaking and the continuation of the City's demonstrated commitment to substantial water quality improvement.

6.2 Implementation Schedule

The Interim Plan construction and related activities initiation and completion deadlines, as specified in the 2020 CSO Control Law and Amendment to the Special Order by Consent, are:

Interim Plan Construction Initiation	Interim Plan Construction Completion
July 1, 2022	July 1, 2027

An implementation schedule, illustrated in Figure 6-1, has been developed for the 10 selected projects. The schedule forecasts project milestones and project completion. The schedule considers each project's anticipated timelines, performance improvements, opportunities for project consolidation, and other qualitative benefits.

While this project schedule is achievable based on the best available information, unforeseeable factors outside the City's control may cause delays to any of the 10 projects. Project management and constructability constraints are noted in Appendix D. State and federal funding availability is unknown as is the lasting impact of the COVID-19 pandemic, both generally and on the City's wastewater utility finances.

While the City is committed to completing the projects by July 1, 2027, there may be circumstances that prevent that from occurring. If that is the case, any project included in this Interim Plan that is not completed by July 1, 2027 will be completed as soon as practicable in coordination with and no later than July 1, 2035 deadline pursuant to the Final Plan.

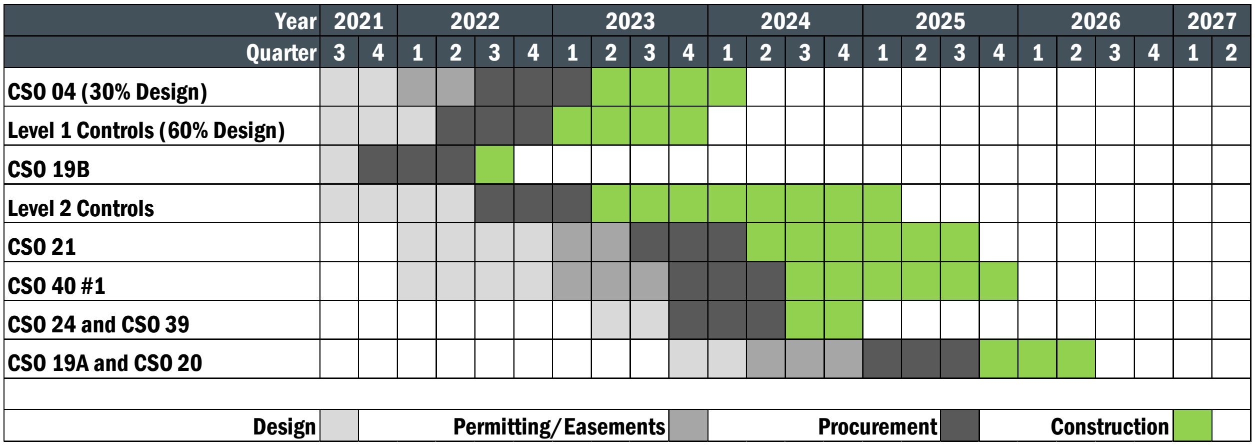


Figure 6-1 Interim Plan Implementation Schedule

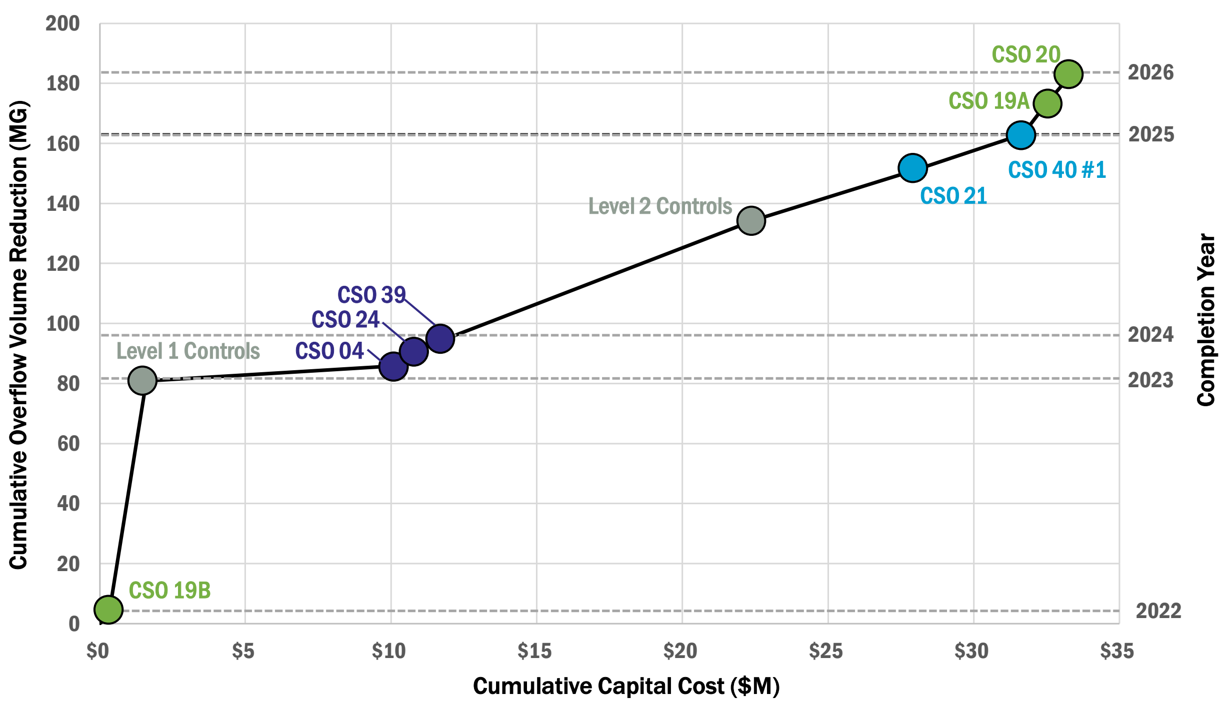


Figure 6-2 Interim Plan Project Implementation

6.3 Proposed Funding Strategies

The City will pursue grant funding assistance and any other available subsidies to offset project costs and minimize potential rate increases, in addition to seeking the appropriation of state funds to support compliance with the Interim and Final Plan deadlines.

The 2020 CSO Law and related Amendment to the 2005 Order references how the Governor and General Assembly may appropriate state funds, as well as how the General Assembly and State Water Control Board may grant extensions to the applicable deadlines in recognition of the fiscal impact of the projects. If state appropriations, grant funding or other subsidies are not available, projects would need to be funded through the issuance of bonds which would be paid back through the wastewater utility rates. A financial capability analysis will be completed in the future to understand how the Final Plan projects could impact these rates.

6.4 Remaining Special Order Project Comparison

The Amendment to the Special Order of Consent includes a provision that allows proposed projects in the Interim Plan to be substituted for projects previously identified in the 2005 Order. The substitution process is subject to DEQ approval and is contingent upon the Interim Plan projects more cost-effectively achieving the same or better CSO improvement than a project included in the 2005 Order.

There are currently five (5) projects identified in the 2005 Order that have yet to be completed. The performance improvements and cost-effectiveness of these projects were re-evaluated during the Interim Plan development process.

Performance	The performance of each of the projects was evaluated using the same CSS H&H model and water quality model (2019 evaluation period) as used for the Interim Plan project evaluation.
Cost	The estimated project capital costs were taken from the "2006 Richmond Program Project Plan" document and were escalated to present day values using Engineering-News Record (ENR) indices.
Cost Effectiveness	The volumetric, bacteria reduction cost effectiveness of each project was calculated for each project using the developed capital cost and overflow volume and bacteria reduction performance metrics.

A comparison of the performance, cost, and cost-effectiveness metrics for the remaining 2005 Order projects and the selected Interim Plan Projects are provided in Table 6-2.

Table 6-2. Remaining 2005 Order Project Evaluation Summary								
Projects		PERFORMANCE				COST ESTIMATES	COST EFFECTIVENESS	
		Overflow Volume Reduction (MG)	Bacteria Load Reduction (Billion CFU/year)	Improvement (%) towards compliance with water quality standards (0%: Existing Scenario – 100%: Full Compliance)		Capital ($M)	$/Gal Reduction	$ / Billion CFU Reduction
				Geomean	STV			
SO #13[A]	Gillies Creek Conveyance Sewer	12.0	111,000	NA[C]	NA[C]	$41	$3.42	$371
SO #16/18[B]	Additional 10 MGD of 2nd Treatment Additional 15 MG of storage at SRB	219.7	894,000	2.8%	11.3%	$180	$0.82	$201
SO #15	160 HRT at WWTP	198.9	754,000	NA[C]	NA[C]	$130	$0.65	$172
SO #19	HRD at SRB	551.1	2,151,000	NA[C]	NA[C]	$171	$0.31	$80
Selected Interim Plan Projects		182.3	879,000	4.1%	21.4%	$33.3	$0.18	$38

A: The Gillies Creek Conveyance Sewer will be evaluated further in the Final Plan and may be necessary to control the local outfalls in the Gillies Creek CSO District

B: Special Order Projects #16 and #18 were intended to be coordinated and constructed simultaneously, so that the 48-hr dewatering rate of the SRB could be maintained

C: Projects were not simulated in the water quality model, due to time constraints

As compared to the 2005 Special Order Projects #16 and #18 (Additional 10 MGD of WWTP secondary treatment, and an additional 15 MG of storage at the SRB), the 10 selected Interim Plan Projects are:

- More cost effective based on flow volume reduction, water quality improvement, and overflow event reduction
- Provide greater improvements with regard to water quality standard compliance and overflow event reductions

A substitution of the 10 selected Interim Plan projects for the two 2005 Special Order Projects #16 and #18 was formally requested in a May 25, 2021 letter to the DEQ. The substitution request was approved by the DEQ in a June 15, 2021 letter to the City. These letters are available in Appendix E.

SECTION 7

Stakeholder Engagement

A Technical Stakeholder Group was previously assembled in 2014 to support the development of the "2017 RVA Clean Water Plan". Information on the Interim Plan Development Process (Project Identification, Screening, Evaluation, and Selection) have been presented to this group to receive feedback.

Two meetings were conducted with the RVA H2O Technical Stakeholder Group, and the presentation materials are available in Appendix F.

Meeting #1 – October 2020
Purpose: Discuss the purpose of the Interim Plan, and inform the group on the identified projects and the on-going evaluation process

Meeting #2 – March 2021
Purpose: Discuss the Project evaluation results, and present which projects were selected to be implemented within the Interim Plan

The Technical Stakeholder Group is composed of multiple key City partner organizations and groups:

Feedback from the Technical Stakeholder Group has been positive and in support of the City implementing the selected projects in the Interim Plan, as cost-effective solutions to reduce overflow volume to the James River.