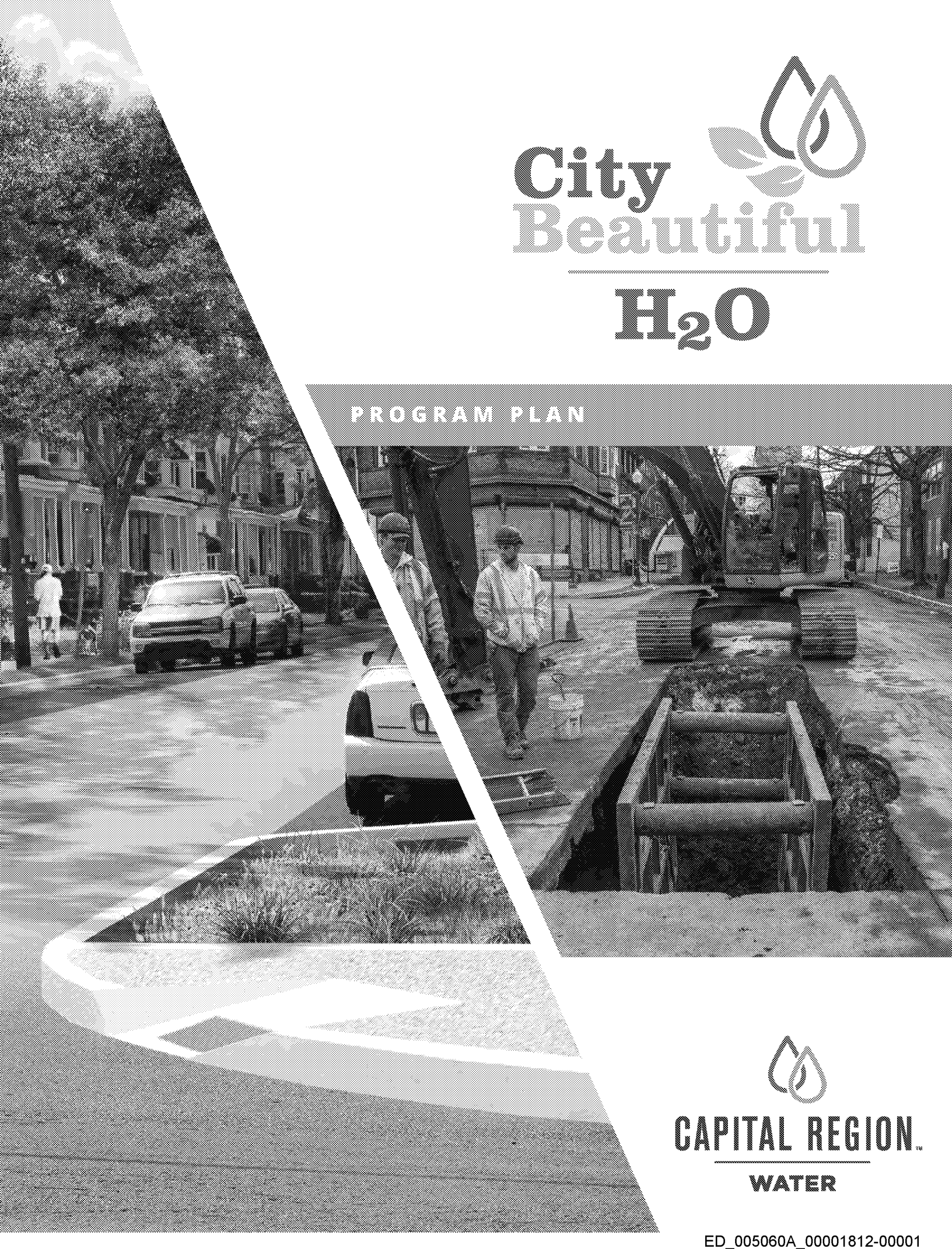
City Beautiful H_2O

PROGRAM PLAN



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March 29, 2018

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Environment and Natural Resources Division
U.S. Department of Justice
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Washington, D.C. 20004
Re: DOJ No. 90-5-1-1-10157

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RE: Civil Action No. 1:15-cv-00291-WWC: Long Term Control Plan

To Plaintiffs, Civil Action No. 1:15-cv-00291-WWC:

Capital Region Water (CRW) is required to submit a revised and updated Long Term Control Plan under Paragraph V(E)(14)(a-b) of the partial Consent Decree lodged February 10, 2015:

14. Long Term Control Plan. By no later than April 1, 2018, CRW shall complete and submit a revised and updated Long Term Control Plan ("LTCP") to Plaintiffs for review and approval in accordance with the requirements of Section VI (Review and Approval of Deliverables). The updated LTCP shall conform to the requirements of the EPA's CSO Policy and EPA's "Guidance for Long-Term Control Plan," EPA 832-B-95-002, September 1995, and consider EPA's "Greening CSO Plans: Planning and Modeling Green Infrastructure for Combined Sewer Overflow (CSO) Control, EPA 832-R-14-001, March 2014, and EPA's Integrated Municipal Stormwater and Wastewater Planning Approach Framework Memorandum, dated June 5, 2012. The updated LTCP shall include schedules, deadlines and timetables for remedial measures designed to meet the following goals:

a. Bring all CSO discharge points into full compliance with the technology-based and water quality-based requirements of the CWA; and

b. Minimize the impacts of CSOs on water quality, aquatic biota, and human health.

The submission of the *City Beautiful H_2O Program Plan* and supporting documentation is in fulfillment of Paragraph V(E)(14)(a-b).

The *City Beautiful H_2O Program Plan* is Capital Region Water's responsible approach to addressing a combination of system-wide infrastructure deterioration and failure with high-priority water quality compliance activities. Capital Region Water must balance delivery of reliable service with the goals, requirements, and guidance outlined above in a manner our ratepayers can afford.

Per the Partial Consent Decree submission requirements, we include with this cover letter:

- a hard copy of the *City Beautiful H_2O Program Plan,* and
- a CD with a digital copy of the *City Beautiful H_2O Program Plan* with all updated supporting documentation.

Please contact me directly to discuss any question or concerns you may have.

Sincerely yours,

David Stewart, P.E., BCEE
Director of Engineering
Capital Region Water

cc: Claire Maulhardt, P.L.A., CRW
Steven Hann, Esq.
John Aldrich, P.E., D.WRE, CDM Smith

Table of Contents

Executive Summary **ES-1**

Section 1 Overview of the Program Plan **1-1**
1.1 Requirements and Objectives of the CRW Program Plan 1-1
1.1.1 Regulatory Requirements 1-1
1.1.2 Program Plan Objectives 1-2
1.2 Public Engagement and Participation 1-2
1.2.1 Existing Public Involvement Programs 1-4
1.2.2 Public Involvement during the Release of the Draft Plan 1-5
1.2.3 Future Public Participation after Submitting the Plan 1-6
1.3 Characteristics of CRW's Wastewater/Stormwater System 1-6
1.3.1 CRW Service Area 1-6
1.3.2 Advanced Wastewater Treatment Facility (AWTF) 1-7
1.4 Problem Analysis and Priorities 1-11
1.4.1 AWTF Problems and Priority Repairs 1-11
1.4.2 Conveyance System Problems and Priority Repairs 1-12
1.4.3 Collection System Problems and Priority Repairs 1-12
1.4.4 Existing Discharges at CSO Regulators and Control Priorities 1-12
1.4.5 Hydraulic Capacity Limitations Causing SSOs and Unauthorized Releases 1-13
1.4.6 Receiving Water Conditions 1-15
1.5 The Long-Term Planning Process 1-15
1.5.1 Characterization and Problem Identification 1-15
1.5.2 Control Technology Screening 1-15
1.5.3 Alternative Development and Evaluation 1-16
1.5.4 Recommended Control Plan and Implementation Phasing 1-16
1.6 Control Technologies and Screening 1-17
1.7 Financial Capability Analysis 1-18
1.8 Development/Evaluation of Alternative Control Strategies 1-20
1.8.1 Baseline Level of Control 1-20
1.8.2 Development of Alternative Control Strategies 1-21
Systemwide Control Strategies 1-21
Local Control Strategies 1-23
1.8.3 Evaluation of Alternative Control Strategies 1-23
1.8.4 Recommended Control Strategy 1-26
1.9 Implementation and Adaptive Management Plan 1-28
1.9.1 Four Implementation Strategies 1-28
1.9.2 Adaptive Management Process 1-29
1.10 Post Construction Monitoring Plan 1-30
1.11 Recommended Plan and Schedule 1-32

Section 2 Public Engagement and Participation **2-1**
2.1 Overview of Public Engagement and Participation 2-1
2.2 Public Involvement Prior to the Draft Program Plan 2-2
2.2.1 NMC and MCM Activities 2-2

ED_005060A_00001812-00005

2.2.2 CRW's Community Greening Plan 2-3
2.3 Public Involvement and Comments during the Release of the Draft Program Plan 2-4
2.3.1 Public Educational Activities 2-4
Advisory Committees 2-4
Individual Stakeholder Meetings 2-5
Neighborhood / Community Meetings 2-5
2.3.2 Outreach to the Public 2-6
Summary of Public Meetings 2-7
2.3.3 Summary of Comments Received from Public Input 2-8
2.4 Future Public Participation 2-9
2.4.1 Continued Public Information and Education 2-9
2.4.2 Continued Public Participation Supporting Program Plan Implementation 2-9

Section 3 Characterization of Current Conditions 3-1
3.1 Overview of Characterization of Current Conditions 3-1
3.2 Treatment, Conveyance, and Collection System Characteristics 3-4
3.2.1 Advanced Wastewater Treatment Facility 3-7
3.2.2 Interceptor System Characteristics and Inspections 3-10
3.2.3 Major Pump Station and Force Main Characteristics 3-13
3.2.4 CSO Regulator Structure and Outfall Characteristics and Inspections 3-14
3.2.5 Collection System Characteristics and Inspections 3-17
3.2.6 Prioritized Asset Management Program 3-18
3.3 Regional Precipitation Characteristics 3-19
3.3.1 Characterization of Precipitation Statistics and Patterns 3-19
3.3.2 Catchment Area Rainfall for H&H Modeling 3-21
3.3.3 Development of the Typical Year Rainfall 3-24
3.3.4 Development of Synthetic Design Storm Rainfall 3-25
3.4 Wastewater and Stormwater Flow Characteristics 3-29
3.4.1 Regulatory Context and Requirements 3-29
3.4.2 Summary of the Hydrologic and Hydraulic Model 3-29
3.4.3 Summary of Monitoring Data used to Support the H&H Model 3-32
3.4.3.1 Interceptor Flow Monitoring and Characterization 3-33
3.4.3.2 Suburban Community Flow Monitoring and Characterization 3-35
3.4.3.3 Combined Collection System Flow Monitoring and Characterization 3-35
3.4.3.4 Separate Sanitary Collection System Flow Monitoring 3-37
3.4.3.5 Characterization of Dry Weather Flow (DWF) 3-39
3.4.3.6 Characterization of Rainfall-Dependent Infiltration/Inflow 3-40
3.4.3.7 Wet Weather Flow Calibration 3-43

Section 4 Problem Analysis and Priorities 4-1
4.1 Overview of Problem Analysis and Priorities 4-1
4.2 Structural/Operational Deficiencies and Debris Buildup 4-3
4.2.1 Advanced Wastewater Treatment Facility Problems 4-4
4.2.1.1 Overview of the Advanced Wastewater Treatment Facility 4-4
4.2.1.2 Known Advanced Wastewater Treatment Facility Problems 4-4
4.2.1.3 Assessment of Advanced Wastewater Treatment Facility Capacity 4-5
4.2.2 Conveyance System 4-10

4.2.3 Collection System Problems 4-12
4.3 Wet Weather Discharges at CSOs and MS4 Outfalls 4-13
4.3.1 Systemwide CSO Discharge Frequency, Duration and Volume 4-14
4.3.2 Existing Performance Statistics for Individual CSO Regulators 4-17
4.3.3 Stormwater Discharges at MS4 Outfalls 4-22
4.3.4 Summary Conclusions on Wet Weather Control Needs 4-24
4.4 Hydraulic Capacity of Combined Trunk Sewers 4-24
4.5 Hydraulic Capacity of Separate Sanitary Sewers 4-25
4.5.1 System Performance during Design Storm Flows 4-26
4.6 Characterization of Receiving Water Conditions 4-28
4.6.1 Regulatory Context, Water Quality Objectives, and Use Designations 4-29
4.6.2 Receiving Water Depth Characterization and Flood Frequency Analysis 4-29
4.6.3 Water Quality Information Sources 4-30
4.6.4 Receiving Water Quality Studies and Characteristics 4-32
4.6.4.1 Susquehanna River Sampling and Studies 4-32
4.6.4.2 Paxton Creek Sampling and Studies 4-33
4.6.5 Pollutants of Concern 4-34
4.6.6 Priority and Sensitive Areas 4-35
4.7 Regulatory Compliance Framework 4-35
4.7.1 Framework for Structural/Operational Deficiencies and Debris Buildup 4-35
4.7.2 Framework for Addressing Water Quality Degradation 4-36
4.7.2.1 Technology-Based Requirements of the CWA 4-36
4.7.2.2 Water Quality-Based Requirements of the CWA 4-37
4.7.2.3 Water Quality Requirements for Bacteria 4-40
4.7.3 Framework for Addressing SSOs and Unauthorized Releases 4-40

Section 5 City Beautiful H_2O Program Planning Process 5-1
5.1 Overview of the Planning Process 5-1
5.2 Characterization and Problem Identification 5-3
5.2.1 Evaluation of Collected System Data and Monitoring Results 5-3
5.2.2 Hydrologic and Hydraulic Model Development 5-3
5.2.3 Characterization of Existing Combined Sewer Systems 5-4
5.2.4 Characterization of Existing Separate Sanitary Sewer Systems 5-4
5.3 Control Technology Screening 5-4
5.3.1 Describe, Evaluate Feasibility of Available Control Technologies 5-4
5.3.2 Define Alternative Levels of Control 5-5
5.3.3 Define a Baseline Level of Control 5-5
5.3.4 Delineate Program Planning Areas 5-6
5.3.5 Establish Feasible Systemwide and Local Control Strategies 5-6
5.4 Alternative Development and Evaluation 5-8
5.4.1 Define Alternatives to Enhance Wet Weather Control 5-8
5.4.2 Perform Knee-of-the-Curve Cost Performance Analyses 5-8
5.4.3 Determine Benefits and Costs of each Control Strategy 5-9
5.5 Recommended Control Plan and Implementation Phasing 5-10
5.5.1 Determine Affordability of Alternative Control Levels 5-10
5.5.2 Prioritize and Phase Implementation of Controls 5-10

ED_005060A_00001812-00007

5.5.3 Prepare Integrated Wet Weather Control Plan 5-11

Section 6 Control Technologies and Screening 6-1

6.1 Overview of Control Technologies and Screening 6-1
6.2 Identification of Feasible CSO Controls 6-1
6.2.1 Source Controls 6-1
6.2.2 Conveyance/Collection System Controls 6-2
6.2.3 Storage Technologies 6-4
6.2.4 Treatment Technologies 6-5
6.2.5 Receiving Water Technologies 6-8
6.3 Alternative Control Strategies 6-9
6.3.1 Minimum Control Requirements 6-9
6.3.2 Baseline Level of Control 6-9
6.3.3 Establish Feasible Control Strategies 6-10
6.4 Screening Results 6-12
6.4.1 Source Controls 6-12
6.4.2 Collection System Controls 6-12
6.4.3 Storage Technologies 6-12
6.4.4 Treatment Technologies 6-12
6.4.5 Receiving Water Technologies 6-12

Section 7 Financial Capability and Affordability Assessment 7-1

7.1 Overview of the Financial Capability and Affordability Assessment 7-1
7.2 Jurisdictional Scope of the Analysis 7-3
7.3 Methodology 7-3
7.3.1 US-EPA Financial Capability Assessment 7-3
7.3.2 Enhancements to the US-EPA Process 7-4
7.4 Overview of the Wastewater Utility 7-4
7.4.1 System Description 7-4
7.4.2 Customer Base 7-5
7.4.3 Historical and Current Costs 7-6
7.4.3.1 Operating Expenses 7-6
7.4.3.2 Capital Improvement Program 7-6
7.4.3.3 Debt Service Obligations 7-7
7.4.3.4 Historical Financial Results 7-7
7.4.4 Wastewater Rates and Customer Bill Comparison 7-8
7.5 Socioeconomic Conditions 7-8
7.5.1 Local Economy 7-8
7.5.2 Populations and Households 7-9
7.5.3 Labor Force and Unemployment 7-10
7.5.4 Poverty Rates 7-11
7.5.5 Income Distribution 7-13
7.5.5.1 Median Household Income 7-13
7.5.5.2 Income Quintiles 7-14
7.5.5.3 Household Income Distribution 7-16
7.5.5.4 Renter and Owner-Occupied Household 7-18
7.5.6 Housing Burden 7-18

7.5.7 Other Economic Indicators 7-19
7.5.7.1 Typical Bill as a Percentage of Federal Poverty Threshold Incomes 7-20
7.6 US-EPA Financial Capability Assessment 7-20
7.6.1 Financial Capability Assessment 7-21
7.6.1.1 Residential Indicator (City) 7-21
7.6.1.2 Community Financial Capability Indicators (City) 7-23
7.6.1.3 Worksheet 10: The Financial Capability Matrix (City) 7-28
7.7 Long-Term Financial Projections and Rate Impacts 7-28
7.7.1 Key Assumptions 7-28
7.7.1.1 Wastewater and Stormwater Revenues 7-29
7.7.1.2 Wastewater and Stormwater Revenue Requirements 7-29
7.7.2 Capital Expenditures and Rate Impacts 7-30
7.8 Conclusions 7-34

Section 8 Development and Evaluation of Alternative Control Strategies 8-1
8.1 Overview: Alternative Approaches to Meeting LTCP Goals 8-1
8.2 Baseline Level of Control 8-2
8.2.1 Baseline Level of Control Definition of Controls 8-2
8.2.2 Baseline Level of Control Cost Performance Evaluation 8-5
8.3 Systemwide Control Strategies 8-7
8.3.1 Systemwide Control Strategy 1: Enhanced Conveyance and Increased Capacity at AWTF 8-7
8.3.1.1 Definition of Control Levels 8-7
8.3.1.2 Cost Performance Evaluation 8-10
8.3.2 Systemwide Control Strategy 2: Deep Tunnel Storage / Conveyance 8-11
8.3.2.1 Definition of Controls 8-11
8.3.2.2 Cost Performance Evaluation 8-13
8.3.3 Systemwide Control Strategy Findings 8-14
8.4 Localized Control Strategy 8-15
8.4.1 Riverside Planning Area 8-17
8.4.1.1 Definition of Controls 8-17
8.4.1.2 Cost Performance Evaluation 8-24
8.4.1.3 Local Control Strategy Findings 8-26
8.4.2 Italian Lake Planning Area 8-29
8.4.2.1 Definitions of Controls 8-29
8.4.2.2 Cost Performance Evaluation 8-32
8.4.2.3 Local Control Strategy Findings 8-32
8.4.3 Uptown Planning Area 8-33
8.4.3.1 Definition of Controls 8-33
8.4.3.2 Cost Performance Evaluation 8-42
8.4.3.3 Local Control Strategy Findings 8-44
8.4.4 Middle Front Street Planning Area 8-47
8.4.4.1 Definitions of Controls 8-47
8.4.4.2 Cost Performance Evaluation 8-56
8.4.4.3 Local Control Strategy Findings 8-57
8.4.5 Lower Front Street Planning Area 8-61

8.4.5.1 Definitions of Controls 8-61
8.4.5.2 Cost Performance Evaluation 8-68
8.4.5.3 Local Control Strategy Findings 8-71
8.4.6 Industrial Road Planning Area 8-73
8.4.6.1 Definitions of Controls 8-73
8.4.6.2 Cost Performance Evaluation 8-75
8.4.6.3 Local Control Strategy Findings 8-77
8.4.7 Upper Paxton Creek West Planning Area 8-79
8.4.7.1 Definitions of Controls 8-79
8.4.7.2 Cost Performance Evaluation 8-88
8.4.7.3 Local Control Strategy Findings 8-89
8.4.8 Arsenal Boulevard Planning Area 8-91
8.4.8.1 Definitions of Controls 8-91
8.4.8.2 Cost Performance Evaluation 8-95
8.4.8.3 Local Control Strategy Findings 8-95
8.4.9 Upper Paxton Creek East Planning Area 8-97
8.4.9.1 Definitions of Controls 8-97
8.4.9.2 Cost Performance Evaluation 8-105
8.4.9.3 Local Control Strategy Findings 8-107
8.4.10 Middle Paxton Creek West Planning Area 8-109
8.4.10.1 Definitions of Controls 8-109
8.4.10.2 Cost Performance Evaluation 8-117
8.4.10.3 Local Control Strategy Findings 8-119
8.4.11 Middle Paxton Creek East Planning Area 8-121
8.4.11.1 Definition of Controls 8-121
8.4.11.2 Cost Performance Evaluation 8-129
8.4.11.3 Local Control Strategy Findings 8-131
8.4.12 Lower Paxton Creek Planning Area 8-133
8.4.12.1 Definitions of Controls 8-133
8.4.12.2 Cost Performance Evaluation 8-143
8.4.12.3 Local Control Strategy Findings 8-146
8.4.13 Hemlock Street Planning Area 8-149
8.4.13.1 Definitions of Controls 8-149
8.4.13.2 Cost Performance Evaluation 8-157
8.4.13.3 Local Control Strategy Findings 8-159
8.4.14 East Harrisburg Planning Area 8-161
8.4.14.1 Definitions of Controls 8-161
8.4.14.2 Cost Performance Evaluation 8-162
8.4.14.3 Local Control Strategy Findings 8-162
8.4.15 Spring Creek Planning Area 8-165
8.4.15.1 Definitions of Controls 8-167
8.4.15.2 Cost Performance Evaluation 8-169
8.4.15.3 Local Control Strategy Findings 8-171
8.5 Evaluation of Alternative Control Strategies 8-173
8.5.1 Alternative Analysis for the Advanced Wastewater Treatment Facility 8-176
8.5.1.1 Storage and Pump-Back 8-177

8.5.1.2 Sewer Separation 8-177
8.5.1.3 Satellite Treatment 8-178
8.5.1.4 NPDES Permit Requirements 8-179
8.6 Recommended Control Strategy 8-182

Section 9 Implementation and Adaptive Management Plan 9-1
9.1 Implementation Overview 9-1
9.2 Prioritized Implementation Strategy 9-2
9.2.1 Asset Rehabilitation and Renewal Strategy 9-3
9.2.1.1 Asset Probability of Failure 9-3
9.2.1.2 Asset Consequence of Failure 9-4
9.2.1.3 Risk Management Zones 9-5
9.2.1.4 Asset Prioritization Approach 9-7
9.2.1.5 Implementation Services 9-8
9.2.2 Decentralized Green / Grey Implementation Strategy 9-8
9.2.2.1 Pilot and Demonstration Projects 9-9
9.2.2.2 Synergistic Project Opportunities 9-10
9.2.2.3 Development-Driven Project Opportunities 9-11
9.2.2.4 Incentive-Driven Project Opportunities 9-14
9.2.2.5 Opportunities on Public Lands and Rights of Way 9-15
9.2.2.6 Vacant Property Re-Utilization Opportunities 9-18
9.2.2.7 Green Parking Lots Initiative 9-19
9.2.2.8 Implementation Services 9-20
9.2.3 Asset Operation and Maintenance Strategy 9-20
9.2.3.1 Monitoring, Controls and Telemetry 9-21
9.2.3.2 Maintenance of Public Facilities 9-21
9.2.3.3 Maintenance of Private Facilities 9-21
9.2.3.4 Green Stormwater Infrastructure Maintenance Manual Process 9-22
9.2.4 Internal and Intergovernmental Communications and Coordination 9-24
9.2.4.1 Strategic Policy and Coordination Program 9-24
9.2.4.2 Internal Communications Plan 9-24
9.3 Implementation Assessment and Adaptive Management Strategy 9-25
9.3.1 Adaptive Management Triggers 9-25
9.3.2 Financial Capability Re-Assessment 9-25
9.3.3 Evaluation and Adaptation Plans 9-25
9.3.4 Adaptive Management Reporting 9-26

Section 10 Post-Construction Monitoring 10-1
10.1 Post-Construction Monitoring Overview 10-1
10.2 Administrative Monitoring and Reporting 10-3
10.3 Precipitation Monitoring and Assessment 10-4
10.4 Interceptor Monitoring and Assessment 10-5
10.5 Suburban Community System Monitoring/Assessment 10-6
10.6 CSO Regulator Structure Monitoring and Assessment 10-6
10.7 CSO Discharge Projections through H&H Modeling 10-8
10.8 Water Quality Monitoring and Assessment 10-8
10.9 Performance Standards 10-9

ED_005060A_00001812-00011

10.10 Paxton Creek Use Attainability Assessment 10-9

Section 11 Recommended Plan and Implementation Schedule 11-1

11.1 Overview of the Recommended Plan 11-1
11.2 Primary Objectives of the Program Plan 11-3
11.3 Recommended Program Plan 11-3
11.3.1 CRW's Financial Capabilities 11-3
11.3.2 A Recommended Program Plan Defined by CRW's Financial Capabilities 11-4
11.3.3 Rehabilitation of Wastewater/Stormwater Assets 11-4
11.3.4 Reduce Pollutant Discharges to Receiving Waters 11-5
11.3.5 Mitigate Unauthorized Releases 11-7
11.3.6 Stabilization of Streambanks 11-8
11.3.7 Stakeholder Engagement 11-8
11.3.8 Sustainable Asset Management 11-9
11.3.9 Maximization of Benefits 11-10
11.4 Implementation Approach 11-10
11.5 Implementation Schedule 11-12
11.5.1 Immediate Implementation Phase Schedule 11-12
11.5.2 Performance of the Immediate Implementation Priorities 11-15
11.5.3 Near-Term Implementation Priorities 11-15
11.5.4 Performance of the Near-Term Implementation Priorities 11-17
11.5.5 Post-Construction Monitoring 11-17

List of Figures

Section 1 Figures

Figure 1-1: Designated Planning Areas within the CRW Service Area 1-3
Figure 1-2: Typical Combined Sewer System with Regulator Structures 1-8
Figure 1-3: CSO Capture Achieved by CRW's Existing Combined Sewer System 1-14
Figure 1-4: Summary of Integrated Wet Weather Control Plan Process 1-16
Figure 1-5: Idealized "Knee-of-the-Curve" and Potential Level of Control Objectives 1-21
Figure 1-6: CSO Volume Capture by Catchment under the Baseline Level of Control 1-22
Figure 1-7. Estimated Capital Cost of Affordable Rehabilitation and Wet Weather Control Projects over the 20-year Planning Horizon 1-34

Section 3 Figures

Figure 3-1: CRW Service Area Including Service Area of Suburban Community Systems 3-2
Figure 3-2: CRW Service Area Collection Sewer System and Catchment Areas 3-5
Figure 3-3: Process Flow Diagram for CRW AWTF Current Conditions 3-8
Figure 3-4: Vortex Grit Chambers at CRW AWTF 3-7
Figure 3-5: Chlorine Contact Tank at CRW AWTF 3-9
Figure 3-6: The CRW Interceptor Sewer System 3-11
Figure 3-7: Locations of CSO Regulator Structures within the CRW System 3-15
Figure 3-8: Configuration of a Typical CRW CSO Regulator Structure 3-16
Figure 3-9: Example of a Diversion Dam 3-16
Figure 3-10: Brown and Brown Control Equipment 3-16
Figure 3-11: Examples of Fixed Orifice Controls 3-16
Figure 3-12: Median Monthly Precipitation Volumes in Harrisburg 3-20
Figure 3-13 Median Number of Monthly Precipitation Events for Harrisburg 3-21
Figure 3-14 Precipitation Monitoring Sites and GARR Grid 3-23
Figure 3-15: Hyetograph for a 2-Year, 24-Hour Synthetic Design Storm 3-26
Figure 3-16: Hyetograph for a 5-Year, 24-Hour Synthetic Design Storm 3-26
Figure 3-17: Hyetograph for a 10-Year, 24-Hour Synthetic Design Storm 3-27
Figure 3-18: Monthly Storm Probability for 60-Minute Rain Durations from NOAA Atlas 14 3-28
Figure 3-19: Monthly Storm Probability for 24-Hour Rain Durations from NOAA Atlas 14 3-28
Figure 3-20: Interceptor and Major Trunk Sewers Represented by the H&H Models 3-31
Figure 3-21: Interceptor and Suburban Community Point of Connection Monitoring Sites 3-34
Figure 3-22: Combined Trunk Sewer and CSO Regulator Monitoring Sites 3-36
Figure 3-23: Separate Sanitary Catchment Monitoring Sites 3-38
Figure 3-24: Typical Flow Characterization in a Separate Sanitary Sewer System 3-39
Figure 3-25: Unit Hydrograph Parameters Derived from SSOAP Toolbox 3-41
Figure 3-26: Monthly Varied R Values at SSMH-2079 (Significant Seasonal Variation) 3-42
Figure 3-27: Monthly Varied R Values at SSMH-0254 (Minimal Seasonal Variation) 3-42

Section 4 Figures

Figure 4-1: Peak HGL along the Front Street Interceptor during Typical Year 4-15
Figure 4-2: Peak HGL along the Paxton Creek Interceptor during Typical Year 4-16

ED_005060A_00001812-00013

Figure 4-3: Distribution of Existing Condition CSO Discharge Volumes 4-20
Figure 4-4: Distribution of Existing Condition CSO Discharge Frequencies 4-21
Figure 4-5: Average Annual Regulator Overflow Frequency by Interceptor 4-22
Figure 4-10: Paxton Creek and Susquehanna River Elevation Monitoring 4-31
Figure 4-11: Susquehanna River Flow Streams in the Vicinity of Rockville, PA 4-33

Section 5 Figures

Figure 5-1: Summary of Integrated Wet Weather Control Plan Process 5-1
Figure 5-2: Designated Planning Areas within the CRW Service Area 5-7
Figure 5-3: Example Cost Performance Curve with Differing Endpoints 5-9

Section 7 Figures

Figure 7-1: Types of Households 7-10
Figure 7-2: Trends in Unemployment Rates 7-11
Figure 7-3: Trends in Poverty Rates 7-12
Figure 7-4: Trends in Median Household Income (Adjusted to 2015 Dollars) 7-15
Figure 7-5: Income Distribution for the City of Harrisburg, CRW's Service Area, Pennsylvania, and the U.S. 7-16
Figure 7-6: Estimated 2018 Income Levels by Census Block for the City of Harrisburg 7-17
Figure 7-7: Proportion of Renter and Owner-Occupied Housing in the City of Harrisburg and Commonwealth of Pennsylvania 7-18
Figure 7-8: Housing Burden for Owner-Occupied Households in the City of Harrisburg (Incomes Less than $35,000 per Year) 7-19
Figure 7-9: Housing Burden for Renter-Occupied Households in the City of Harrisburg (Incomes Less than $35,000 per Year) 7-19
Figure 7-10: Distribution of Future Residential Wastewater and Stormwater Bill as Percentage of MHI (2027) 7-33

Section 8 Figures

Figure 8.2-1: CSO Volume Capture by Catchment under the Baseline Level of Control 8-6
Figure 8.3-1: Location of Systemwide Control Strategy 1 Facilities: Enhanced Conveyance and Increased Capacity at AWTF 8-9
Figure 8.3-2: Enhanced Conveyance and Increased Capacity at AWTF CSO Capture Performance and Opinion of Probable Cost Estimate 8-10
Figure 8.3-3: Location of Systemwide Control Strategy 2: Deep Tunnel Storage/Conveyance 8-12
Figure 8.3-4: Deep Tunnel Storage / Conveyance CSO Capture Performance and Opinion of Probable Cost Estimate 8-14
Figure 8.4.1-1: Riverside - Existing Hydraulic and Structural Problems 8-18
Figure 8.4.1-2: Riverside - Decentralized Green and Grey Infrastructure Opportunities 8-21
Figure 8.4.1-3: Riverside - Satellite Treatment / Storage Opportunities 8-23
Figure 8.4.1-4: Riverside - CSO Capture Performance and Opinion of Probable Cost Estimate 8-25
Figure 8.4.1-5: Riverside - Annual CSO Event Frequency and Duration Performance by Control Strategy 8-27
Figure 8.4.2-1: Italian Lake - Existing Hydraulic and Structural Problems 8-30

Figure 8.4.2-2: Italian Lake - Green Stormwater Infrastructure / Sediment Reduction Opportunities 8-31
Figure 8.4.3-1: Uptown - Existing Hydraulic and Structural Problems 8-34
Figure 8.4.3-2: Uptown - Decentralized Green and Grey Infrastructure Opportunities 8-37
Figure 8.4.3-3: Uptown - Satellite Treatment / Storage Opportunities 8-40
Figure 8.4.3-4: Uptown - CSO Capture Performance and Opinion of Probable Cost Estimate 8-43
Figure 8.4.3-5: Uptown - Annual CSO Event Frequency by Control Strategy 8-45
Figure 8.4.3-6: Uptown - Annual CSO Duration by Control Strategy 8-46
Figure 8.4.4-1: Middle Front Street - Existing Hydraulic and Structural Problems 8-48
Figure 8.4.4-2: Middle Front Street - Decentralized Green and Grey Infrastructure Opportunities8-51
Figure 8.4.4-3: Middle Front Street - Satellite Treatment / Storage Opportunities 8-54
Figure 8.4.4-4: Middle Front Street - CSO Capture Performance and Opinion of Probable Cost Estimate 8-57
Figure 8.4.4-5: Middle Front Street - Annual CSO Event Frequency by Control Strategy 8-58
Figure 8.4.4-6: Middle Front Street - Annual CSO Duration by Control Strategy 8-59
Figure 8.4.5-1: Lower Front Street - Existing Hydraulic and Structural Problems 8-62
Figure 8.4.5-2: Lower Front Street - Decentralized Green and Grey Infrastructure Opportunities 8-65
Figure 8.4.5-3: Lower Front Street - Satellite Treatment / Storage Opportunities 8-67
Figure 8.4.5-4: Lower Front Street - CSO Capture Performance and Opinion of Probable Cost Estimate 8-69
Figure 8.4.5-5: Lower Front Street - Annual CSO Event Frequency and Duration Performance by Control Strategy 8-72
Figure 8.4.6-1: Industrial Road - Existing Hydraulic and Structural Problems 8-74
Figure 8.4.6-2: Industrial Road - Green Stormwater Infrastructure / Sediment Reduction Opportunities 8-76
Figure 8.4.7-1: Upper Paxton Creek West - Existing Hydraulic and Structural Problems 8-80
Figure 8.4.7-2: Upper Paxton Creek West - Decentralized Green and Grey Infrastructure Opportunities 8-84
Figure 8.4.7-3: Upper Paxton Creek West - Satellite Treatment / Storage Opportunities 8-87
Figure 8.4.7-4: Upper Paxton Creek West - CSO Capture Performance and Opinion of Probable Cost Estimate 8-88
Figure 8.4.7-5: Upper Paxton Creek West - Annual CSO Even Frequency and Duration Performance by Control Strategy 8-90
Figure 8.4.8-1: Arsenal Boulevard - Existing Hydraulic and Structural Problems 8-92
Figure 8.4.8-2: Arsenal Boulevard - Green Stormwater Infrastructure / Sediment Reduction Opportunities 8-94
Figure 8.4.9-1: Upper Paxton Creek East - Existing Hydraulic and Structural Problems 8-98
Figure 8.4.9-2: Upper Paxton Creek East - Decentralized Green and Grey Infrastructure Opportunities 8-101
Figure 8.4.9-3: Upper Paxton Creek East - Satellite Treatment / Storage Opportunities 8-103
8-106
Figure 8.4.9-4: Upper Paxton Creek East - CSO Capture Performance and Opinion of Probable Cost Estimate 8-106
Figure 8.4.9-5: Upper Paxton Creek East - Annual CSO Event Frequency and Duration Performance by Control Strategy 8-108

ED_005060A_00001812-00015

Figure 8.4.10-1: Middle Paxton Creek West - Existing Hydraulic and Structural Problems....8-110
Figure 8.4.10-2: Middle Paxton Creek West - Decentralized Green and Grey Infrastructure Opportunities....8-113
Figure 8.4.10-3: Middle Paxton Creek West - Satellite Treatment / Storage Opportunities....8-115
Figure 8.4.10-4: Middle Paxton Creek West - CSO Capture Performance and Opinion of Probable Cost Estimate....8-118
Figure 8.4.10-5: Middle Paxton Creek West - Annual CSO Event Frequency and Duration Performance by Control Strategy....8-120
Figure 8.4.11-1: Middle Paxton Creek East - Existing Hydraulic and Structural Problems....8-122
Figure 8.4.11-2: Middle Paxton Creek East - Decentralized Green and Grey Infrastructure Opportunities....8-126
Figure 8.4.11-3: Middle Paxton Creek East - Satellite Treatment / Storage Opportunities....8-128
Figure 8.4.11-4: Middle Paxton Creek East - CSO Capture Performance and Opinion of Probable Cost Estimate....8-131
Figure 8.4.11-5: Middle Paxton Creek East - Annual CSO Event Frequency and Duration Performance by Control Strategy....8-132
Figure 8.4.12-1: Lower Paxton Creek - Existing Hydraulic and Structural Problems....8-134
Figure 8.4.12-2: Lower Paxton Creek - Decentralized Green and Grey Infrastructure Opportunities.8-137
Figure 8.4.12-3: Lower Paxton Creek - Satellite Treatment / Storage Opportunities....8-140
Figure 8.4.12-4: Lower Paxton Creek - Stormwater Disconnection and Full Catchment Separation...8-142
Figure 8.4.12-5: Lower Paxton Creek - CSO Capture Performance and Opinion of Probable Cost Estimate....8-144
Figure 8.4.12-6: Lower Paxton Creek - Annual CSO Event Frequency Performance by Control Strategy....8-147
Figure 8.4.12-7: Lower Paxton Creek - Annual CSO Duration Performance by Control Strategy..8-148
Figure 8.4.13-1: Hemlock Street - Existing Hydraulic and Structural Problems....8-150
Figure 8.4.13-2: Hemlock Street - Decentralized Green and Grey Infrastructure Opportunities...8-153
Figure 8.4.13-3: Hemlock Street - Satellite Treatment / Storage Opportunities....8-155
Figure 8.4.13-4: Hemlock Street - CSO Capture Performance and Opinion of Probable Cost Estimate....8-158
Figure 8.4.13-5: Hemlock Street - Annual CSO Event Frequency and Duration Performance by Control Strategy....8-160
Figure 8.4.14-1: East Harrisburg - Existing Hydraulic and Structural Problems....8-163
Figure 8.4.14-2: East Harrisburg - Green Stormwater Infrastructure / Sediment Reduction Opportunities....8-164
Figure 8.4.15-1: Spring Creek - Existing Hydraulic and Structural Problems....8-166
Figure 8.4.15-2: Spring Creek - Green Stormwater Infrastructure / Sediment Reduction Opportunities....8-168
Figure 8.5-1: Flow Distribution and Storage Pump-Back with 45 MGD AWTF Capacity....8-178

Section 9 Figures

Figure 9-1: Process Flow Diagram for Estimating Asset Condition for Wastewater Infrastructure Assets....9-4

Figure 9-2: Core Risk Plot with Risk Management Zones 9-6

Section 11 Figures

Figure 11-1. Typical Year CSO Volume Controlled through Phased implementation of Decentralized Controls (Green-Grey) 11-6
Figure 11-2. Adaptive Management Strategy for Additional, Affordable Investments 11-7
Figure 11-3. Estimated Capital Cost of Affordable Rehabilitation and Wet Weather Control Projects over the 20-year Planning Horizon 11-11
Figure 11-4. Projected CSO Volume Control over the 20-year Planning Horizon 11-15

ED_005060A_00001812-00017

List of Tables

Section 1 Tables
Table 1-1: Pipe Length Statistics 1-8
Table 1-2: Existing CSO Discharge Statistics by Interceptor 1-13
Table 1-3: Summary of Preferred Control Strategy – Decentralized Controls (Green / Grey) 1-27
Table 1-4. Implementation Phases, Affordable Costs, and CSO Control Volume Targets 1-33

Section 3 Tables
Table 3-1: Monitoring Site Summary 3-3
Table 3-2: Catchment Area Types and Tributary Area Statistics 3-6
Table 3-3: CRW AWTF NPDES Discharge Limits 3-10
Table 3-4: Key Characteristics of Interceptors in the CRW Conveyance System 3-12
Table 3-5: Summary of Recommended Interceptor Cleaning and Rehabilitation 3-13
Table 3-6: Front Street Pump Station Wet Well Operating Levels 3-13
Table 3-7: Spring Creek Wet Well Operating Levels 3-14
Table 3-8: CRW Rapid Assessment Inspection Summary 3-17
Table 3-9: Median Monthly Precipitation Volumes in Harrisburg 3-20
Table 3-10: Median Monthly Precipitation Events in Harrisburg 3-21
Table 3-11: Precipitation Monitoring Site Summary 3-22
Table 3-12: Point Precipitation Frequency Estimates* for Harrisburg for a 1-Year Recurrence Interval 3-24
Table 3-13: Characteristics of CRW's Collection/Trunk Sewer Model 3-30
Table 3-14: Interceptor System Monitoring Site Summary 3-33
Table 3-15: Suburban Community POC Monitoring Site Summary 3-35
Table 3-16: Combined Collection System Flow Characterization Monitoring Site Summary 3-37
Table 3-17: City of Harrisburg Separate Sanitary Sewer Data Collection Site Summary 3-39
Table 3-18: Estimated Dry Weather Flow Measured Within CRW's Conveyance System 3-40
Table 3-19: Summary RDII Analysis Results for CRW Separate Sanitary Sewer Catchment Areas 3-43
Table 3-20: Summary RDII Analysis Results for Suburban Separate Sanitary Sewer Catchment Areas 3-43
Table 3-21: Selected Storm Events for H&H Model Calibration and Validation 3-44

Section 4 Tables
Table 4-1: Recommended High Priority Rehabilitation Projects at the AWTF 4-5
Table 4-2: Primary Clarifier Design Criteria 4-6
Table 4-3: AWTF Flow and Primary Clarifier Surface Overflow Rates 4-7
Table 4-4: Susquehanna River Flood Elevations at AWTF 4-10
Table 4-5: Recommended Rehabilitation of CRW's Interceptor System 4-12
Table 4-6: Combined Sewer System Wet Weather Characterization of Current Conditions 4-14
Table 4-7: Existing Combined Sewer System Wet Weather Characterization by CSO Regulator 4-18
Table 4-8: Summary of Hydraulic Conditions along Combined Trunk Sewer Pipes 4-25
Table 4-9: Summary of Hydraulic Conditions at Combined Trunk Sewer Manholes 4-25
Table 4-10: Summary of Hydraulic Conditions along Separate Sanitary Sewer Pipes 4-26

ED_005060A_00001812-00018

Table 4-11: Summary of Hydraulic Conditions at Separate Sanitary Manholes....4-27
Table 4-12: Ground Water Infiltration along the Spring Creek Interceptor....4-28
Table 4-13: Attainment Status of Waters Receiving CRW Combined Sewer System Discharges....4-29
Table 4-14: Paxton Creek Water Surface Elevation Monitoring Summary....4-30
Table 4-15: Pollutants of Concern Discharging from CRW's Combined Sewer System....4-34
Table 4-16: Numeric Water Quality Criteria for Designated Uses of Pennsylvania Waters....4-39

Section 5 Tables

Table 5-1: Triple Bottom Line Evaluation Criteria and Relationship to CRW Strategic Goals and Objectives....5-10

Section 6 Tables

Table 6-1: Feasible Wet Weather Control Alternatives for CRW's Service Area....6-11

Section 7 Tables

Table 7-1: Wastewater Billed Flow by Municipality....7-6
Table 7-2: Historical and Budgeted O&M Expenses....7-6
Table 7-3: Wastewater Capital Project Expenditures....7-7
Table 7-4: Outstanding Debt of the Wastewater System (As of December 31, 2017)....7-7
Table 7-5: Historical Wastewater Utility Operating Results....7-8
Table 7-6: Existing Wastewater Rates (FY 2018)....7-8
Table 7-7: Historic Population Trends....7-9
Table 7-8: National Poverty Thresholds (2016)....7-12
Table 7-9: City of Harrisburg Poverty Rate Trend....7-12
Table 7-10: Percentage of Population with a Bachelor's Degree or Higher....7-13
Table 7-11: Median Household Income (adjusted to 2015 dollars)....7-14
Table 7-12: Income Quintiles of the U.S., Pennsylvania, Dauphin County, CRW's Service Area, and the City of Harrisburg....7-15
Table 7-13: Water and Wastewater Bill as a Percentage of Federal Poverty Threshold Incomes....7-20
Table 7-14: US-EPA Residential Indicator Financial Impacts....7-21
Table 7-15: Worksheet 1: Cost Per Household....7-22
Table 7-16: Worksheet 2: Residential Indicator....7-22
Table 7-17: Worksheet 4: Overall Net Debt as a Percentage of Full Market Property Value....7-24
Table 7-18: US-EPA Indicator Ranges for Overall Net Debt as a Percentage of Full Market Property Value....7-24
Table 7-19: Worksheet 5: Unemployment Rates (2016)....7-25
Table 7-20: US-EPA Indicator Ranges for the Unemployment Rate....7-25
Table 7-21: Worksheet 6: Median Household Income....7-25
Table 7-22: US-EPA Indicator Ranges for MHI....7-25
Table 7-23: Worksheet 7: Property Tax Revenues as a Percentage of Full Market Property Value 7-26
Table 7-24: Property Tax Revenues as a Percentage of Full Market Property Value....7-26
Table 7-25: Worksheet 8: Property Tax Revenue Collection Rate....7-27
Table 7-26: Property Tax Revenue Collection Rate Benchmarks....7-27
Table 7-27: Worksheet 9: Financial Capability Indicator Score....7-27
Table 7-28: Worksheet 10: Financial Capability Matrix Score....7-28

ED_005060A_00001812-00019

Table 7-29: Expense Category Cost Escalation Rates 7-30
Table 7-30: Summary of Projected R&R and Program Plan Capital Expenditures (escalated) 7-31
Table 7-31: Long Term Financial Plan and Affordability Projection 7-32

Section 8 Tables

Table 8.2-1: Baseline Level of Control Optimization and Enhancement Opportunity Descriptions 8-3
Table 8.2-2: Baseline Rehabilitation and Enhancement of the Regulator & Outfall Structures 8-3
Table 8.2-3: Baseline Level of Control Project Costs and Priorities 8-5
Table 8.4.1-1: Riverside - Baseline Level of Control Improvements 8-17
Table 8.4.1-2: Riverside – Existing/Baseline CSO Performance During Typical Year 8-19
Table 8.4.1-3: Riverside - High and Moderate Potential Opportunities for GSI 8-20
Table 8.4.1-4: Riverside – Levels of Control (Local Control Strategy 3) 8-24
Table 8.4.2-1: Italian Lake - High and Moderate Potential Opportunities for GSI 8-32
Table 8.4.3-1: Uptown - Baseline Level of Control Improvements 8-33
Table 8.4.3-2: Uptown – Existing/Baseline CSO Performance During Typical Year 8-36
Table 8.4.3-3: Uptown - High and Moderate Potential Opportunities for GSI 8-38
Table 8.4.3-4: Uptown – Levels of Control (Local Control Strategy 3) 8-41
Table 8.4.4-1: Middle Front Street - Baseline Level of Control Improvements 8-47
Table 8.4.4-2: Middle Front Street – Existing/Baseline CSO Performance During Typical Year 8-50
Table 8.4.4-3: Middle Front Street - High and Moderate Potential Opportunities for GSI 8-52
Table 8.4.4-4: Middle Front Street – Levels of Control (Local Control Strategy 3) 8-55
Table 8.4.5-1: Lower Front Street - Baseline Level of Control Improvements 8-61
Table 8.4.5-2: Lower Front Street – Existing/Baseline CSO Performance During Typical Year 8-64
Table 8.4.5-3: Lower Front Street - High and Moderate Potential Opportunities for GSI 8-66
Table 8.4.5-4: Lower Front Street – Levels of Control (Local Control Strategy 3) 8-68
Table 8.4.6-1: Industrial Road - High and Moderate Potential Opportunities for GSI 8-75
Table 8.4.7-1: Upper Paxton Creek West - Baseline Level of Control Improvements 8-79
Table 8.4.7-2: Upper Paxton Creek West – Existing/Baseline CSO Performance During Typical Year 8-82
Table 8.4.7-3: Upper Paxton Creek West - High and Moderate Potential Opportunities for GSI 8-83
Table 8.4.7-4: Upper Paxton Creek West – Levels of Control (Local Control Strategy 3) 8-86
Table 8.4.8-1: Arsenal Boulevard - High and Moderate Potential Opportunities for GSI 8-93
Table 8.4.9-1: Upper Paxton Creek East - Baseline Level of Control Improvements 8-97
Table 8.4.9-2: Upper Paxton Creek East – Existing/Baseline CSO Performance During Typical Year 8-99
Table 8.4.9-3: Upper Paxton Creek East - High and Moderate Potential Opportunities for GSI 8-102
Table 8.4.9-4: Upper Paxton Creek East – Levels of Control (Local Control Strategy 3) 8-104
Table 8.4.10-1: Middle Paxton Creek West - Baseline Level of Control Improvements 8-109
Table 8.4.10-2: Middle Paxton Creek West – Existing/Baseline CSO Performance During Typical Year 8-112
Table 8.4.10-3: Middle Paxton Creek East - High and Moderate Potential Opportunities for GSI 8-114
Table 8.4.10-4: Middle Paxton Creek West – Levels of Control (Local Control Strategy 3) 8-117
Table 8.4.11-1: Middle Paxton Creek East - Baseline Level of Control Improvements 8-123
Table 8.4.11-2: Middle Paxton Creek East – Existing/Baseline CSO Performance During Typical Year 8-124

Table 8.4.11-3: Middle Paxton Creek East - High and Moderate Potential Opportunities for GSI.8-125
Table 8.4.11-4: Middle Paxton Creek East – Levels of Control (Local Control Strategy 3) 8-129
Table 8.4.12-1: Lower Paxton Creek - Baseline Level of Control Improvements.....8-133
Table 8.4.12-2: Lower Paxton Creek – Existing/Baseline CSO Performance During Typical Year8-136
Table 8.4.12-3: Lower Paxton Creek - High and Moderate Potential Opportunities for GSI.....8-138
Table 8.4.12-4: Lower Paxton Creek – Levels of Control (Local Control Strategy 3) 8-141
Table 8.4.13-1: Hemlock Street - Baseline Level of Control Improvements.....8-149
Table 8.4.13-2: Hemlock Street – Existing/Baseline CSO Performance During Typical Year.....8-152
Table 8.4.13-3: Hemlock Street - High and Moderate Potential Opportunities for GSI.....8-154
Table 8.4.13-4: Hemlock Street – Levels of Control (Local Control Strategy 3) 8-157
Table 8.4.14-1: East Harrisburg - High and Moderate Potential Opportunities for GSI.....8-162
Table 8.4.15-1: Spring Creek - High and Moderate Potential Opportunities for GSI.....8-169
Table 8.5-1: Triple Bottom Line Evaluation Criteria and Relationship to CRW Strategic Goals and Objectives.....8-173
Table 8.5-2: Evaluation of Systemwide and Local Control Strategies.....8-174
Table 8.5-3: CRW AWTF NPDES Discharge Limits (Excerpts from NPDES Permit No. PA 0027197) 8-179
Table 8.5-4: CRW AWTF Average Discharge Characteristics.....8-180
Table 8.5-5: Predicted Advanced Treatment Bypasses at the CRW AWTF.....8-181
Table 8.5-6: CRW AWTF Total Discharge Mass Loadings Summary 8-181

Section 9 Tables

Table 9-1: Major Failure Modes and Their Definitions..... 9-3
Table 9-2: Triple Bottom Line Evaluation Criteria and Relationship to CRW Strategic Goals and Objectives..... 9-5
Table 9-3: Proxy Attributes for TBL Consequence of Failure Elements..... 9-6
Table 9-4: Services to Implement CRW's Asset Rehabilitation and Renewal Strategy..... 9-8
Table 9-5: Services to Implement CRW's Decentralized Green / Grey Implementation Strategy....9-20
Table 9-6: Services to Implement CRW's Asset Maintenance Strategy 9-24

Section 10 Tables

Table 10-1: PCMP Precipitation Monitoring Sites 10-5
Table 10-2: PCMP Interceptor System Monitoring Sites 10-6
Table 10-3: PCMP Suburban Community POC Monitoring Sits 10-6
Table 10-4: PCMP CSO Regulator Structure Monitoring Sites.....10-8

Section 11 Tables

Table 11-1. Implementation Phases, Affordable Costs, and CSO Control Volume Targets 11-2
Table 11-2: Recommended Projects for Rehabilitation of Wastewater/Stormwater Assets 11-5
Table 11-3. Recommended Early Action Wet Weather Control Projects 11-6
Table 11-4 Existing and Anticipated Future CRW Administrative and Operational Components...11-9
Table 11-5: Program Implementation Schedule – Immediate Implementation Phase 11-13
Table 11-6 Program Implementation Phasing – Near-Term 11-17

ED_005060A_00001812-00021

Appendices

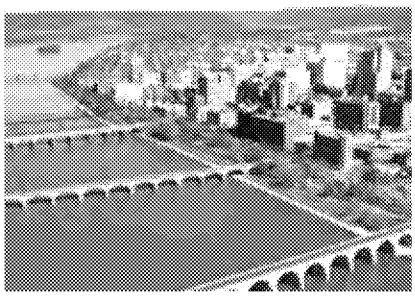
Appendix A Hydraulic Capacity of Combined Trunk Sewers

Appendix B Basis of Cost Opinions

Appendix C Public Participation Documents

Executive Summary

The *City Beautiful H_2O Program Plan* (Program Plan) is Capital Region Water's responsible approach to addressing a combination of system-wide infrastructure deterioration and failure with high-priority water quality compliance activities. Capital Region Water (CRW) must balance delivery of reliable service with Federal Clean Water Act (CWA) and Commonwealth Clean Streams Law obligations in a manner our ratepayers can afford.



The Program Plan balances the high-priority activities between two broad categories:

- ***Rehabilitation of the Sewer System***: Catch-up on previously deferred operation and maintenance needs, and implement a comprehensive asset management system to ensure the sewer system continues to provide reliable service to Capital Region Water customers.
- ***Wet Weather Control:*** Reduce combined and sanitary sewer overflows, and control backups onto streets and into basements to improve the health of local waterways, and protect public health and safety.

The financial capability of Capital Region Water's City ratepayers frames the balanced priorities of the Program Plan, setting the upper limit of service costs that will be assessed in the next 20 years.

A financial capability and affordability analysis was completed in accordance with the United States Environmental Protection Agency (US-EPA) requirements to assess the financial capability of Capital Region Water and its customers within the City of Harrisburg to pay for the Program Plan. The results of the analysis revealed that there is significant financial stress and economic hardship for customers located within the City of Harrisburg. The following key customer statistics highlight this limited financial capability:

- Unemployment has ranged between 14 percent and 17 percent in recent years, which has averaged approximately 10 percentage points higher than national, state and county levels.
- Approximately 32 percent of the population is living below the poverty level, which is more than double the national, state and county poverty levels.
- The median household income of $33,289 (in 2015) is more than $20,000 lower than that of the national, state, and county, and is only approximately $8,000 higher than the poverty threshold for a family of four.

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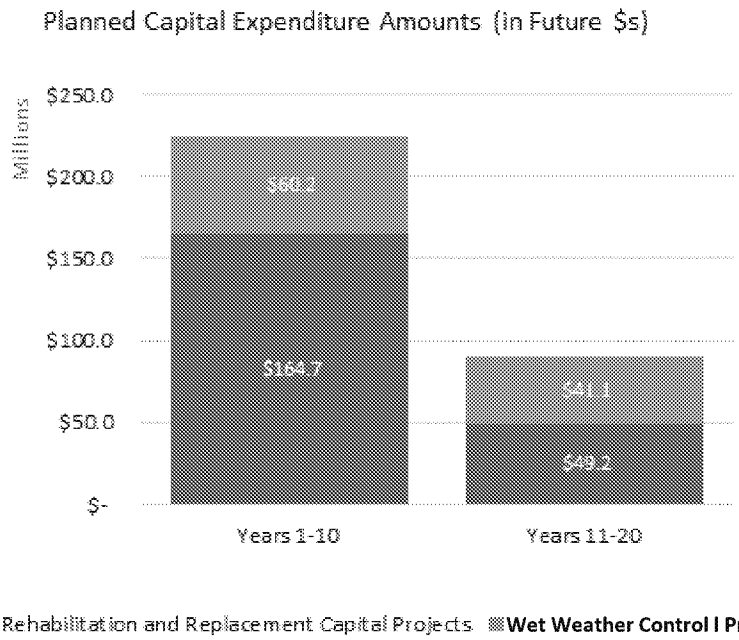
- An estimated 25 percent of the households within the City currently pay a wastewater bill that is more than 2.0 percent of their income, and approximately 30 percent of households have a combined water and sewer bill that exceeds 4.0 percent of income. Federal affordability guidelines state that there is a high financial burden when the total residential wastewater and stormwater costs reach 2.0 percent of the median household income (MHI).

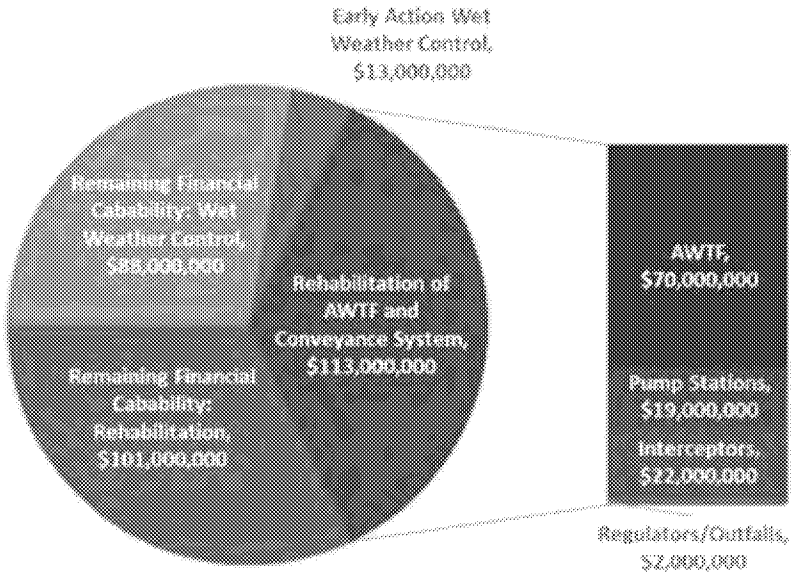
A high financial burden level, according to Federal affordability guidelines, is expected to occur in Harrisburg when approximately $225 million (escalated), or $185 million (in 2017 dollars) of additional capital costs are incurred by CRW over the next ten years. This will require a more than doubling of Capital Region Water's residential wastewater bills to generate sufficient revenue, from approximately $336 per year to $787 per year over the next 10 years. However, some customers in Harrisburg are already experiencing economic hardship and affordability issues, and these conditions may worsen as capital spending continues, and rates increase in the future.

Capital Region Water has already determined that approximately $113 million (escalated), or $102 million (in 2017 dollars) is required to fund high-priority projects to rehabilitate the Advanced Wastewater Treatment Facility and the conveyance system. This leaves only approximately $112 million (escalated), or $83 million (in 2017 dollars) of additional capital funding capacity over the next 10 years before the level of high financial burden is reached according to Federal guidelines. This is why Capital Region Water is pursuing the maximum amount of schedule relief possible from the US-EPA for Program Plan implementation and why an implementation plan of longer than 20-years is justified.



Projected Type	Years 1-10	Years 11-20	Total
Rehabilitation & Replacement	$164,700,000	$49,200,000	$213,900,000
Wet Weather Control	60,200,000	41,100,000	101,300,000
Total	$224,900,000	$90,300,000	$315,200,000

A 20-year financial analysis concluded that a total of approximately $***315 million in capital projects*** ($253 million in 2017 dollars) could be funded by Capital Region Water over a 20-year period ($225 million in the first 10 years and $90 million in the next) while keeping the affordability threshold at or just below the high financial burden threshold. A portion of this total 20-year investment will be needed to continue to address decades of deferred maintenance (prior to CRW ownership and operation) and to preserve system reliability ($214 million), whereas the remaining portion of this capital funding capacity ($101 million) will be available for local, neighborhood, green stormwater infrastructure (GSI) projects.



Priorities for implementing these projects will be established annually, based on the findings of the CCTV inspections, the combined sewer overflow (CSO) and/or sewer surcharge reduction benefits gained, and opportunities to incorporate controls into development or public works projects, gaining economies of scale.

Within the affordability framework of the Program Plan, the high-priority activities will address the following problems with our separate and combined wastewater/stormwater collection, conveyance, and treatment systems:

Collection System. An initial assessment revealed that nearly 40 percent of CRW's collection sewers may be in poor to very poor condition. Capital Region Water is conducting a systemwide video camera inspection survey to identify specific rehabilitation priorities and costs. In addition, modeling of Capital Region Water's collection system revealed numerous hydraulic "pinch-points", heightening the risk of surcharged sewers backing up into basements or flooding streets. Ultimately, the cost of repairs and stormwater controls are expected to ***exceed $100 million***.

Conveyance System. Capital Region Water's estimated cost to accomplish high-priority improvements is ***$43 million ($41 million in 2017 dollars)***, to preserve/enhance existing capacity and minimize the risk of system failure. Completed inspections identified structural and operational deficiencies and debris buildups, attributed to decades of deferred maintenance along the interceptor sewers. Major repairs and hydraulic enhancements are required for CRW's two major pumping stations, interceptor pipe, and each of its 59 flow regulating structures.

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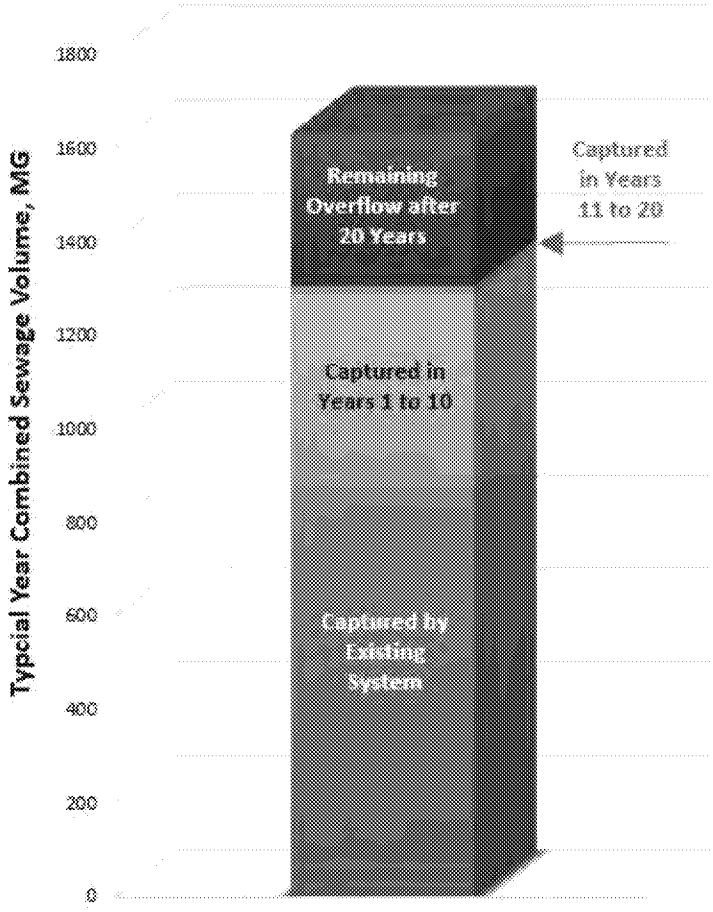
Advanced Wastewater Treatment Facility (AWTF). Recent evaluations reveal that most treatment processes are in fair overall physical condition, but require some capital replacement investments and additional operation and maintenance (O&M) expenditures. Capital Region Water's estimated cost to accomplish these improvements is ***$70 million ($61 million in 2017 dollars)***, which are considered to be a high priority, needed to preserve and enhance existing capacity and minimize the risk of major system failure.

Overall Program Plan Benefits

Over the next 20 years, with the implementation of $315 million in capital projects ($253 million in 2017 dollars), the Program Plan is expected to provide distinct benefits to Capital Region Water's customers:

- Renew Capital Region Water's major wastewater assets, restoring structural integrity, enhancing operational performance, and providing a sustainable foundation for efficient system performance.
- Improve water quality, eliminating nearly 500 million gallons per year of combined sewer discharges and restore stream function.
- Support community renewal, providing reliable sewer infrastructure that incorporates green stormwater infrastructure to reduce polluted discharges and flood risks.



Section 1

Overview of the Program Plan

This section provides an overview of Capital Region Water's (CRW's) *City Beautiful H_2O Program Plan* (Program Plan). An Executive Summary preceding this Section provides a concise description of the Program Plan, why it is needed, what it will accomplish, and how the total cost was established. The Program Plan is divided into eleven sections, and each section is summarized briefly in this overview.

1.1 Requirements and Objectives of the CRW Program Plan

1.1.1 Regulatory Requirements

On February 10, 2015 CRW became party to a Partial Consent Decree (PCD) with the U.S. Department of Justice (US-DOJ), U.S. Environmental Protection Agency (US-EPA), and Pennsylvania Department of Environmental Protection (PA-DEP). Consent Decrees and PCDs have been issued to municipalities and sewer authorities across the nation to establish compliance requirements and schedules beyond the framework of a traditional National Pollution Discharge Elimination System (NPDES) Permit. The PCD is consistent with objectives set by the federal Clean Water Act, the Combined Sewer Overflow (CSO) Control Policy, federal/commonwealth regulations for pollutant discharges from municipal separate storm sewer systems (MS4s), as well as state laws and regulations. Its objective is to improve water quality in receiving waters as necessary to achieve their designated waterway uses (e.g., drinking water, recreation, aquatic life, and others) and protect public health, safety, and welfare. The primary PCD requirements are to:

- Conduct comprehensive inspections of the CRW conveyance and collection systems, (see **Section 3.2**) and implement required rehabilitation measures to resolve deferred maintenance and correct identified critical structural and/or maintenance deficiencies,
- Develop and implement a CSO Nine Minimum Control (NMC) Plan, incorporating the MS4 Six Minimum Control Measures (MCM), that provides minimum technology-based controls and practices to address wet weather problems without extensive engineering studies or significant construction costs, prior to implementing long-term control measures,
- Develop a Long-Term Control Plan (LTCP) to resolve hydraulic capacity constraints and control the frequency, duration, and volume of CSOs being discharged into Paxton Creek and the Susquehanna River, and

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- Eliminate sanitary sewer overflows (SSOs) and other unauthorized discharges.

1.1.2 Program Plan Objectives

The objective of this Program Plan is to identify and prioritize affordable activities that CRW will undertake to comply with the Federal Clean Water Act (CWA) and the Commonwealth's Clean Streams Law. It is intended to meet the LTCP requirements of the PCD and incorporate other CRW program initiatives to comply with the PCD, following US-EPA's Integrated Municipal Stormwater and Wastewater Planning Approach Framework (Integrated Approach). The Program Plan describes each activity and its projected level of control in the following areas:

- ***Rehabilitation of the conveyance and collection systems***: catch-up on previously deferred operation and maintenance needs, and implement a comprehensive asset management system to ensure the sewer system continues to provide reliable service to CRW customers,
- ***Wet Weather Control:*** Reduce CSOs, SSOs, unauthorized releases, and MS4 discharges to improve the health of local waterways, and protect public health, safety, and welfare.

The Program Plan divides the CRW service area into 15 planning areas, located mostly within the City of Harrisburg (City) and generally coinciding with City neighborhoods. This structure allows the Program Plan to establish the needs, priorities, recommended activities, and consequent levels of control for each planning area, then roll these up into the full Program Plan. A map of the designated planning areas is provided in **Figure 1-1**.

1.2 Public Engagement and Participation

Capital Region Water's (CRW) challenge is not unlike those of the nearly 800 other CSO cities across the United States. It must finance an expensive, long-lasting and disruptive project via ratepayers who already have serious affordability concerns. A critical part of the solution is a thorough public engagement strategy involving CRW's City Beautiful H_2O brand and the use of partnerships with community and environmental organizations. CRW's public participation activities for the draft Program Plan built upon previous efforts and were designed to engage the public by bringing the information to a number of different audiences through various communication methods and outreach events.

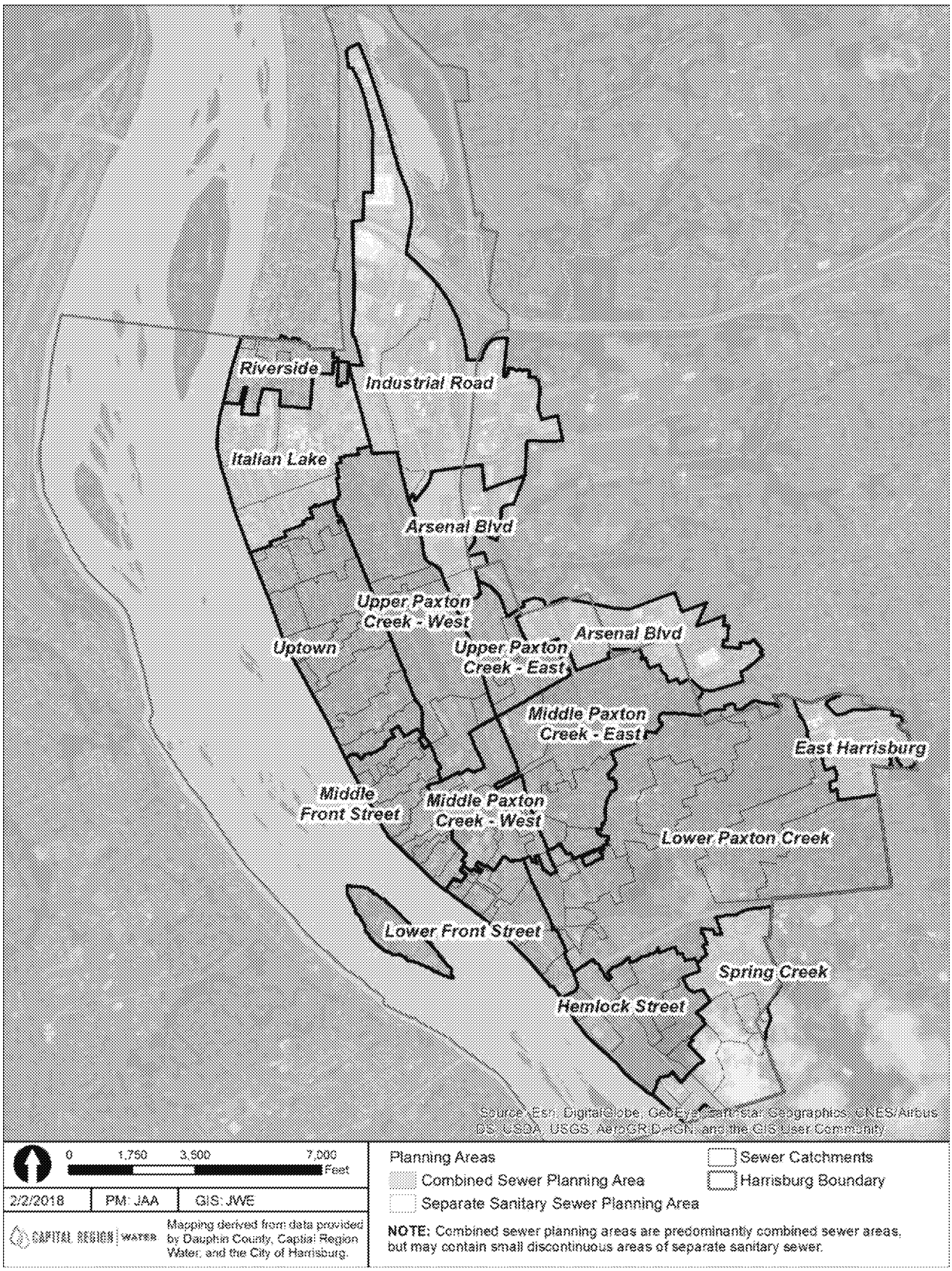

Figure 1-1: Designated Planning Areas within the CRW Service Area

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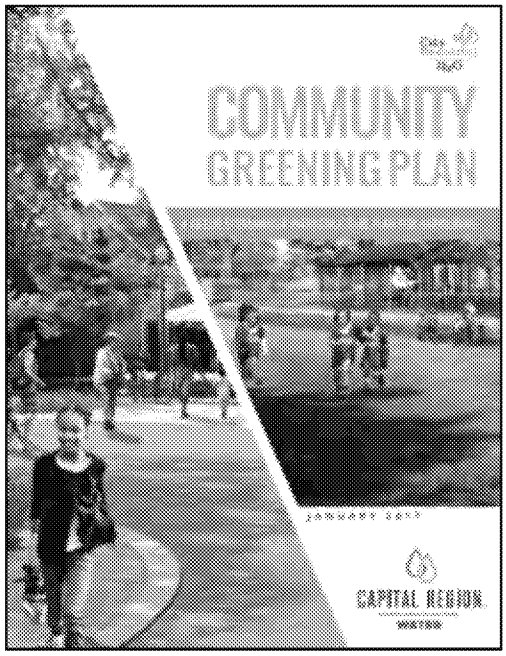
1.2.1 Existing Public Involvement Programs

CRW's on-going public involvement program and activities are documented in the Nine Minimum Control (NMC):

- Minimum Control 7 requires the development and implementation of pollution prevention and public education programs. Pollution prevention programs are part of the public education process and can help reduce the amount of contaminants and floatable materials that enter the Susquehanna River and Paxton Creek via CSO/MS4 discharges. CRW was successful in implementing programs such monthly trash clean-ups, an annual city-wide clean-up event, and street sweeping operations.

- Minimum Control 8 requires the development and implementation of public notification programs. Public notification programs also are part of the public education process and intended to ensure the public receives adequate information about CSOs, their potential health and environmental impacts, and precautions concerning recreational activities, such as swimming, during and immediately after CSOs. Therefore, the CRW public notification program informs people using the Susquehanna River or Paxton Creek for recreation about the potential associated health risks.



These minimum controls also achieve PA-DEP's MS4 stormwater permitting requirements for public education/outreach (Minimum Control Measure 1) and public participation/involvement (Minimum Control Measure 2).

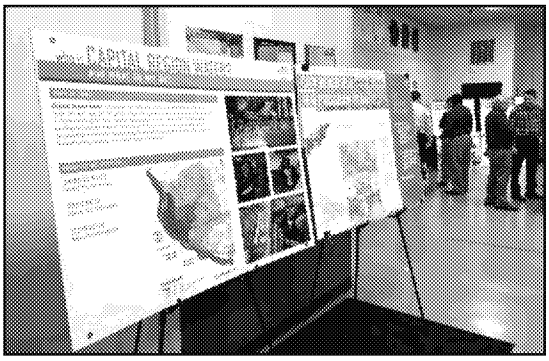
Community engagement also was an essential component in the preparation of CRW's Community Greening Plan, the green stormwater infrastructure masterplan for Harrisburg that was released in January 2017. Two large public engagement phases, one in the winter of 2016 and one in the summer of 2016, were held including several large events and more than thirty smaller engagement opportunities throughout the process. The process engaged over 1,000 residents from all areas of the city.

1.2.2 Public Involvement during the Release of the Draft Plan

CRW implemented a public involvement program to support development of this Program Plan that builds on the public involvement approaches and activities described in the NMC Plan, and the experience gained during preparation of the Community Greening Plan. This program provides several avenues for public involvement in the refinement and finalization of the draft Program Plan. A Companion Document that provided summary explanations of the Program Plan was prepared and distributed. The official public review and comment period for the Program Plan commenced on February 12, 2018 and extended through March 9. CRW conducted three large public involvement meetings for the Program Plan. The locations were selected with guidance from CRW's Community Ambassadors.

These meetings were organized in an open house format with five stations to explain the Program Plan and gather input from the public. Each station was led by a subject matter expert with assistance from community volunteers. Food and activities for kids were made available for free at each meeting to make it more convenient for families with children to attend. Attendees were asked to sign in when they entered the meeting and received a companion document, comment form, and pen. Attendees were then free to visit all 5 stations, listen to each speaker, and ask questions.

Meeting 1: Southern Harrisburg
Date: Thursday, February 15, 6:00 – 8:00 PM
Location: Sylvan Heights Science Charter School
915 South 13th Street, Harrisburg, PA 17104
Number of attendees: 5
Number of comments received from attendees: 0



Meeting 2: Lincoln School
Wednesday, February 21, 6:00 – 8:00 PM
Location: Lincoln School
1601 State Street, Harrisburg, PA 17103
Number of attendees: 13
Number of comments received from attendees: 2

Meeting 3: Camp Curtin YMCA
Thursday, March 1, 6:00 – 8:00 PM
Location: Camp Curtin YMCA
2135 North 6th Street, Harrisburg, PA 17110
Number of attendees: 11
Number of comments received from attendees: 2

CRW accepted public comments through an online form, in person at its Customer Service Center and its Administrative Office, and in person at its public meetings. In person comments were

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documented using a comment form. CRW also accepted letters and emails submitted during the public comment period. All comments were scanned and archived.

1.2.3 Future Public Participation after Submitting the Plan

Moving forward, CRW will continue to perform the public education and involvement activities described in its NMC Plan and will also continue the public participation activities initiated in association with the development and initial implementation of its Community Greening Plan. These activities include developing regulations, policies, design/construction standards, and O&M agreements that require implementing Green Stormwater Infrastructure (GSI) principals in development and redevelopment projects, and proactively distributing and explaining them to existing and potential stakeholders. CRW will work toward developing proactive partnerships with future developers/redevelopers to implement collaborative public-private partnerships for development/redevelopment projects. CRW will also define stormwater fee credits and other incentives to spur property owners to install decentralized stormwater controls.

PUBLIC ENGAGEMENT
SHARE YOUR VOICE
SHAPE OUR CITY

1.3 Characteristics of CRW's Wastewater/Stormwater System

The foundation for the *City Beautiful H_2O Program Plan* (Program Plan) is an accurate and up-to-date understanding of the sources of wastewater and stormwater within the CRW service area, the configuration and operation of CRW's sewer collection, conveyance, and treatment systems, and the surface waters receiving discharges from these systems. CRW developed and implemented a series of data collection and analysis programs, and incorporated the data and analysis results into a hydrologic and hydraulic (H&H) model of the CRW system. The data and the model were used as tools to quantify and characterize existing system configurations and flows, and establish a baseline condition on which to develop alternative CSO and SSO control measures.

1.3.1 CRW Service Area

Located along the east shore of the Susquehanna River, CRW is a municipal authority that provides wastewater and stormwater collection, conveyance, and treatment services to over 17,200 customer accounts in the City of Harrisburg. CRW assumed operation and maintenance responsibilities for the wastewater and stormwater collection and conveyance systems in late 2013, which followed decades of deferred maintenance. CRW also provides wastewater conveyance and treatment services to six suburban communities as wholesale customers. These suburban communities are identified below:

- Lower Paxton Township
- Paxtang Borough
- Penbrook Borough
- Steelton Borough
- Susquehanna Township
- Swatara Township

CRW owns, operates, and maintains the wastewater and stormwater infrastructure within the City of Harrisburg and receives wastewater flow from the suburban communities through four gravity points of connection and a pump station force main. A map of the CRW service area,

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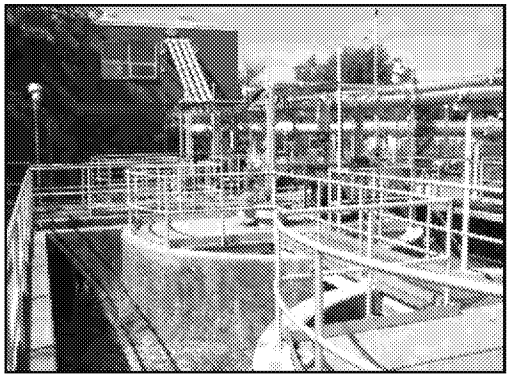
including the service area of each suburban community collection system, is provided in **Figure 3-1** (in the main body of the Program Plan).

1.3.2 Advanced Wastewater Treatment Facility (AWTF)

CRW owns and operates the AWTF located at 1662 South Cameron Street in Harrisburg. It is among the largest publicly owned treatment facilities in the Commonwealth and currently the largest in Pennsylvania within the Chesapeake Bay Watershed. CRW's AWTF treats wastewater from the City of Harrisburg and the six suburban communities located within its service area. The 5-year average annual wastewater flow at the AWTF during 2013 to 2017 was 21.4 million gallons per day (MGD). The permitted monthly average daily design capacity of the AWTF is 45 MGD.

AWTF Hydraulic Capacity	
Headworks	80 MGD
Primary Clarifiers	80 MGD
Secondary Treatment	45 MGD
BNR	45 MGD
Disinfection	80 MGD
2017 Influent Flow to AWTF	
Average Daily Flow	20.9 MGD
Max Avg. Daily Flow	51.9 MGD
Max Monthly ADF	25.8 MGD
Peak Flow	74.1 MGD



1.3.3 Conveyance System Conditions

The CRW conveyance system consists of the following facilities:

- Two major pumping stations – Front Street and Spring Creek – with associated force mains, that convey all wastewater flow from the City and five of the six suburban communities. Steelton's combined sewage is pumped directly to CRW's AWTF.
- Six major interceptor sewers, 13.8 miles in length, ranging in size and shape from 24-inch circular, to 60-inch by 72-inch arch, or rectangular pipe. Two of the interceptors, Asylum Run and Spring Creek convey separate sanitary flow. The other four interceptors, Front Street, Paxton Creek, Paxton Creek Relief, and Hemlock Street, are combined sewers.
- 59 CSO diversion structures and 58 CSO outfalls (two structures share an outfall) distributed along the interceptor sewers, plus an emergency overflow outfall at each of the two pumping stations. Combined wastewater enters the diversion structures and under dry weather conditions, all the flow is diverted towards the interceptor sewer and AWTF. During wet weather, the rate and volume of stormwater flow from the combined sewers increases

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significantly and can exceed the capacity of the regulators, downstream interceptor sewers and/or the treatment facility, causing a CSO. This process is shown in **Figure 1-2**.

Table 1-1 summarizes the length of the CRW's sewer systems, while maps of the CRW interceptor systems and regulator structures are provided in the Program Plan main body **Figures 3-6** and **3-7**.

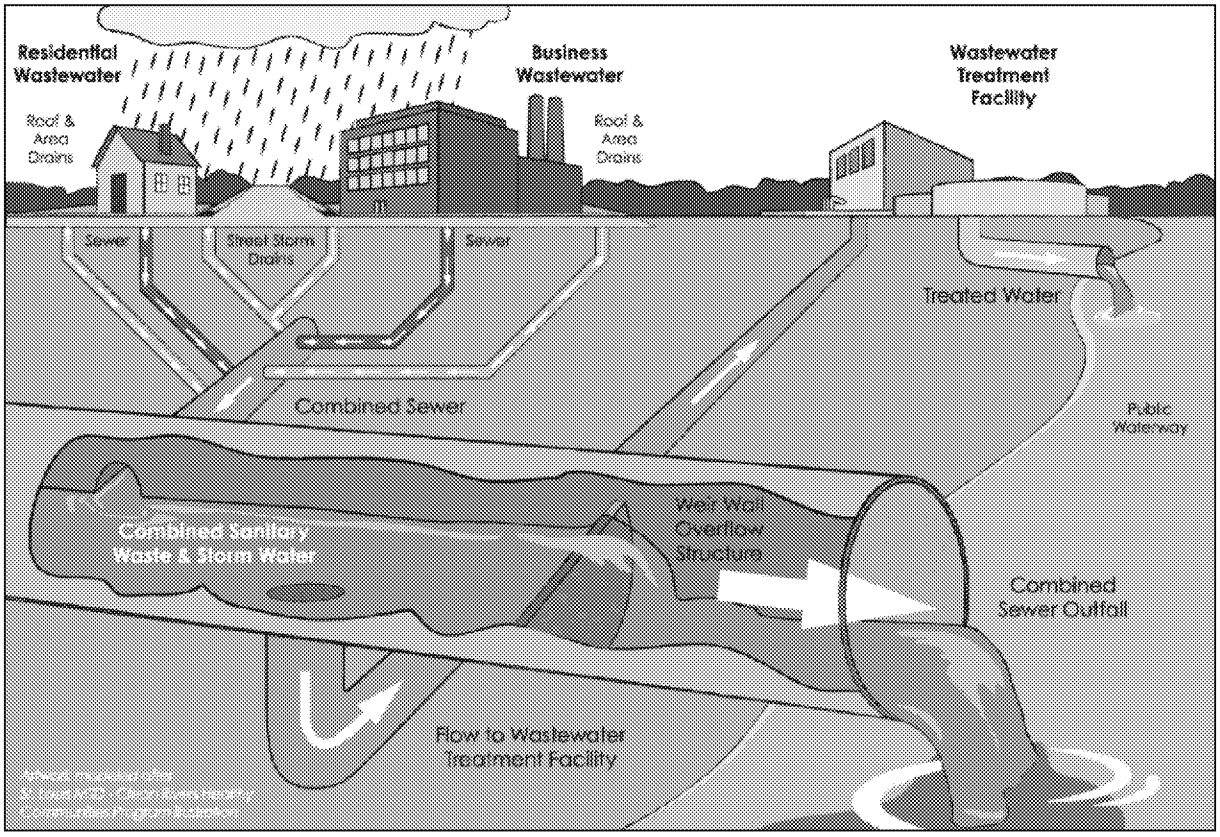


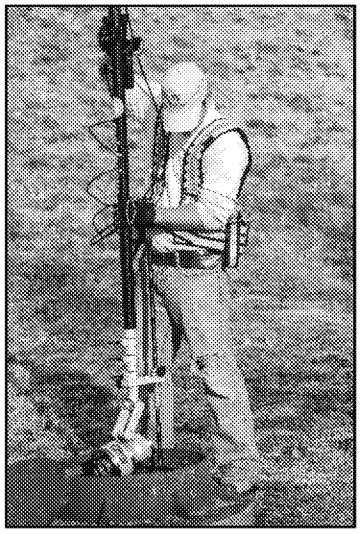
Figure 1-2: Typical Combined Sewer System with Regulator Structures

Table 1-1: Pipe Length Statistics

Pipe Class	Lengths (Miles)			
	Combined	Separate Sanitary	Separate Storm	Total
Interceptor	11.1	2.8	0	13.8
Collection System				
Trunk	24.3	5.4	0	29.7
Branch	62.7	27.8	40.0	130.5
Outfall Pipes	1.6	0	0	1.6
CSO Regulator Pipes	1.3	0	0	1.3
Total	**100.9**	**36.0**	**40.0**	**176.9**

1.3.4 Collection System Conditions

About 60 percent of CRW's wastewater and stormwater collection systems are comprised of combined sewers, some of which were built over a century ago. Steelton Borough also has a combined sewer system. In a combined sewer system, a single pipe carries sewage and stormwater. The remaining 40 percent of CRW's system, and the other five suburban community customers are served by separate and distinct wastewater and stormwater systems.



In the initial stages of the Program Plan, CRW needed to quickly update its original geographic information system (GIS) mapping of the configuration of the combined and separate sanitary sewer collection systems within the service area. The time required to perform a closed-circuit television (CCTV) inspection of the entire system exceeded the PCD schedule and milestone deadlines. Therefore, CRW elected to implement a Rapid Assessment Inspection Program, conducted via a pole camera inspection of every known manhole and connecting pipe within the collection system. The rapid assessment allowed CRW to:

- Collect the data necessary to build and apply its H&H model within PCD deadlines,
- Identify critical system blockages / failures visible from the manholes, and
- Develop and implement a prioritized CCTV inspection program to fully inspect the entire collection system and develop priorities for system rehabilitation.

Section 3.2.5 of the Program Plan describes the CRW collection system and the inspection investigations.

1.3.5 Regional Precipitation Characteristics

The median annual rainfall over the greater Harrisburg region is 39.6 inches. The median number of significant precipitation events is 86 storms per year. To quantify and characterize precipitation patterns, and support the development of the Program Plan, CRW successfully developed and implemented a precipitation gauge network consisting of eight tipping bucket rain gauges located throughout the CRW service area. Hourly rainfall data were also collected from the two National Weather Service gauges located at the Capital City Airport and at the Harrisburg International Airport. Like any rain gauge network, the CRW system cannot detect precipitation that occurs between the gauges. To fill these gaps and characterize the spatial variability of rainfall events throughout the CRW

Harrisburg Region Precipitation

Annual Precipitation Volume:

- Median: 39.6 inches
- Range: 31.7 to 47.9 inches

Annual Number of Precipitation Events:

- Median: 86
- Range: 74 to 98
- Volume: 0.46 inches per event
- Duration: 1.68 hours per event

Extreme (Design Storm) Rainfall:

Storm	24-hr. Volume (inches)	Peak Intensity (inch/hour)
2-year	2.90	3.3
5-year	3.67	4.1
10-year	4.36	4.8

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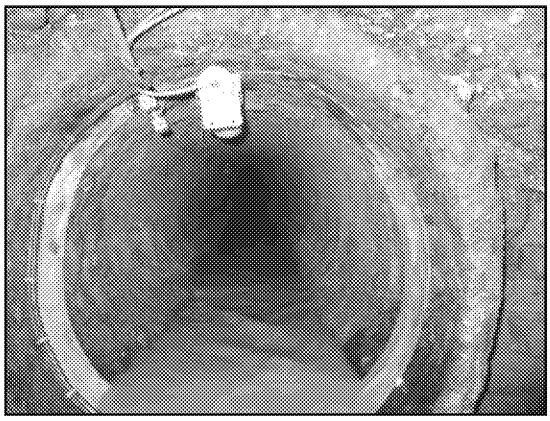
service area, gauge adjusted radar rainfall (GARR) data were obtained and used along with the gauge network data.

A representative or typical year precipitation dataset for the CRW service area was created for use with a H&H model of CRW's conveyance system to establish the frequency, duration, and volume of CSO discharges; characterize their potential water quality impacts; and develop and assess alternative CSO control strategies.

To quantify and characterize specific locations with the potential for SSOs and unauthorized combined sewer discharges to occur within the CRW service area, a series of synthetic design storms (with 1-year, 2-year, 5-year and 10-year recurrence intervals) were developed and applied to the H&H models. **Section 3.3** of the Program Plan describes the precipitation data that were collected and the subsequent analyses that were conducted.

1.3.6 Wastewater Flow Monitoring



An accurate and up-to-date understanding was needed of existing wastewater flows generated within CRW's separate and combined catchment areas under dry and wet weather conditions, and the resulting flow along the CRW sewer interceptors. A flow monitoring plan was developed and implemented to collect the data needed to characterize the CRW system and to refine and validate the H&H model. Flow monitoring was performed at the following locations and more detailed descriptions of the monitoring program are provided in **Section 3.4.3**.

- At the four major points of connection (POCs) where wastewater flows from the suburban community collection systems are conveyed to the CRW system
- At five representative CRW separate sanitary sewer catchment areas to characterize base wastewater flow (BWF), groundwater infiltration (GWI), and rainfall dependent infiltration/inflow (RDII)
- At thirteen representative CSO regulator structures to characterize the hydrology of their tributary catchment areas
- At nine selected points along the CRW interceptor system to calibrate/validate hydraulic model of the conveyance system

1.3.7 Hydrologic and Hydraulic Modeling

CRW incorporated the sewer system information obtained through its completed facility inspection programs to update and refine its H&H model of the CRW conveyance system and major trunk sewers within its collection system. CRW utilized the precipitation monitoring and flow monitoring data to properly calibrate and validate its H&H model. The model was used to develop a thorough understanding of the wastewater and stormwater flow characteristics of its

sewer system in response to precipitation events of varying duration and intensity. The following goals were achieved:

- To quantify the hydraulic capacity along the conveyance and collection systems,
- To quantify and characterize sewer system overflows, and unauthorized combined sewer system discharges, and
- To support the development of the Program Plan.

The monitoring programs and the development and use of the H&H models are documented in Program Plan **Section 3.4**.

1.4 Problem Analysis and Priorities

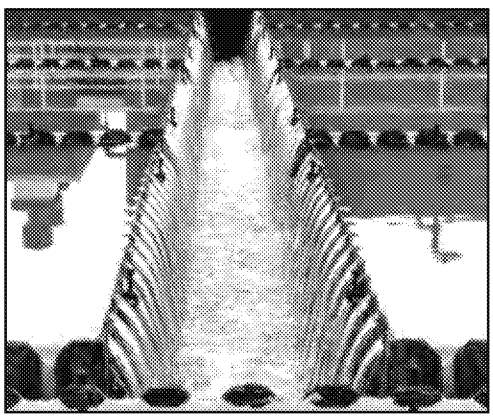
CRW's *City Beautiful H_2O Program Plan* (Program Plan) seeks a balanced, affordable approach to addressing the following challenges with its separate and combined wastewater/stormwater collection, conveyance, and treatment systems:

- Equipment failure and structural/operational deficiencies attributed to decades of deferred maintenance at the AWTF,
- Structural/operational deficiencies and debris buildups attributed to decades of deferred maintenance along the conveyance and collection systems,
- Water quality degradation attributed to wet weather sewer discharges from CSOs and municipal separate stormwater sewer systems (MS4s) to receiving waters, and
- Separate sanitary sewer overflows (SSOs) from separate sewers and unauthorized releases from combined sewers (basement backups), attributed to hydraulic capacity limitations.

To develop an effective Program Plan, the specific problems identified within the existing CRW systems need to be characterized and prioritized so needed remediation measures can be developed and implemented.

1.4.1 AWTF Problems and Priority Repairs

Recent evaluations reveal that most treatment processes are in fair overall physical condition but require some capital replacement investments and additional O&M expenditures. The AWTF currently has no screening facilities and the design and installation of a screen system has commenced. Design has also begun for the rehabilitation of the existing primary clarifiers, including installation of baffles and other improvements to enhance hydraulic capacity and treatment efficiency. Other deficiencies have been identified within the anaerobic digester, waste activated sludge (WAS) thickening, trucked in/hauled waste, co-generation, dewatering, and gravity thickener facilities. CRW's estimated cost to accomplish needed AWTF



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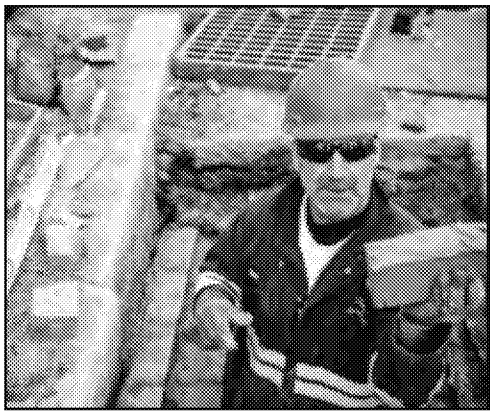
improvements is $70 million ($61 million in 2017 dollars), which are considered to be a high priority, needed to preserve/enhance existing capacity and to minimize the risk of major system failure.

1.4.2 Conveyance System Problems and Priority Repairs

Inspections identified structural and operational deficiencies and debris buildups, attributed to decades of deferred maintenance along the conveyance system. The inspections of the CSO regulators and outfalls found 15 CSO outfall pipes in need of repair and 40 CSO structures subject to potential river intrusion during a 2-year flood event or less. The interceptor system inspections prompted implementation of a cleaning program in 2016 where 1,800 tons of debris were removed and the pipes were re-inspected to confirm cleaning effectiveness and perform structural condition assessments. A scheduled interceptor system rehabilitation program was developed and is being implemented, and a 5-year cycle of re-inspection and cleaning has been recommended. Specific rehabilitation measures and upgrades have been recommended for the Front Street and Spring Creek wastewater pumping stations. CRW's estimated cost to accomplish these improvements is $39 million, which are also considered to be a high priority, needed to preserve/enhance existing capacity and to minimize the risk of major system failure.

1.4.3 Collection System Problems and Priority Repairs

CRW retained a contractor to perform the collection system Rapid Assessment Inspection Program in 2015 and 2016. CRW subsequently evaluated the collected data to assign condition scores to the assets. The results, which should not be confused with the level of confidence provided by full pipe televising, indicated that 17 percent of the inspected pipes were in excellent condition, 19 percent in good condition, 25 percent in fair condition, 21 percent in poor condition, and 17 percent in very poor condition. There were understood limitations to the information provided, so subsequently, CRW developed and is implementing a prioritized CCTV inspection program to fill in the information gaps at a pace within the capabilities of its equipment and staff.



CRW has developed an approach to identify and prioritize asset renewal needs as part of the overall Asset Management Program. This approach combines an asset's probability of failure and consequence of failure to determine the core risk, placing each asset in risk management zones, which in turn are used to develop priority levels. CRW has also implemented a stormwater inlet and catch basin cleaning and repair program, scheduled to be completed in 2021, to address inlets that are blocked with debris and those that require complete reconstruction when cleaned. Additional repair priorities will be established as condition assessment data becomes available. Existing structural and maintenance problems are documented in **Section 4.2** of the Program Plan.

1.4.4 Existing Discharges at CSO Regulators and Control Priorities

The results from the calibrated hydrologic and hydraulic model quantified wet weather sewer discharges from CSOs. The frequency, duration and volume (in million gallons) of CSO discharges

from each CSO outfall is provided in **Section 4.3** of the Program Plan. **Figure 1-3** illustrates the percent CSO capture by catchment within each of the 10 combined sewer planning areas, while **Table 1-2** summarizes this performance by interceptor. At EPA's request, discharges to the Susquehanna River are prioritized, with controls implemented within the financial capabilities of CRW and its customers.

Table 1-2: Existing CSO Discharge Statistics by Interceptor

Interceptor	Number of CSO Outfalls	Drainage Area (acres)	Captured Volume (million gallons)	Overflow Volume (million gallons)	Percent Capture	Annual Number of Overflows	Annual Overflow Duration (hours)
Front Street	27	723	302	247	55%	21 to 86	12 to 622
Paxton Creek	27	1,223	683	391	64%	9 to 74	2 to 620
Hemlock Street	5	124	40	28	59%	36 to 84	24 to 305
System Total	**59**	**2,900**	**1,024**	**666**	**61%**	**9 to 86**	**2 to 622**

1.4.5 Hydraulic Capacity Limitations Causing SSOs and Unauthorized Releases

Synthetic design storm rainfall was applied to the H&H model to estimate peak wastewater flows and water surface elevations within the existing separate sanitary sewer systems during the 2-year, 5-year, and 10-year 24-hour design storm events. The 2-year design storm has a 50 percent statistical probability of being equaled or exceeded in a given year. The 5-year design storm has a 20 percent probability of being equaled or exceeded in a given year, and the 10-year design storm has a 10 percent probability of being equaled or exceeded in a given year. The modeling results were able to identify specific locations where the design storm flows exceed sewer capacity, increasing the risk of unauthorized releases from the combined collection system and SSOs from the separate sanitary system. These pipe and manhole locations are depicted on maps provided in Program Plan **Appendix A** and the analyses are described in **Sections 4.4 and 4.5**.

The H&H model simulations also revealed limitations in the hydraulic capacity of the Spring Creek interceptor during the design storm events, increasing the risk of surcharging the interceptor and causing SSOs at manholes that have not been bolted down. Over 90 percent of the flow in the Spring Creek interceptor is generated by the suburban communities discharging into CRW's system, and a regional/intermunicipal solution is needed for the Program Plan. Unauthorized releases and SSOs caused by these hydraulic capacity limitations are prioritized primarily based on their relative risk to public health, safety, and welfare, with consideration of potential water quality impacts.

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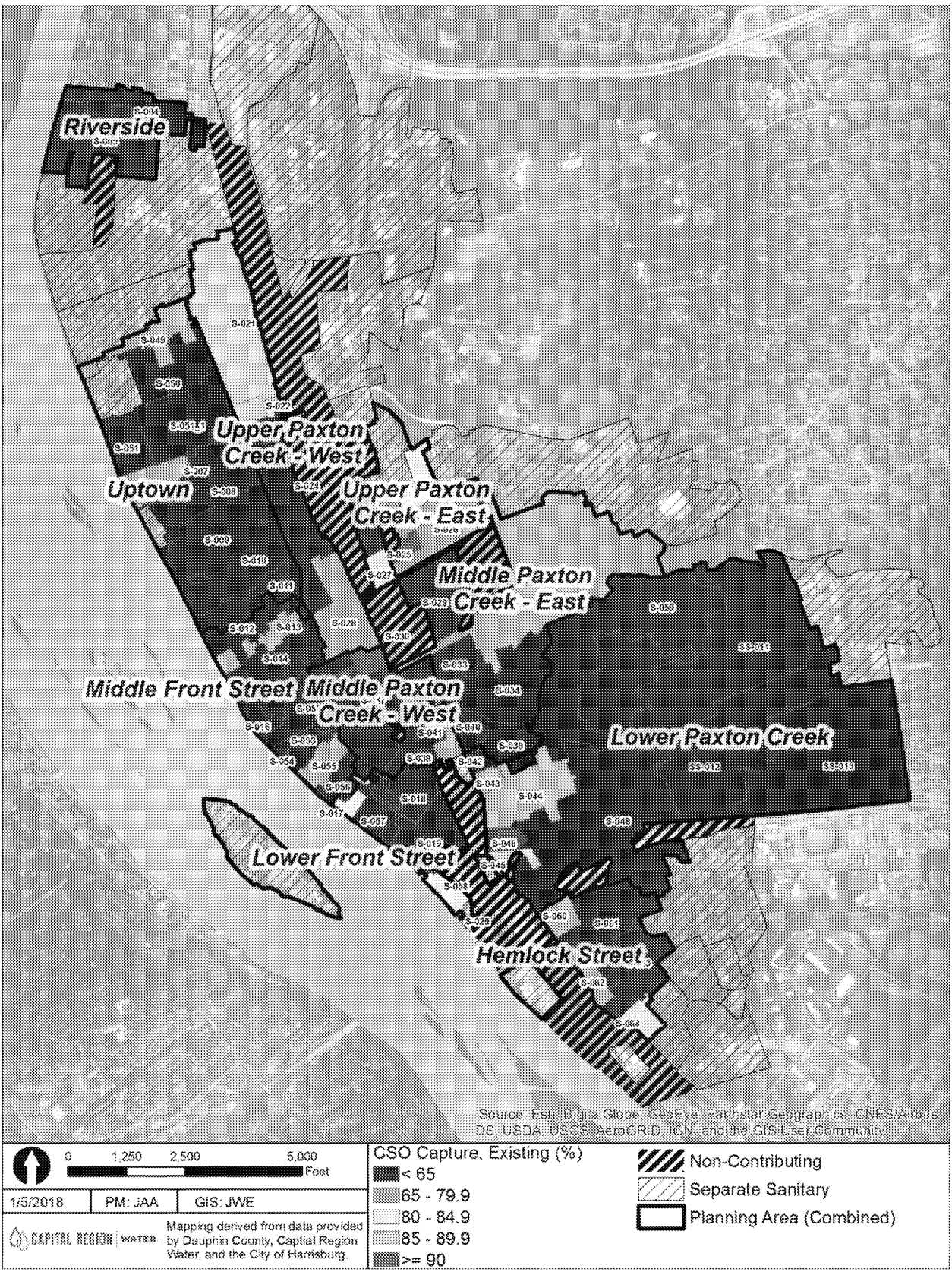
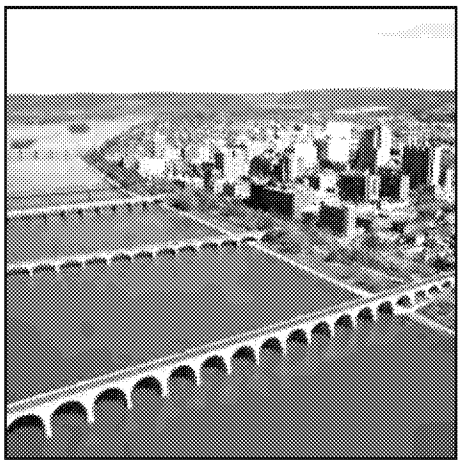


Figure 1-3: CSO Capture Achieved by CRW's Existing Combined Sewer System

1.4.6 Receiving Water Conditions



Over the past 10 years, extensive water quality monitoring and analysis has been conducted by CRW and PA-DEP on the two waterbodies receiving direct discharges from CRW's CSOs, the Susquehanna River and Paxton Creek. Conclusions were drawn from these data regarding CSO discharge characteristics, water quality, physical stream assessments, and biomonitoring. The primary pollutant of concern for the Susquehanna River is bacteria. The primary pollutants of concern for Paxton Creek are bacteria, sediments from excessive erosion, and oxygen-demanding substances that cause dissolved oxygen concentrations to fall below limits necessary to sustain aquatic life. Descriptions of receiving water quality are provided in **Section 4.6** of the Program Plan.

1.5 The Long-Term Planning Process

This section summarizes the governing principal objectives, approach, and planning process for developing CRW's *City Beautiful H_2O Program Plan* (Program Plan). The Program Plan meets the Long-Term Control Plan (LTCP) and integrated stormwater / wastewater planning requirements of the Partial Consent Decree (PCD). It provides a long-term, integrated strategy to address the hydraulic and structural deficiencies of CRW's wastewater and stormwater assets, improve in-stream water quality, beautify neighborhoods through community greening, and protect public health. **Figure 1-4** illustrates the major steps in this planning process, defined in more detail in the following sections.

1.5.1 Characterization and Problem Identification

The first major phase of the Program Plan development process was to implement the activities and processes required to fully understand the existing system; how it is configured, its current condition and defects, and how it performs hydraulically. CRW's characterization and problem identification process revealed substantial asset rehabilitation needs attributable to years of deferred maintenance throughout the treatment, conveyance, and collection systems. Hydraulic evaluation revealed frequent, short-duration overflows at each of CRW's regulated CSO outfalls, coupled with localized hydraulic constraints presenting increased risk of unauthorized releases and SSOs.

1.5.2 Control Technology Screening

The second major phase of Program Plan development process consisted of evaluating available stormwater/wet weather control technologies, categorizing them to fit the baseline, systemwide, and local control strategies, and eliminating from consideration technologies that are not feasible or relevant to implement within CRW's system. CRW's service area was divided into program planning areas, a standard procedure for the development of all Long-Term Control Plans. Fifteen planning areas were delineated, based on receiving water, interceptor sewershed, recognized neighborhoods, and logical groupings of catchments to support satellite control strategies.

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1.5.3 Alternative Development and Evaluation

The third major phase of the Program Plan development process is to formulate feasible control strategies. Control strategies for the CRW service area involved both centralized strategies for the entire system, and decentralized strategies for each planning area. Within each of the program planning areas, these control strategies help to solve existing problems regarding uncontrolled CSO discharges, significant structural deterioration, and hydraulic pinch-points presenting a heightened risk of unauthorized discharges or SSOs (e.g. localized flooding and basement backups). Appropriate control technologies are selected for each control strategy, a "knee-of-the-curve" cost performance analysis was conducted, limitations on the level of control achievable within each strategy were defined, and the benefits of each strategy were evaluated using triple bottom line evaluation criteria. Specific control technologies were selected for each control strategy, as well as feasible levels of implementation based upon an evaluation of the opportunities and barriers to implementing these controls within CRW's system.

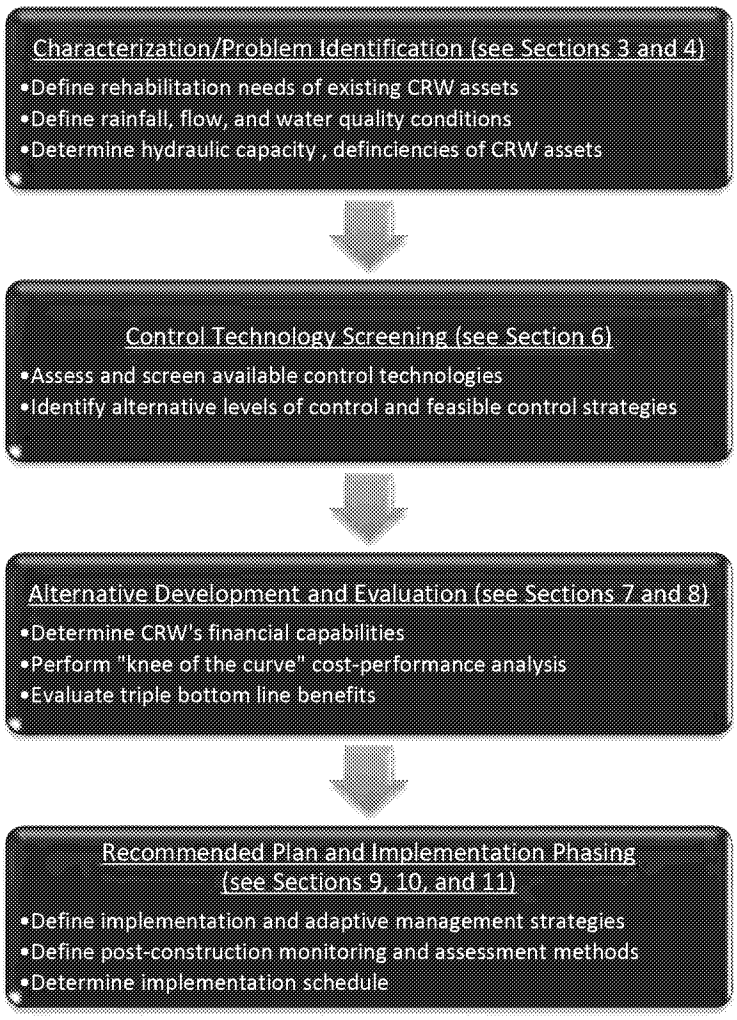

Figure 1-4: Summary of Integrated Wet Weather Control Plan Process

1.5.4 Recommended Control Plan and Implementation Phasing

The final phase of the Program Planning process is to use the findings of the screening activities and the selected control strategy/technology combinations to consider a range of facility sizes and associated control ranges, and to conduct affordability and cost-effectiveness analyses to identify the optimal control range and implementation schedule and duration. A control plan was selected that minimizes CSO discharges, improves water receiving quality, addresses stormwater management and local flooding, and meets affordable guideline constraints for rate payers. It must be understood that strongly desired projects and/or control facility elements may need to be ruled out, and not incorporated into the selected plan, because their costs are outside the range of affordability, even though the component may be "needed" or provide significant desired

benefits. The selected plan, as identified and defined in the Program Plan, will evolve over time under an adaptive management implementation approach.

1.6 Control Technologies and Screening

This section describes the potential CSO control technologies to be considered by CRW for integration into the *City Beautiful H_2O Program Plan* (Program Plan). The screening process evaluates available control technologies, identifying those that would be effective in the CRW system, and eliminating from consideration technologies that are not feasible or relevant to implement within CRW's system. The technologies included in the screening analysis are generally grouped into the following categories:

- ***Source Controls:*** Measures that reduce the volume, peak flow, or pollutant load of runoff, either before it enters the Collection System or is redirected to an MS4, including green stormwater infrastructure. Non-structural source controls are required under the minimum controls of the CSO policy and the MS4 permit, while structural source controls (e.g., green stormwater infrastructure) are implemented through a local, decentralized control strategy.
- ***Collection System Controls:*** Measures that restore and maintain the resiliency of CRW's sewer assets, increase their hydraulic capacity, and/or reduce the volume, peak flow, or pollutant load of flows within the Collection System. Collection system controls have localized effects on CSOs, SSOs, MS4 discharges, and unauthorized releases within a single catchment, and are also implemented through a local, decentralized control strategy.

- ***Conveyance System Controls:*** These controls are intended to increase the hydraulic capacity of the conveyance system (i.e., CSO regulators, interceptors, pump stations), and/or increase the wet weather treatment capacity of CRW's AWTF. Conveyance enhancements may be part of satellite control strategies (i.e., consolidation sewers that convey flow from the collection system to a satellite control site), or as part of a strategy to enhance capacity. Conveyance system controls affect the performance of the entire sewer system and are implemented through a systemwide control strategy.
- ***Storage Technologies:*** In-line and off-line storage for wet weather flows that are detained during significant storm events and released once rainfall/snowmelt has ended and treatment and conveyance capacity have been restored. This category of control is typically deployed at or near a CSO outfall (or consolidated set of outfalls), providing storage upstream of the AWTF. Storage technologies may be implemented through local, satellite control

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strategies or, for larger facilities that affect the performance of the entire sewer system, through a systemwide control strategy.

- ***Treatment Technologies:*** Technologies that treat the wet weather flow prior to discharge from the conveyance system to reduce pollutant load to the receiving waters. This category of control is also typically deployed at or near a CSO outfall (or consolidated set of outfalls), providing treatment upstream of the AWTF. Satellite controls were evaluated for each of the various planning areas established within CRW's service area. Treatment technologies may be implemented through local, satellite control strategies or, for larger facilities that affect the performance of the entire sewer system, through a systemwide control strategy.
- ***Receiving Water Technologies:*** Methods for removing pollutants after they have been discharged to the receiving waters. Streambank stabilization measures recommended under the Joint Pollution Reduction Plan for Paxton Creek and other receiving waters utilizes receiving water technologies.
- ***Not Applicable/Not Feasible:*** Some controls may not be applicable to CRW's system, or may not be feasible to implement within CRW's system. Not applicable/not feasible control options are not considered further in this plan.

1.7 Financial Capability Analysis

Paragraph 18 of the PCD required that the draft *City Beautiful H_2O Program Plan* (Program Plan) include a final Financial Capability Assessment (FCA) as described in the 1994 US EPA CSO Control Policy and subsequent guidance documents. The FCA is a two-phased process. The residential indicator (RI) is the percentage of median household income (MHI) expended on wastewater and stormwater services annually. US EPA considers that expenditures exceeding 2.0 percent of MHI impose a high burden. Therefore, the upper limit of affordability within the City of Harrisburg (City) is the point where the total cost for wastewater and stormwater services exceeds 2.0 percent of the City's MHI.

The second phase of the FCA provides a financial indicator (FI) of the permittee's ability to finance capital CSO controls. The financial capability indicator assesses debt burden, socioeconomic conditions, financial operations, and certain economic and demographic conditions such as the area's unemployment rate and MHI compared to those of the entire United States. The RI and FI are combined into a financial capability matrix to determine the level of financial burden on households and permittees.

The FCA methodology identified in the US EPA guidance presents a "snapshot" view of affordability which assumes that all capital expenditures will occur simultaneously. It starts with the current wastewater system annual costs, onto which are added to the incremental debt service and operation and maintenance costs in current dollars resulting from CSO controls and all other known capital improvements, e.g. collection system rehabilitation. The percentage of costs attributable to residential users is identified and the typical costs per household is

calculated using the number of households. Using this methodology, total future capital expenditures by CRW attributable to the City of Harrisburg of approximately $185 million (in 2017 dollars) would trigger the 2.0 percent high burden RI for the City residents.

The US EPA "snapshot" methodology is very limited in its ability to account for the impact that long term capital improvement programs will have on community, customer bills, and affordability. In order to present a more comprehensive picture of the City of Harrisburg's financial capability and customer affordability a comprehensive long-term financial planning model was prepared that is based on the model that CRW uses to evaluate budgets and set wastewater rates, and to assess the impacts of program alternatives on customer bills. This model includes known and necessary priority capital expenditures. These expenditures total approximately $315 million (escalated), or $253 million (in 2017 dollars), largely for critical investments in existing treatment and conveyance facilities.

The long-term financial planning model indicates that significant wastewater rate increases will be needed over the first five years of the plan. Including the 7.1 percent rate increase that was adopted by CRW in 2017 for 2018, the financial plan would require cumulative increases in wastewater rates of 75.4 percent over the period of 2018-2022. After 2022, the residential bill as a percentage of MHI approaches 2 percent and remains at this level throughout the remaining portion of the 20-year period (2023-2037).

To hold the Harrisburg RI at the 2.0 percent high burden threshold, future annual capital expenditures will need to be limited to projected expenditures in years 11 through 20 through 2047 when current 30-year debt is paid off. Strategically, three categories of investment will need to be funded through this available amount: collection system rehabilitation / renewal, decentralized green and grey CSO controls, and new operational and administrative activities required to implement the nine minimum controls and the decentralized green and grey controls.

While the long-term financial plan and affordability model was designed to keep total annual City residential customer cost for wastewater and stormwater service at or below 2 percent of MHI, it is anticipated that there will still be financial capability and affordability issues for some customers within the City. For some customers within the City, the cost as a percentage of income will far exceed 2 percent. The cost as a percentage of income for some Census tracks within the City, representing approximately 17 percent of the population, are anticipated to exceed 3 percent, of MHI, and several census tracts, representing an additional 4 percent of the population, will be in the 2.5 – 3.0 percent range. This indicates that the increases in wastewater and stormwater costs to residential customers within the City may be unaffordable and result in significant economic hardship for some customers, even if the cost as a percentage of the MHI stays at or below 2 percent.

Given these considerations, CRW should receive the maximum schedule relief possible for implementing its Program Plan. The implementation schedule presented in this report, is a

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reasonable timeline to take into account affordability considerations and concerns in the more vulnerable areas of the CRW's service area.

1.8 Development/Evaluation of Alternative Control Strategies

The PCD requires that the Program Plan assess the potential size and cost of alternative control technologies to reach various levels of control. This evaluation defined the level of CSO discharge control (i.e. the reduction in the frequency, volume and duration of discharges during typical year precipitation) that could be achieved by each technology over a range of sizes. The CRW H&H model was used to perform what is called a "knee-of-the curve" cost performance evaluation, required by the Partial Consent Decree. These cost-performance curves were used to indicate the level of control needed to reach certain control objectives:

- A ***baseline level-of-control***, defined as the level of CSO control achieved through imlementation of the system rehabilitation measures outlined in **Section 4**.
- An ***affordable level of control***, defined as additional wet weather controls that can be implemented within CRW's financial capabilities, as presented in **Section 7**,
- A ***cost-effective level of control***, defined as the additional wet weather controls at the "knee of the curve", where the inflection point along each cost curve indicates the level of control above which any additional control measures would be less cost effective, and
- A ***presumptive level of control***, defined as the controls necessary to capture and treat 85 percent of the systemwide combined sewage during the typical year.

A graph showing the results of a typical knee-of the curve analysis is provided in **Figure 1-5**. Knee-of-the-curve analyses were conducted for two systemwide control strategies and three local control strategies within the 15 planning areas composing CRW's service area.

1.8.1 Baseline Level of Control

The ***baseline level of control*** involves multi-objective projects that rehabilitate priority system assets by optimizing existing sewer system performance. It includes relatively low-cost operating changes, repairs, and small-scale capital projects that can improve the capacity, efficiency, and performance of the combined sewer system in the near term. **Figure 1-6** illustrates the CSO capture achieved under the Baseline Control Strategy. The figure indicates, that systemwide CSO volume capture increases from 53 percent to 78 percent through implementation of baseline controls, achieved through a $2.2 million investment (in 2017 dollars) in regulator modifications and hydraulic enhancements achieved by previously scheduled re-investments in the AWTF, major pumping station, and interceptor sewers described in **Section 4**. The baseline level of control is the recommended foundation for evaluation of alternative control strategies, with baseline control investments representing the highest priority projects and activities under this plan, with implementation anticipated during the first 10 to 15 years following approval of this Program Plan.

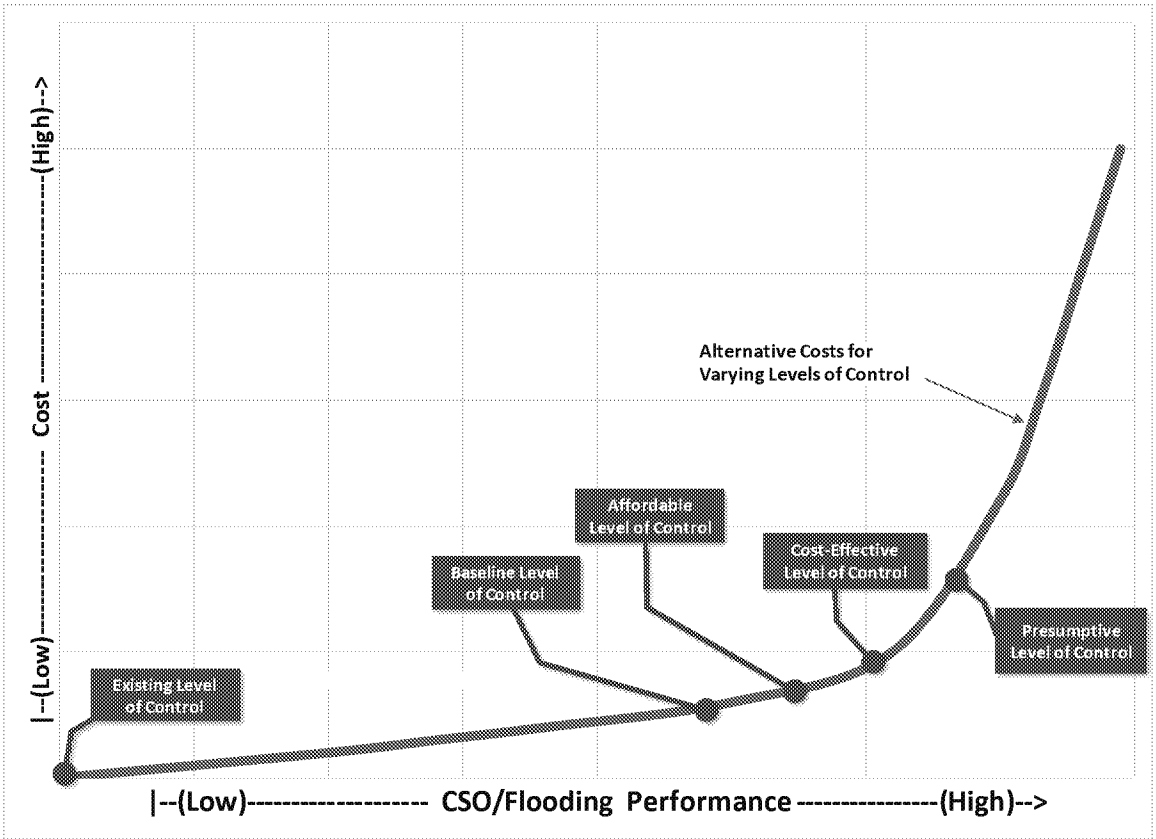

Figure 1-5: Idealized "Knee-of-the-Curve" and Potential Level of Control Objectives

1.8.2 Development of Alternative Control Strategies

The following ***alternative control strategies*** were developed by combining a unique set of the stormwater/wet weather control technologies previously evaluated in **Section 6**:

Systemwide Control Strategies

Systemwide control strategies focus on feasible technologies that further enhance the control of stormwater and wet weather flow within CRW's conveyance and treatment systems, i.e., the AWTF, major pump stations, interceptors, and/or regulator structure. Systemwide control strategies enhance system resiliency and contribute to receiving water quality improvement, but are ineffective at addressing sanitary sewer overflows (SSOs) and unauthorized releases (i.e. sewage backup into basements and manhole flooding into streets) within the collection system. Two alternative systemwide strategies were evaluated.

Systemwide Strategy 1: *Enhanced Conveyance and Increased AWTF Capacity* increases existing conveyance capacity by upgrading interceptors, regulators, major pump stations, and the AWTF. This strategy only provides a single control option within CRW's affordable level of control range, offers no opportunity to address unauthorized releases from the combined sewer system, and involves significant major capital projects, restricting CRW's ability to address critical collection system rehabilitation needs.

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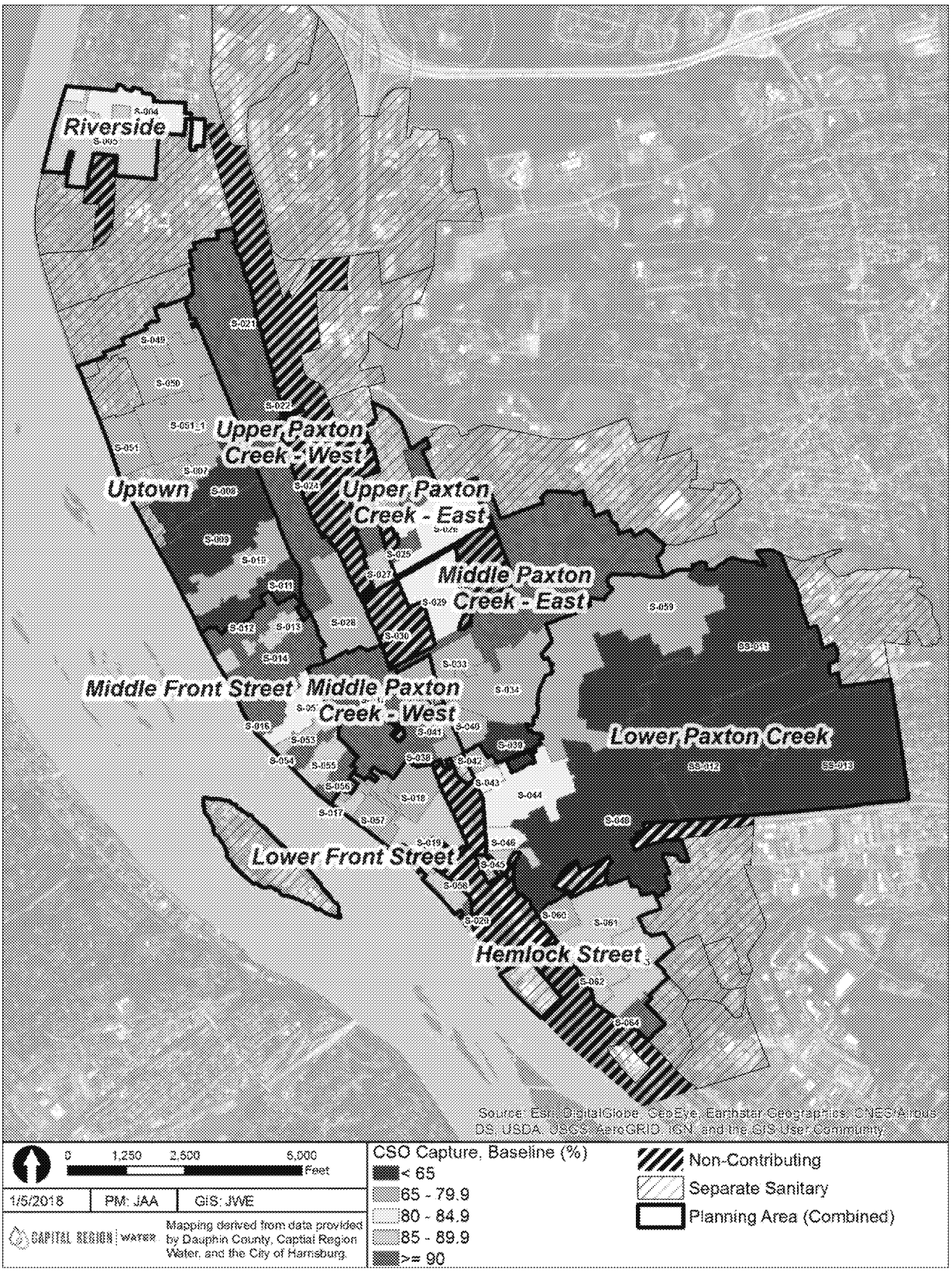

Figure 1-6: CSO Volume Capture by Catchment under the Baseline Level of Control

- ***Systemwide Strategy 2:*** *Build a deep tunnel* involves collecting/storing combined sewage flows exceeding the existing conveyance capacity, with post-storm dewatering to the AWTF. The smallest feasible control level under this strategy, a 14 million gallon tunnel is unable to be phased / financed within CRW's remaining financial capability, costs approximately four times more than the upper limit of CRW's affordable level of control range, and costs over twice as much as Enhanced Conveyance and Increased AWTF Capacity to achieve an equivalent level of CSO control. As a result, it is not considered to be a feasible control strategy for CRW's system.

Local Control Strategies

Local control strategies place technologies within CRW's collection system to address both neighborhood flooding and water quality impacts of discharges to receiving waters. Local control strategies use decentralized or local planning basin area approaches that implement various combinations of the grey control technologies and the green control technologies that were selected through the previously completed control technology screening process.

- ***Local Strategy 1:*** *Decentralized controls* (green-grey) within neighborhoods and individual catchment areas to reduce CSOs/SSOs/ unauthorized discharges, and MS4 discharges; maximize triple bottom line benefits, and leverage non-traditional funding sources.

- ***Local Strategy 2:*** *Satellite controls* place storage/treatment/conveyance facilities near outfalls to control CSOs, with limited opportunities to control SSOs, unauthorized releases, and MS4 discharges.

- ***Local Strategy 3:*** *Separation* of stormwater and wastewater sewers within catchment areas where the baseline strategy does not achieve the desired level of control, accompanied by green infrastructure sized to treat stormwater.

A subsection was created for systemwide control strategies and local control strategies for each of the 15 designated planning areas that comprise the City of Harrisburg (City). Each planning area subsection contains the following three map figures:

- A map figure depicting existing CSO discharge statistics at each outfall, hydraulic bottlenecks and surface flooding, and structural problems,

- A map figure depicting targeted areas for decentralized green and grey infrastructure implementation, the intersection of (a) impervious areas with high to moderate potential for control with green infrastructure, (b) areas of high risk for unauthorized releases/SSOs, (c) catchments with high CSO volumes / frequencies, and (d) potential integration with high priority sewer rehabilitation projects, and

- A map figure depicting satellite treatment and/or storage opportunities and the resulting improvements to CSO discharge statistics at each outfall.

1.8.3 Evaluation of Alternative Control Strategies

Each planning area subsection also provides a graphical representation of the results of the knee-of-the-curve analysis showing the CSO capture performance (representing the water quality

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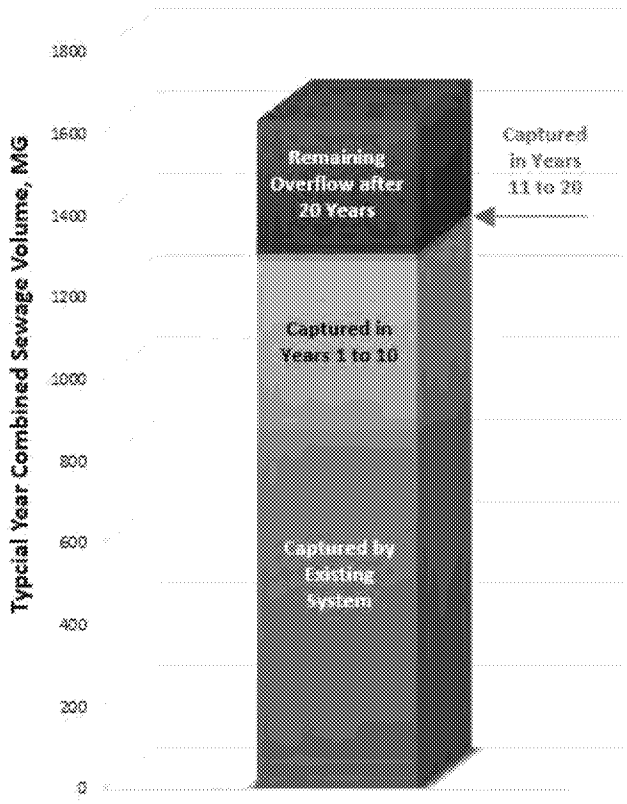
benefit) versus the associated opinion of probable cost. Cost curves show the baseline level of control allocated to each planning area, as well as the level of control achieved by each alternative systemwide and local control strategy. Also depicted on the graphic are the costs associated with the alternative levels of control (baseline, affordable, cost-effective, presumptive). The following conclusions about a systemwide and decentralized/local control strategy are drawn from the cost performance evaluation.

- Five of the fifteen planning areas are served by separate sanitary and storm sewer systems. H&H modeling revealed a limited number of locations where sewer surcharging may increase the risk of basement backups/SSOs. These areas will be monitored for customer complaints about basement backups to establish the priority for considering system improvements, as CRW has not received reports of basement backups in these areas to date. In addition, CRW has not observed or received reports of SSOs on the Spring Creek interceptor since CRW bolted down select manholes. Flow equalization storage is considered the recommended alternative for reducing this surcharging, however the need, priority, and phasing of this project will depend upon additional monitoring and assessment.

- The baseline level of control is highly cost-effective and recommended for implementation. It leverages planned investments in rehabilitation of CRW's AWTF, major pumping stations, and interceptors, increasing the overall hydraulic and primary treatment capacity of this system to 80 mgd. An additional $2.1 million investment to renovate CRW's CSO regulators and outfalls with modern flow regulating technology directs more flow into the interceptor, pumping stations, and AWTF, utilizing CRW's full hydraulic and primary treatment capacity. The baseline level of control also dramatically decreases CSO volumes and durations.

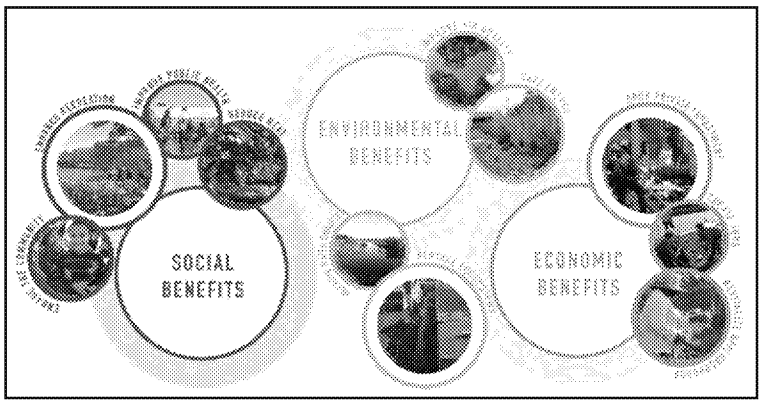
- The baseline level of control is able to achieve or exceed the presumptive level of control (i.e., capture 85 percent of the combined sewage volume in a typical year) in seven of the ten Planning Areas served by combined sewers. As such, these seven planning areas are considered to be a low priority for additional CSO control during the 20-year planning horizon of the Program Plan. Opportunities for additional control in these planning areas will depend on sewer rehabilitation priorities assigned through CCTV inspections of collection system sewers and development/public works projects that may be able to cost-effectively incorporate stormwater management controls.



- In the remaining three planning areas, the baseline level of control does not achieve the presumptive level of control (i.e., capture 85 percent of the combined sewage volume in a typical year). These three planning areas are considered to be a high priority for additional CSO control during the 20-year planning horizon of the Program Plan. In these areas, Local Control Strategy 1: Decentralized controls (green-grey) consistently provides an equal or higher level of control for the same cost as the other two control strategies. The decentralized control strategy also provides CRW the greatest flexibility to integrate controls into development and public works projects while addressing critical collection system rehabilitation and mitigate potential unauthorized releases. CRW' remaining financial capability over the next 20 years must be balanced between collection system rehabilitation and wet weather control priorities.

- The systemwide control strategies involve large capital investments in expanding the conveyance and/or treatment capacity of CRW's interceptors, pumping stations, and AWTF. In general, the cost of even the most modest of these control strategies far exceeds CRW's remaining financial capability for additional capital projects over the next 20 years. In addition, projects under the systemwide control strategy do not address priority structural and hydraulic problems within CRW's collection system, and would divert CRW funding from these projects. As such, the systemwide control strategies are not considered an appropriate control strategy for CRW over the 20-year planning horizon of this Program Plan.

Clearly, achieving an increased level of control is limited by CRW's financial capability constraints highlighted in Section 7 and high-priority system rehabilitation needs identified in Section 4. The decentralized control (green-grey) strategy is affordable, cost-effective, and flexible, allowing continued progress at integrated stormwater and wastewater control. To implement this strategy, future investment decisions in both asset rehabilitation and decentralized control implementation will be guided by CRW's triple bottom line (TBL) framework that incorporates three dimensions of performance: social, environmental and financial. TBL is a concept which seeks to broaden the focus on the financial bottom line by including social and environmental responsibilities and Program Plan benefits.



The CRW planning process included preparing and considering three different (and quite separate) bottom lines. One is ***financial***, the traditional bottom line of the cost and benefit analysis. The second is ***social/community***, the bottom line of the Plan's "people account", a measure in some shape or form of how socially responsible the Plan is in improving the quality of life for CRW's customers. The third is ***environmental,*** the bottom line of the Plan's "planet account", a measure of how environmentally responsible it is. This TBL framework will be applied to guide adaptive management decision-making as the Program Plan is implemented.

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1.8.4 Recommended Control Strategy

The alternative evaluation presented in **Section 8** indicates that Local Control Strategy 1 – Decentralized Controls (green-grey) is the preferred control strategy for CRW. In summary, the following major reasons support this recommendation.

- ***It is affordable and cost-effective***, meeting wet weather control objectives and supporting a multitude of multi-objective benefits, with significant opportunity for public-private partnerships to share implementation costs with CRW ratepayers.
- ***It is flexible,*** installed in small, incremental investments throughout the system, using technologies that can be designed to also address unauthorized releases and integrate with sewer rehabilitation projects, and suitable for integration with a broad range of redevelopment and public works projects. Indeed, with the limited financial capabilities of CRW and the remaining uncertainty in the magnitude of collection system renewal needs, it may represent the only viable strategy to begin meaningful wet weather control.
- ***It is balanced,*** providing CRW the opportunity to invest throughout the community as well as avoid areas of excessive community impacts. It does not favor or place undue burden on any part of the community and, in fact, is designed to "lift up" the community through strategic investments that benefit water quality, public health and safety, and promote re-investment in the community.
- ***It builds upon the baseline level of control,*** with its initial focus on the rehabilitation and enhanced reliability of CRW's AWTF and conveyance system, anticipated to provide significant wet weather control benefits within the first 10 years of program implementation, with deployment of decentralized controls in priority areas to "fill gaps" in existing system performance.
- ***It has community support,*** consistently demonstrated through public engagement opportunities, and representing the only strategy that "gives back" to the community, potentially providing ancillary economic benefits that enhance the financial capabilities of CRW and its ratepayers.

Table 1-3 indicates priorities for investment in decentralized controls, along with the anticipated time frame for implementation under the affordable level of control. According to a preliminary evaluation performed for CRW's Community Greening Plan:

- A high potential exists to control approximately 20 percent of the impervious area within the City with decentralized controls (green/grey).
- A moderate potential exists to control an additional 44 percent of the impervious area within the City with decentralized controls (green/grey), including 39 percent of the impervious area within the combined sewer system.

The decentralized control strategy will prioritize implementation of these high-to-moderate potential decentralized controls:

- Strategic control areas delineated to meet multiple control objectives (control CSOs, reduce unauthorized discharges, and maximize triple bottom line benefits) existing for approximately 29 percent of the impervious area within the combined sewer system,
- Planning-area-specific CSO control targets are established for the three planning areas (i.e., Uptown, Lower Front, and Lower Paxton) where baseline controls are less effective at reducing CSOs. As such, these planning areas should be considered a higher priority when determining where to site decentralized controls (green/grey) in the future.
- City-wide, non-priority/strategic controls are anticipated within the other planning areas via coordinated right-of-way/streetscape project, development projects, and/or other initiatives. Their effectiveness at controlling CSOs, unauthorized releases, and/or MS4 discharges will need to be determined based on their actual implementation location and design criteria.

Table 1-3: Summary of Preferred Control Strategy – Decentralized Controls (Green / Grey)

Planning Area	Impervious Area (Acres)	GSI Implementation Opportunities[1]			Cumulative GSI Implementation Targets	
		High Potential	Moderate Potential	Strategic[2]	Immediate (Years 1-10)	Near-Term (Years 11-20)
Combined Sewer System						
Riverside	53.7	13%	46%	10%	0%	0%
Uptown	246	18%	41%	24%	6%	9%
Middle Front Street	131	22%	31%	19%	0%	0%
Lower Front Street	59.1	19%	62%	48%	15%	15%
Upper Paxton Creek - West	162	33%	52%	47%	0%	0%
Upper Paxton Creek - East	28.5	15%	64%	52%	0%	0%
Middle Paxton Creek - West	97.3	44%	39%	69%	0%	0%
Middle Paxton Creek - East	201	22%	40%	9%	0%	0%
Lower Paxton Creek	510	15%	34%	25%	5%	10%
Hemlock Street	68.2	1%	15%	44%	0%	0%
Subtotal	**1556**	**20%**	**39%**	**29%**	**3%**	**5%**
Separate Storm/Sanitary Sewer System[3]						
Italian Lake	157	29%	46%	0%	N/A	N/A
Industrial Road	208	9%	80%	0%	N/A	N/A
Arsenal Blvd	120	39%	49%	0%	N/A	N/A
East Harrisburg	64	34%	60%	0%	N/A	N/A
Spring Creek	103	1%	35%	0%	N/A	N/A
Subtotal	**652**	**21%**	**57%**	**0%**	**0%**	**0%**
City-wide Non-Priority/Strategic						
	N/A	N/A	N/A	N/A	1%	2%
Total	**2208**	**20%**	**44%**	**20%**	**3%**	**5%**

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1.9 Implementation and Adaptive Management Plan

The CRW Program Plan (Program Plan) involves a range of operational and administrative services to support implementation of the proposed controls. Four distinct strategies will be implemented under the Program.

1.9.1 Four Implementation Strategies

An ***Asset Rehabilitation and Renewal Strategy*** will entail the continual inspection, assessment, and prioritized renewal of CRW's wastewater/stormwater assets as part of the overall Asset Management Program. In this framework, there are two parameters used for prioritization decision-making. Asset Probability of Failure (POF) is a function of remaining service life and is correlated to the asset's physical condition and other performance considerations. Asset Consequence of Failure (COF) is evaluated based on estimating the environmental/regulatory, financial and social impacts of a defined failure of the asset. These two parameters are linked together and evaluated based on triple bottom line assessment of the failure of the asset.

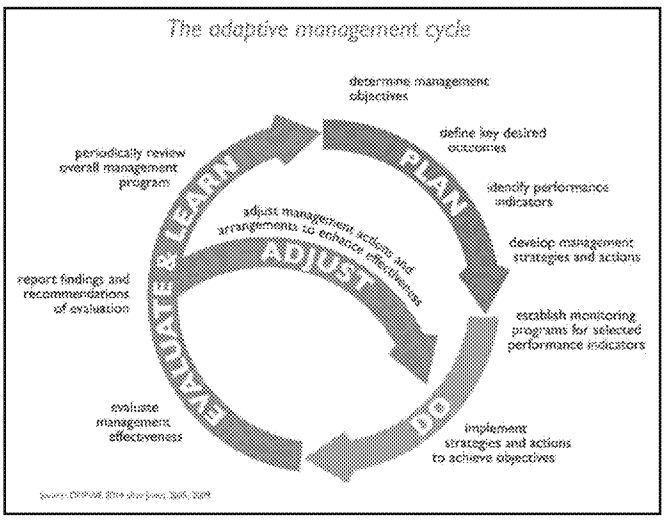
A ***Decentralized Green / Grey Implementation Strategy*** will continually seek affordable and cost-effective opportunities to implement stormwater controls within the context of related infrastructure and community renewal and redevelopment projects. Under its Community Greening Plan, CRW will implement selected pilot projects aimed at demonstrating the utility of various green stormwater infrastructure (GSI) control technologies in highly urbanized areas, intended to help raise awareness of GSI among City residents and the regulatory community. GSI elements will be incorporated into public works projects by intent and/or through enhanced standardized design requirements. CRW will be demonstrating various GSI tools along streets including stormwater tree pits, curb cuts, bump-outs, porous pavement and tree trenches. CRW will evaluate implementing an impervious area-based stormwater fee to provide a fair and true cost of service allocation that provides incentives for non-residential and stormwater-only customers to incorporate stormwater management practices where practicable.

An ***Asset Operation and Management Maintenance Strategy*** will keep CRW's treatment, collection and conveyance assets in good working order, free from structural deficiencies, debris, and blockages, allowing them to continue to operate as designed. CRW will also seek opportunities to integrate monitoring and control technologies into its assets as part of rehabilitation projects, with a goal of implementing telemetered surveillance and control where proven to enhance system operation and performance. CRW will determine the maintenance needs associated with various types of stormwater control measures to guide their maintenance by public agencies and by private entities on private property.

An ***Internal and Intergovernmental Communications and Coordination Strategy*** will build implementation partnerships with various stakeholders. CRW will continue to promote effective interagency coordination to define strategic policies and streamline protocols and communication pathways to better align with full-scale GSI implementation. In addition, an Internal Communications Plan to improve synchronization within CRW will be developed. This communications plan will identify and evaluate policy barriers to implement the Program Plan, and will initiate strategies to address these challenges.

1.9.2 Adaptive Management Process

Implementation of the Program Plan elements will rely upon an Adaptive Management Process. This adaptive management approach will require flexibility and periodic program assessments throughout the implementation period. Adaptations in the management approaches are expected throughout this period to ensure that compliance goals are met, to optimize and enhance the program, to maximize benefits, and minimize the costs of implementation. Major decisions on management approaches will be made every five years based on progress toward the goals and will be described in Evaluation and Adaptation Plans (EAPs).



- ***Adaptive Management Triggers:*** This Program Plan outlines an adaptive management process with "decision points" every five years. These decision points are used to evaluate progress towards Program Plan implementation and determine refinements to the implementation approach gained from "lessons learned" and new information acquired during the implementation period.

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- ***Financial Capability Re-Assessment:*** Financial capability will help determine what programmatic changes will be feasible, necessary, and achievable. Local economic conditions, including changes in household income, revenue, capital spending in response to new regulations or requirements, construction and operating costs, and CRW's financial position and cost of capital, will be assessed. Adjustments to the program that either increase the rate of progress toward goals or decrease spending to avoid economic hardship will be considered.

- ***Evaluation and Adaptation Plans:*** A series of EAPs will be created at 5-year intervals. The first EAP will be developed and submitted after 10 years of Program Plan implementation. Each EAP will be a comprehensive assessment of CRW's progress towards full implementation of the approved Program Plan with descriptions of program elements expected to be implemented in the next five-year period. The EAP will include a description of the outcome of adaptive management decisions and changes in implementation for the following five years. Any proposed change in priorities or approach for meeting the milestones in the following five years will be described, including altering approaches to implementing GSI and, if necessary, targeted traditional infrastructure investments or changes in design approaches.

- ***Adaptive Management Reporting:*** Through CRW's annual reporting process, continuous updates on the adaptation of the implementation program will be provided. if the CRW were to fail to achieve one or more of the metrics documented in an EAP, the subsequent Annual Reports will include an update describing CRW's progress towards meeting those metrics. Such updates will be provided in subsequent Annual Reports until all the applicable metrics have been achieved.

1.10 Post Construction Monitoring Plan

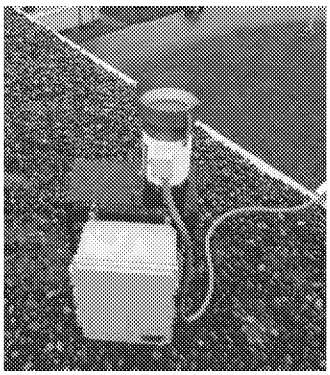
Post-construction compliance monitoring is a required element for all long term wet weather plans, and is intended to provide sufficient information to estimate the effectiveness of the control measures implemented under the *City Beautiful H_2O Program Plan* (Program Plan). The Post Construction Monitoring Plan (PCMP) for the CRW Program Plan was developed to verify that activity commitments have been implemented and to quantify and characterize the efficacy of CRW Program Plan improvements. PCMP reporting will have two aspects:

- ***Annual reporting,*** implemented through the existing series of annual Chapter 94 Reports submitted to the US-EPA and the PA-DEP.

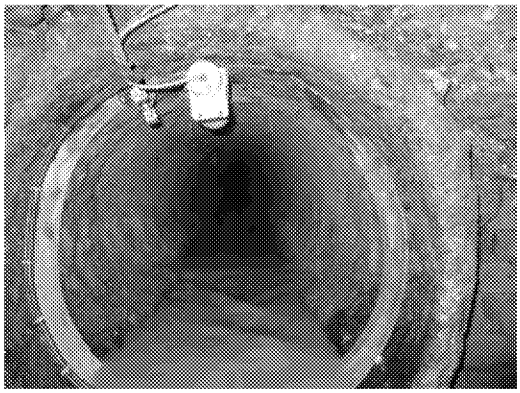
- A ***comprehensive report,*** prepared and submitted after the Program Plan has been implemented, anticipated approximately ten years following approval of this Program Plan.

Eight categories of monitoring and reporting are included in the PCMP and summarized below.

- ***Administrative Monitoring and Reporting:*** Accounting-based factors including impervious area draining to green infrastructure, miles of rehabilitated sewers, annual debris removal volumes, system maintenance efforts, and other appropriate measures will be documented and reported to verify Program Plan commitments have been implemented.

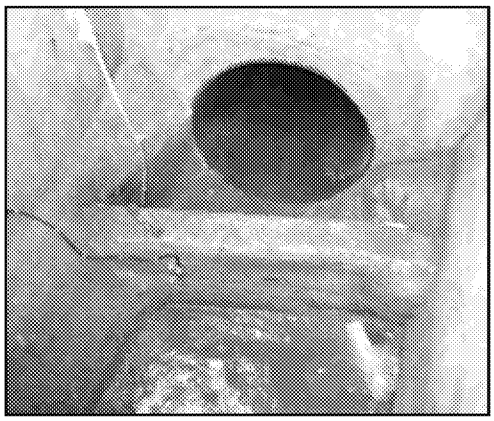


- ***Precipitation Monitoring and Assessment:*** The existing gauge network and gauge adjusted radar rainfall (GARR) data will be used to quantify and characterize precipitation for the PCMP. The current typical year precipitation volumes and frequencies will be used by the updated hydrologic and hydraulic (H&H) models to quantify and characterize typical year CSO discharge statistics. The high resolution, spatially distributed GARR precipitation data will be used by the H&H models to provide the annual CSO discharge statistics for each CRW CSO outfall location.



- ***Interceptor Monitoring and Assessment:*** The existing network of nine interceptor monitoring sites will be used to quantify and characterize interceptor flow for the PCMP. Existing interceptor monitoring activities may be suspended until needed to assess the benefits of system improvements as key Immediate Implementation Phase Program Plan items are completed.

- ***Suburban Community System Monitoring and Assessment:*** The existing network of four points of connection monitoring sites will be used for the PCMP to quantify and characterize dry and wet weather flow from the suburban community separate sanitary sewer systems.



- ***CSO Regulator Structure Monitoring and Assessment:*** For annual reporting, the daily inspections conducted by CRW crews at all the CSO regulator structures will continue as the Program Plan is implemented. Wooden blocks placed on the crests of the diversion weirs indicate CSO activity and observations will continue to be logged on a daily basis in the Cityworks asset management system for the PCMP. To support preparation of the comprehensive report for the Immediate Implementation Phase, the PCMP will also include installing area-velocity meters at 10 selected CSO regulators for a 6-month duration. The resulting data from the inspections and monitoring will be used to validate the revised H&H model.

- ***CSO Discharge Projections through H&H Modeling:*** The calibrated CRW hydrologic and hydraulic model will be used to simulate dry and wet weather flow from all catchment areas within the City of Harrisburg, for both separate and combined sewer systems, and from the suburban community systems. As system improvements are completed as part of the Program Plan, corresponding revisions and updates will be made to the H&H model to reflect these revisions. The improved condition model results for CSO discharges will be compared with the existing condition results to quantify and characterize the performance of the

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improved CRW system and verify that the level of CSO reductions predicted in the Program Plan are achieved.

- ***Water Quality Monitoring and Assessment:*** Water quality monitoring and characterization for the CRW PCMP will be implemented by partnering with PA-DEP to collect and assess water quality data. The water quality parameters previously measured by PA-DEP have been total settleable solids, total suspended solids, BOD_5, total nitrogen, total phosphorus, and fecal Coliform bacteria.
- ***Paxton Creek Use Attainability Assessment:*** The water quality compliance strategy for Paxton Creek is to coordinate with PA-DEP to have a Use Attainability Study conducted that would change the use designation for the creek. For the PCMP, CRW will provide progress updates on its coordination activities with PA-DEP as part of its annual Program Plan reporting.

1.11 Recommended Plan and Schedule

The *City Beautiful H_2O Program Plan* (Program Plan) presents a long-term, integrated strategy to address the hydraulic and structural deficiencies of Capital Region Water's wastewater and stormwater assets, improve in-stream water quality, and protect public health. Many alternative technologies, specific control strategies, and levels of control were evaluated. This section summarizes the affordable and cost-effective measures recommended under the Program Plan for control of wet weather issues (CSOs, SSOs, and MS4 discharges), rehabilitation of CRW assets, and enhancing service area communities.

The Financial Capability Assessment (FCA) presented in **Section 7** is used to identify an affordable level of investment in this Program Plan. **Table 1-4** defines implementation phases, the anticipated level of CSO volume control achieved, and the estimated available level of expenditure within each phase to maintain CRW wastewater rates at no more than 2 percent of the mean annual household income within the City of Harrisburg ($33,289 in 2015). While CSO volume capture is presented as the primary metric for compliance during each implementation time frame, other, more affordable and cost-effective projects that improve water quality and/or reduce SSOs/unauthorized releases may receive a higher priority for implementation under the integrated stormwater/wastewater planning framework.

Table 1-4. Implementation Phases, Affordable Costs, and CSO Control Volume Targets

Phase	Anticipated Time Frame	Projected Type	Affordable Spending (Escalated)	Affordable Spending (2017$)[1]	CSO Volume Capture[2]
Existing	N/A	N/A	N/A	N/A	53%
Immediate	0-10 years	Rehabilitation	$165 million	$146 million	79%
		Wet Weather	$60 million	$50 million	
Near-Term	10-20 years	Rehabilitation	$49 million	$31 million	80%
		Wet Weather	$41 million	$26 million	
		Total	**$315 million**	**$253 million**	

[1] Partially funded via 30-year revenue bond
[2] Includes up to $5M annual stormwater fee revenue
[3] During the typical year

The following components would be funded from CRW's annual financial capability over the next 20 years, according to the FCA presented in Section 7:

- CRW's 2018 budgeted and anticipated operational expenses of $14.3 million annually (**Table 11-4** in the Program Plan main body),
- An estimated bond repayment amount of approximately $18.8 million annually, used to finance:
  - Past capital improvements (e.g., biological nutrient removal at CRW's AWTF),
  - Up to approximately $13 million (escalated and in 2017 dollars) for early action wet weather control projects,
  - Up to approximately $113 million (escalated), or $102 million (in 2017 dollars) for priority projects to address critical Advanced Wastewater Treatment Facility (AWTF) and conveyance system rehabilitation needs, some that also provide significant CSO control benefits,
  - Up to approximately $88 million (escalated), or $64 million (in 2017 dollars) for additional wet weather control projects, and
  - Up to $101 million (escalated), or $74 million (in 2017 dollars) be expended on collection system rehabilitation projects.

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Figure 1-7 illustrates how the projected capital cost of $315 million (escalated), or $253 million (in 2017 dollars) is allocated between rehabilitation projects and wet weather control projects.

Specific investments to CRW's stormwater / wastewater assets will be defined periodically through a decision-making process, implemented through an ongoing adaptive management process, presented in Section 9, that weighs the following factors:

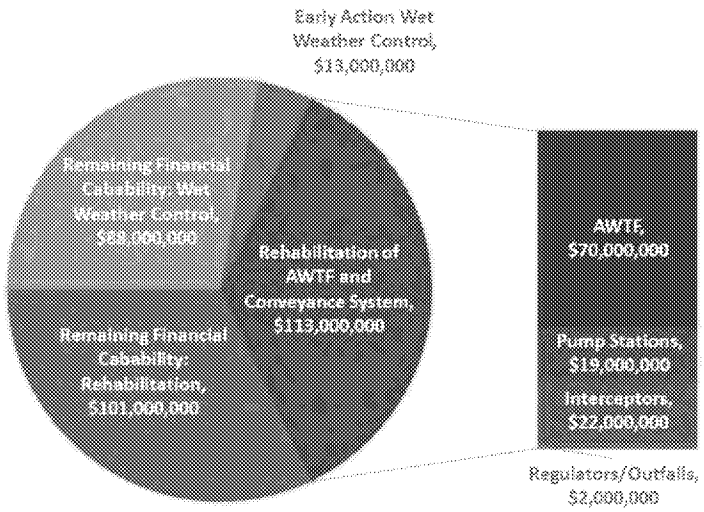

Figure 1-7. Estimated Capital Cost of Affordable Rehabilitation and Wet Weather Control Projects over the 20-year Planning Horizon

1. The Business Risk Exposure of each asset, established through CRW's asset management program.
2. The public health and welfare benefits to CRW ratepayers provided by the investment.
3. The degree of water quality enhancement achieved by the investment.
4. Synergies with other investments within the City of Harrisburg, including opportunities for collaboration with other implementation partners and/or sources of funding.
5. The affordability and cost-effectiveness of the investment.
6. The effectiveness of previous investments determined through post-construction monitoring and H&H modeling.
7. Appropriate phasing of investments to avoid short-term degradation to current conditions.
8. An appropriate investment in the operation and maintenance of the CRW wastewater/stormwater systems and administration of the Program.
9. Changes to the financial capabilities of CRW's ratepayers.

The *City Beautiful H_2O Program Plan* is an opportunity to select an alternative to bolster public support for improvements that address modern challenges to managing water resources and infrastructure in a sustainable way. CRW's recommended alternative provides a clear pathway that reinvests and rehabilitates wastewater/stormwater assets, brings community leaders, stakeholders, and residents together, and complies with environmental laws and regulations to improve the health of local waterways.

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Section 2

Public Engagement and Participation

"We all share this earth together. So we have to look at the environment and how we're going to work to heal it together."

– Rafiyqa Muhammad, Capital Region Water Community Ambassador

2.1 Overview of Public Engagement and Participation

Capital Region Water's (CRW) challenge is not unlike those of the nearly 800 other combined sewer overflow (CSO) cities across the United States. It must finance an expensive, long-lasting and disruptive project via ratepayers who already have serious affordability concerns. CRW's constituents will not be able to influence the overall direction of the wet weather control plan or the nature and timing of the rate changes needed to pay for it. But their acceptance of, and advocacy for, the project is critical to its success after the initial planning ends.

The solution is a thorough public engagement strategy involving CRW's City Beautiful H_20 brand and the use of partnerships with community and environmental organizations. *City Beautiful H_2O Program Plan* (Program Plan) was selected as the name for CRW's wet weather program. CRW's public participation activities for the draft Program Plan were built upon previous efforts and were designed to engage the public by bringing the information to a number of different audiences through various communication methods and outreach events. The following goals were established for CRW's public engagement strategy.

- Provide a public participation process that actively involves ratepayers and stakeholders in the development and refinement of the draft Program Plan.
- Provide an opportunity for ratepayers and stakeholders to examine the draft plan and provide public forums for having the draft plan presented and explained.
- Provide an opportunity for public comment and input on the draft plan.

CRW identified the following central themes for public involvement for the Draft Program Plan:

- City Beautiful H_2O is a shared responsibility among the entire community;
- CRW will develop an affordable, cost effective Program Plan, consisting of projects to:
  - Renew the structural and operational integrity of CRW's wastewater/stormwater assets, enhance the environment, and protect public health and safety by alleviating local flooding and backups; and
  - Provide additional environmental, social, and economic benefits through green infrastructure.

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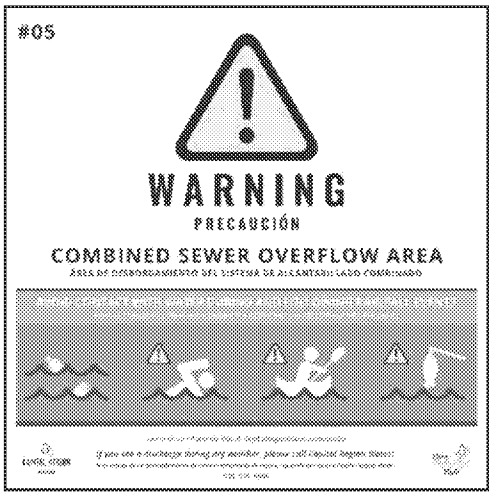
2.2 Public Involvement Prior to the Draft Program Plan

The initial focus and activities for CRW's public involvement program, prior to the development of the draft Program Plan, centered around implementing its Nine Minimum Control (NMC) Plan[1] for CSO control. NMC 7 requires the development and implementation of pollution prevention and public education programs, and NMC 8 requires the development and implementation of public notification Programs. These NMC's also achieve the following PA-DEP minimum control measures (MCMs) under MS4 stormwater permitting requirements for public education and outreach (MCM 1) and public participation/involvement (MCM 2). Another initial focus was the public development and launching of the CRW Community Greening Plan.

2.2.1 NMC and MCM Activities

Public notification programs are intended to ensure the public receives adequate information about CSOs, their potential health and environmental impacts, and precautions concerning recreational activities, such as swimming, during and immediately after CSOs. The CRW public notification program was intended to inform persons using the Susquehanna River or Paxton Creek for recreation about the potential associated health risks.



CRW implemented the following NMC public notification measures and activities:

- Incorporated signage at all combined sewer outfall locations,
- Developed and installed three pilot CSO advisory signs, and
- Advanced a signage implementation plan within their overall communications plan.

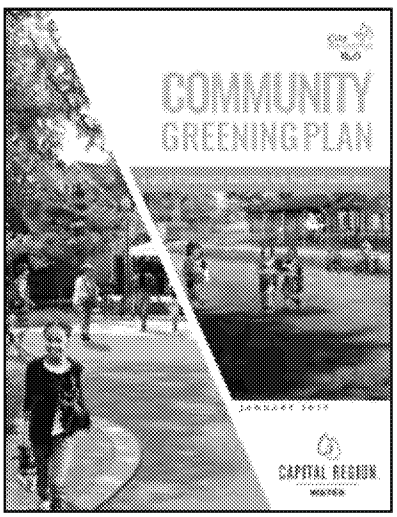
Pollution prevention programs can help reduce the amount of contaminants and floatable materials that enter the Susquehanna River and Paxton Creek via CSO/MS4 discharges. The CRW pollution prevention program is being implemented through the respective legal authorities of and collaborative operational protocol between CRW and the City of Harrisburg, which continue to be developed and refined. However, CRW has no restrictions on the development of its public education programs. An informed and knowledgeable community is crucial to the success of CRW's pollution prevention programs because it is believed it will inspire greater support and participation. CRW's

[1] Capital Region Water Nine Minimum Control Plan, Version 3.0, August 2017, available at **https//capitalregionwater.com/cbh2o/**

public education programs included active communication with the public via social media, email, flyers, and mailing.

CRW was successful in developing and implementing the following aspects of its pollution prevention and public education programs, including but not limited to: monthly trash clean-ups, annual city-wide clean-up event, water and wastewater facility tours, annual conservation carnival outreach event, multiple forms of social media, press releases, and monthly community stakeholder meetings. In 2015 and 2016, CRW participated in funding City of Harrisburg street sweeping operations. In Spring 2017, CRW also implemented a street cleaning program with an outside vendor that utilizes regenerative air technology.

2.2.2 CRW's Community Greening Plan



Community engagement was an essential component in the development of Capital Region Water's Community Greening Plan[2], the green stormwater infrastructure (GSI) masterplan for Harrisburg that was released in January 2017. Stakeholder involvement in the Greening Plan is an essential part of stakeholder involvement for the Program Plan since the entire rationale for the Greening Plan is to achieve wet weather control in a way that supports multi-objective community needs.

Two large public engagement phases, one in the winter of 2016 and one in the summer of 2016, were held including several large events and more than thirty smaller engagement opportunities throughout the process. The process engaged over 1,000 residents from all areas of the city.

The first public phase included two large meetings. The first was held in Uptown at the Camp Curtin YMCA, and the second was held in North Allison Hill at the Lincoln School. The meetings focused on educating Harrisburg residents about stormwater and potential solutions to alleviate flooding and environmental issues. Residents learned about stormwater runoff and impervious surfaces with demonstration projects provided by the Penn State Extension. After learning about stormwater and runoff, residents looked at potential green stormwater infrastructure strategies and provided input on how to prioritize program funding – whether investment should be focused on building GSI in public space, providing grants or incentives to community groups to build GSI, providing grants or incentives to homeowners to build GSI, or building larger sewers.

Residents also provided input on how the community should pay for investments in stormwater infrastructure. Based on models used in other cities, options included fees integrated in sewer fees, flat fees per parcel, fees based on the size of the parcel, and fees based on the amount of stormwater generated. An impact station provided residents with information about potential employment opportunities that may result from a green stormwater management program in Harrisburg. The results from this initial set of public meetings provided CRW with guidance on where to focus program dollars, how to pay for green stormwater infrastructure, how residents

[2] Capital Region Water Community Greening Plan, January 2017, available at **https//capitalregionwater.com/cbh2o/**

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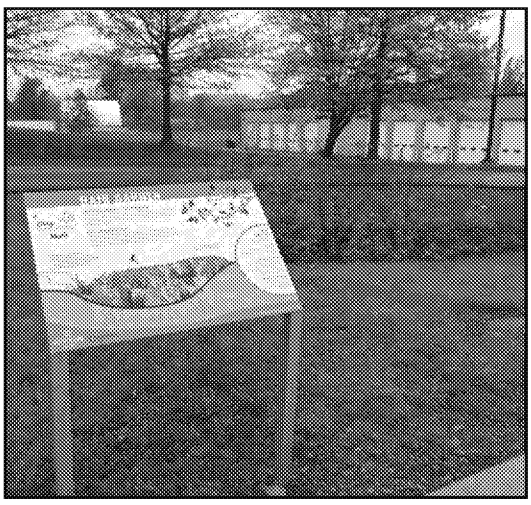
would like to be involved in the program, and what areas need investment or community greening. The majority of people felt that investment should be focused on greening streets, parks, vacant lots, and schools. CRW continued to engage with residents between public meetings by hosting small focus groups, attending community events, holding Community Ambassador Workgroup meetings, and hosting community clean-ups.

2.3 Public Involvement and Comments during the Release of the Draft Program Plan

The National Combined Sewer Overflow (CSO) policy presents a comprehensive national strategy to ensure that sewer and water authorities, municipalities, regulatory authorities and the public engage in a comprehensive and coordinated planning effort. This effort is intended to achieve cost effective CSO controls that ultimately meet appropriate health and environmental objectives. Further, Element 3 of EPA's 2012 Integrated Municipal Stormwater and Wastewater Planning Approach Framework suggests *"a process which opens and maintains channels of communication with relevant community stakeholders in order to give full consideration of the views of others in the planning process and during implementation of the plan."* CRW provided several avenues for public involvement in the refinement and finalization of the draft City Beautiful H_2O Program Plan. The official public review and comment period for the Program Plan commenced on February 12, 2018 and extended through March 12, 2018.

2.3.1 Public Educational Activities

Engaging the Harrisburg community is a key component of Capital Region Water's Program Plan. Not only does public involvement improve the plan itself, but CRW has a responsibility to inform its customers of what they will be investing in over the next several decades. CRW's engagement for the Program Plan was a multifaceted approach including advisory committees, individual stakeholder meetings, media outreach, public meetings, neighborhood and community meetings, digital outreach, and printed communications. This campaign was informed by a customer survey and communication plan developed in 2017.



Advisory Committees

Community Ambassador Committee

Engaging every community in Harrisburg was one of the most important components of Capital Region Water's Community Greening Plan. CRW created a Community Ambassador Committee to empower interested residents with knowledge about stormwater issues and encourage them to reach out to their neighbors to share this information and get feedback through face-to-face interactions. They act as advocates for their neighborhood, provide information about upcoming events, and help educate their community about green stormwater infrastructure and community greening measures. CRW continues to meet monthly with the ambassadors to build capacity and advocate for their neighborhoods and their city.

City Beautiful H_2O Stakeholder Committee

Capital Region Water established an additional stakeholder committee for the City Beautiful H_2O Program Plan in 2017. Invitations were sent to representatives of property owners with a large amount of impervious surface, faith-based organizations, residents, government agencies (local and state), and community / social organizations. Three meetings were held in 2017 and a fourth was held in 2018.

Moving forward, Capital Region Water may reconvene this stakeholder group to discuss rate restructuring and other aspects of the City Beautiful H_2O Program.

- The Stakeholder Meetings section in Appendix C provides supporting information on these meetings, including copies of the presentations that were made.

Individual Stakeholder Meetings

Capital Region Water identified the largest 50 properties by impervious surface and sent a letter inviting them to discuss the Program Plan and possible rate restructuring in November 2017. In addition to letters, CRW contacted property owners by phone and email if that information could be found. Out of the original list of 50 properties, there were 36 different property owners, with some property owners owning more than one property. Capital Region Water connected with 20 of these owners through in-person meetings, phone meetings, or Stakeholder Committee Meetings.

Some property owners declined to meet and some were unresponsive. CRW will continue efforts to keep these organizations informed about the City Beautiful H_2O Program.

- The Impervious Surface Meetings section in Appendix C provides supporting information identifying the 50 properties and a copy of the letter of invitation to the meetings.

Neighborhood / Community Meetings

Capital Region Water maintains a list of about 50 neighborhood, community, environmental, and faith-based organizations in Harrisburg. Organizations on this list were invited to meet with CRW staff to discuss the Program Plan or to have CRW present at one of their meetings. Many of the organizations were also invited to participate in the City Beautiful H_2O Stakeholder Committee or attend public meetings. CRW connected with 21 of these organizations as part of its public involvement for the City Beautiful H_2O Program Plan.

Some organizations declined to meet and some were unresponsive. CRW will continue efforts to keep these organizations informed about the City Beautiful H_2O Program moving forward. Capital Region Water will annually review this list of community organizations and add additional organizations as needed.

- The Community Group Meetings section in Appendix C provides a listing of the associations, organizations, and groups that were contacted and the corresponding meeting dates.

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2.3.2 Outreach to the Public

Capital Region Water also made efforts to involve the general public in addition to its targeted outreach to community organizations and large property owners. Capital Region Water accepted public comments for four weeks between February 12 and March 12, 2018. Information was provided by mail, door to door, through the media, online, and in person at three public meetings.

Bill Inserts

Customers that receive a bill from Capital Region Water received information about the City Beautiful H_2O Program Plan in their February and March bills. These bill inserts provided information about the Program Plan, where it could be accessed for review, the time and location of three public meetings and how they could provide public comment.

- The Bill Inserts section in Appendix C provides copies of the bill inserts that were distributed.

Door to Door Outreach

1,000 door hangers were printed and delivered to homes surrounding each of the three public meeting locations. This served as a notice for homes that did not receive information through other communication channels and a reminder for those that did.

- The Door Hanger section in Appendix C provides a copy of the doorhanger that was distributed.

Media Outreach

Local media outlets were notified of the Program Plan and public meetings beginning on February 12, 2018 through a press release distributed by email. Seven news stories including one television, one podcast, and five online news stories were captured during the public comment period.

- The Media Outreach section in Appendix C provides copies of the information communicated through various local media outreach.

Digital Outreach

Capital Region Water created a page on its website dedicated to the City Beautiful H_2O Program Plan: capitalregionwater.com/cbh2o. This page contained a draft of the Program Plan in its full form but also in summary formats easier for readers to gather information quickly. All materials, digital or printed, directed the public to this website for more information.

- The Website section of Appendix C provides a screen shot of the City Beautiful H_2O home page.

Capital Region Water maintains an email list of over 2,000 people to regularly send emails with information related to CRW's service. Three emails were sent to this email list directing the public to the website or to one of CRW's public meetings on February 12, 15, and 28.

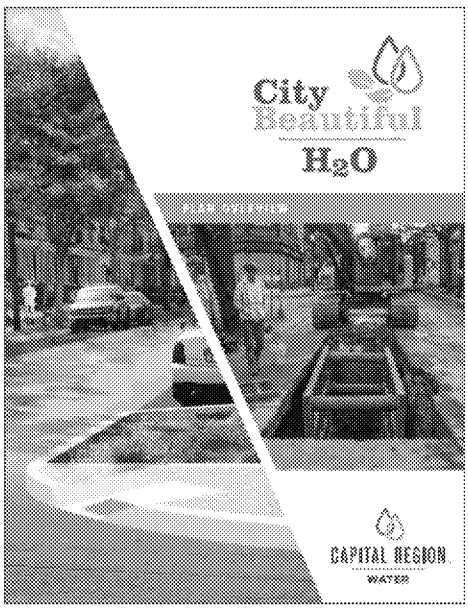
- The Emails section of Appendix C provides copies of the email information that was distributed and associated circulation statistics for each email distribution.

Capital Region Water maintains an active presence on Facebook, Twitter, and Nextdoor. In concert with its other outreach efforts, CRW made four Facebook posts, eight Twitter posts, and three NextDoor posts related to the Program Plan and public meetings. In addition, CRW purchased targeted Facebook advertisements to increase its reach in Harrisburg, PA.

- The Social Media section of Appendix C provides copies of these social media posts.

Companion Document

A companion document was produced and distributed to provide a brief overview of the Program Plan. This document is intended to make the contents of the Program Plan more accessible to the general public through the use of infographics and non-technical summaries. This companion document was provided at all meetings during the public comment period.



- The Companion Document section of Appendix C provides a copy of the Companion Document.

Summary of Public Meetings

CRW conducted three large public involvement meetings for the Program Plan in February/March 2018. The meeting facilities were well known community centers or schools selected with guidance from CRW's Community Ambassadors spaced out to be convenient for residents in different parts of the city. These meetings were organized in an open house format with several stations to explain the Program Plan and gather input from the public.

At each meeting, there were five stations: (1) An introduction to CRW, the Consent Decree, and the Program Plan, (2) an overview of the infrastructure and pollution challenges CRW is facing, (3) an overview of the technologies and strategies evaluated in the Program Plan and how CRW evaluated the alternative strategies, (4) a summary of the strategies selected, the cost of the program, and future rate increases, and (5) a summary of next steps including future negotiations, projects, and possible rate restructuring. Each station was led by a subject matter expert with assistance from community volunteers.

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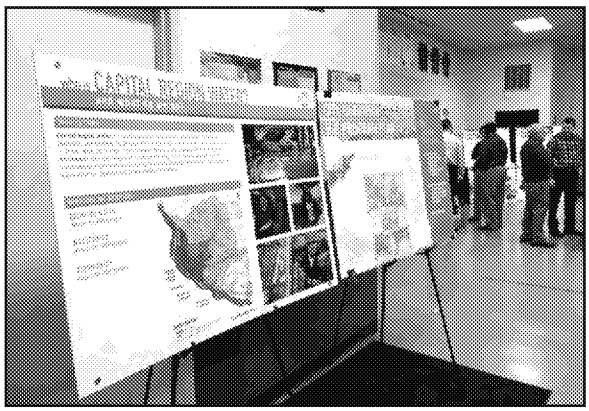
Food and activities for kids were made available for free at each meeting to make it more convenient for families with children to attend. Attendees were asked to sign in when they entered the meeting and received a companion document, comment form, and pen. Attendees were then free to visit all five stations, listen to each speaker, and ask questions.

Meeting 1: Southern Harrisburg
Date: Thursday, February 15, 6:00 – 8:00 PM
Location: Sylvan Heights Science Charter School
915 South 13th Street, Harrisburg, PA 17104

Number of attendees: 5
Number of comments received from attendees: 0



Meeting 2: Lincoln School
Wednesday, February 21, 6:00 – 8:00 PM
Location: Lincoln School
1601 State Street, Harrisburg, PA 17103

Number of attendees: 13
Number of comments received from attendees: 2

Meeting 3: Camp Curtin YMCA
Thursday, March 1, 6:00 – 8:00 PM
Location: Camp Curtin YMCA
2135 North 6th Street, Harrisburg, PA 17110

Number of attendees: 11
Number of comments received from attendees: 2

- The Public Meetings section of Appendix C provides images of the public meetings and copies of the sign in sheets.

2.3.3 Summary of Comments Received from Public Input

CRW accepted public comments through an online form, in person at its Customer Service Center and its Administrative Office, and in person at its public meetings. In person comments were documented using a comment form. CRW also accepted letters and emails submitted during the public comment period. All comments were scanned and archived.

Committee and meeting discussions were not documented. Rather, participants were encouraged to submit comments through the methods CRW provided during the public comment period.

A total of 15 comments were collected during the public comment period. Eight comments were submitted using CRW's online form. Four comments were received at the public meetings. One comment was collected at a neighborhood meeting. Two letters were also submitted via email.

Not including the two letters, nine commenters "liked" the plan, three "disliked" the plan, and one commenter both "liked" and disliked" the Program Plan. The two letters received were supportive of the Program Plan.

In summary, commenters were supportive of the Program Plan because it will address aging infrastructure and protect the environment by reducing CSOs. Commenters were also supportive of the Program Plan's use of decentralized green infrastructure and the co-benefits associated with it.

Commenters were most concerned with the future rate increases outlined in the Program Plan, especially as it relates to low income residents. Commenters were also concerned about future rate structuring to charge for stormwater and the equitability of future rates and project locations.

- The Public Comments section of Appendix C provides copies of the comments forms and letters submitted by the public, and a compiled summary of the received comments.

2.4 Future Public Participation

2.4.1 Continued Public Information and Education

Moving forward, CRW will continue to perform the public education and involvement activities described in its NMC Plan, as summarized previously in Section 2.2. These activities are also intended to fulfill the public education, outreach, involvement, and participation requirements of MCMs 1 and 2 of the individual NPDES MS4 permit to be issued to CRW by PA-DEP. CRW will also update the public on the progress of the Program Plan through annual bill inserts and meetings with community organizations. CRW will also complete its CSO notification procedures and signage.

Following the submission of the Program Plan, CRW will conduct a similar campaign to gather input on rate restructuring to fund projects outlined in the Program Plan. CRW has developed outreach protocols to notify stakeholders during the construction of projects.

2.4.2 Continued Public Participation Supporting Program Plan Implementation

CRW will also continue the public participation activities initiated in association with the development and initial implementation of its Community Greening Plan, described in Sections 2.2.2 and 2.3.1. Continuous engagement of stakeholders will be instrumental for the development and implementation of decentralized green/grey stormwater control strategies within the collection system. This is anticipated to build on past/ongoing efforts such as general public engagement activities, advisory committees, neighborhood/community meetings, and direct contact with individual stakeholders. The following Program Plan implementation activities will be supported by continuous stakeholder engagement:

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- ***Development-Driven Project Opportunities:*** Developing regulations, policies, design/construction standards, and O&M agreements that require implementing GSI principals in development and redevelopment projects, and proactively distributing and explaining them to existing and potential stakeholders. Developing proactive partnerships with future developers and redevelopers to implement collaborative public-private partnerships for development/redevelopment projects.
- ***Synergistic Opportunities for Public Works Projects:*** Building partnerships with City, County, and State agencies that have jurisdiction over public works project design/construction standards so GSI principals and standards are integrated.
- ***Incentive-Driven Opportunities:*** Defining stormwater fee credits and other incentives to spur property owners to install decentralized stormwater controls.
- ***Opportunities on Public Lands and Rights-of-Way:*** Collaborating with a broad range of public and private stakeholders to determine how to best leverage their collective investments to financially support multi-objective projects, and thereby increase the level of control achieved.

Section 3
Characterization of Current Conditions

The foundation for the *City Beautiful H_2O Program Plan* (Program Plan) is an accurate and up-to-date understanding of existing conditions within the Capital Region Water (CRW) service area and the configuration and operation of the sewer collection, conveyance, and treatment systems. CRW developed and implemented a series of data collection and analysis programs, and incorporated the data and analysis results into a hydrologic and hydraulic (H&H) model of the CRW system. The model was used as a tool to quantify and characterize existing system configurations and flows, and establish a baseline condition on which to develop alternative combined sewer overflow (CSO) and sanitary sewer overflow (SSO) control measures.

3.1 Overview of Characterization of Current Conditions

Located along the east shore of the Susquehanna River, CRW is a municipal authority that provides wastewater and stormwater collection, conveyance and treatment services to over 17,200 customers in the City of Harrisburg (City). CRW also provides wastewater conveyance and treatment services to six suburban communities as wholesale customers. CRW owns, operates, and maintains the wastewater and stormwater infrastructure within the City and receives wastewater flow from the suburban communities served by separate sanitary sewer systems through four gravity points of connection. Flow from Steelton Borough, served by a combined sewer system, is received via the Trewick Pump Station that conveys wastewater directly to the advanced wastewater treatment facility (AWTF). This overview section is intended to provide a concise executive summary of the information provided in the more detailed report sections that follow. A map of the CRW service area, including the service area of the suburban community collection systems, is provided in **Figure 3-1**.

Section 3.2 characterizes CRW's wastewater and stormwater collection and conveyance systems, consisting of a 45 MGD capacity AWTF, two major pumping stations, 1.3 miles of force mains, 13.8 miles of interceptor sewer, 59 CSO regulators and 58 CSO outfalls (two share a common outfall), approximately 160 miles of separate and/or combined collection system sewers, and approximately 4,300 storm inlets and catch basins. A map of the CRW conveyance and collection systems within the City limits is provided in Figure 3-1. Comprehensive inspection programs were successfully conducted for the CSO regulator structures, the interceptor system (both prior to and after cleaning), the pump stations, and the force mains. These inspections provided the necessary information to properly understand the configuration, critical elevations, and maintenance conditions along the CRW sewer system infrastructure. A Rapid Assessment Inspection was conducted at every known manhole and connecting pipe within the sewer collection system to quickly update the geographic information system (GIS) database and mapping, and to identify sewer segments with immediate structural or maintenance needs. These rapid assessment inspections are also being used to prioritize areas for systematic CCTV inspections to better define and prioritize remedial maintenance and repair needs.

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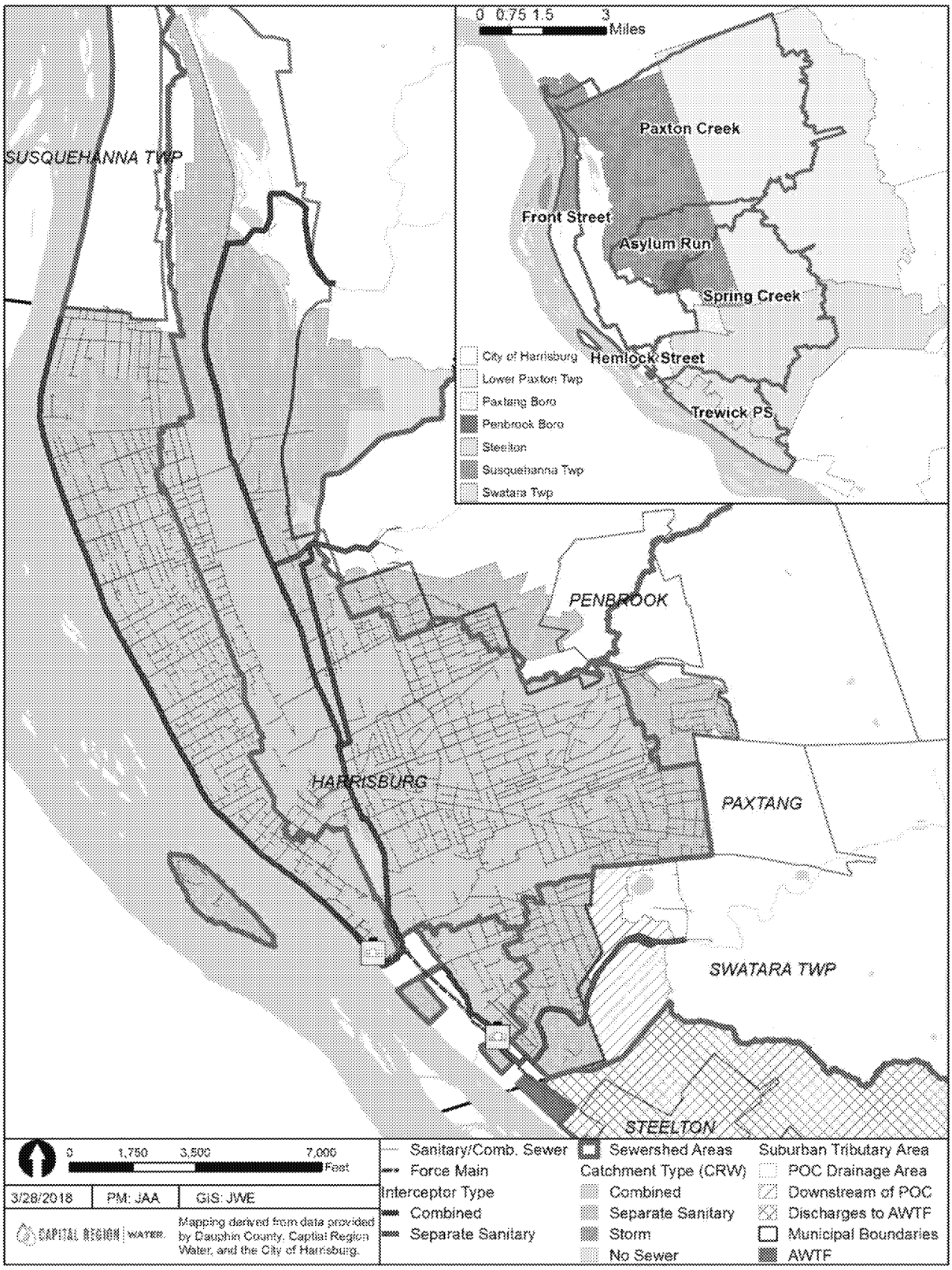

Figure 3-1: CRW Service Area Including Service Area of Suburban Community Systems

Section 3.3 describes the monitoring and analysis of precipitation data that was conducted to quantify and characterize current precipitation patterns within the CRW service area and long-term trends. A gauge adjusted radar rainfall (GARR) system combined Doppler radar technology with a regional gauge network to develop high resolution, spatially distributed precipitation to support the development and validation of the H&H models. The long-term gauge records from the Capital City and Harrisburg International Airports were analyzed statistically to develop a "typical year" precipitation dataset. This typical year precipitation was applied to the H&H models of the CRW system to establish the frequency, duration, and volume of CSO discharges and develop and assess alternative control strategies. To assess the capacity and levels of service provided by the separate sanitary collection/conveyance system and the combined sewer collection system, a set of synthetic design storms was developed to represent conditions during the 2-year, 5-year and 10-year, 24-hour storm events.

Section 3.4 describes the updated hydrologic and hydraulic (H&H) model and the monitoring data used to validate it. CRW incorporated the sewer system information obtained through its completed facility inspection programs to update and refine its H&H model of the CRW conveyance system. CRW also performed extensive precipitation monitoring and flow monitoring to properly calibrate and validate its H&H model as shown in **Table 3-1**. The CRW hydrologic model simulates dry and wet weather flow and represents all catchment areas within the City of Harrisburg contributing to the conveyance system, for both separate and combined sewer systems. As required by the 2015 Partial Consent Decree (PCD), the hydraulic model was extended to major trunk sewers within the collection system. The model was used to develop a thorough understanding of the wastewater and stormwater flows characteristics of its sewer system in response to precipitation events of varying duration and intensity; to characterize hydraulic capacity, sewer system overflows, and unauthorized combined sewer system discharges; and to support the development of the Program Plan.

Table 3-1: Monitoring Site Summary

Monitoring Category	Number of Monitoring Sites
Satellite Community	4
Interceptor System	9
Combined Sewer	13
Separate Sewer Area	7

These modelling assessment results indicate that a comprehensive rainfall dependent infiltration/inflow (RDII) reduction program would not be cost-effective for CRW, since the completed wastewater flow monitoring and analysis activities showed the existing sewer collection systems are relatively "tight," and allow a minimal amount of extraneous RDII flow to enter. However, the high ground water infiltration flows monitored along Industrial Road, adjacent to Paxton Creek and Wildwood Lake, indicate that the trunk sewer could be a cost-effective candidate for a sewer lining project.

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3.2 Treatment, Conveyance, and Collection System Characteristics

Section V-E, paragraph 21 of the PCD requires CRW to prepare and submit a characterization of its existing collection and conveyance systems, providing all the information required by the National CSO Policy. This requirement was successfully met in CRW's revised *Combined Sewer System Characterization Report* [1]and *Separate Sanitary Sewer Capacity Assessment Report*,[2] as summarized in this Section.

A map of the CRW service area collection sewer system is provided in **Figure 3-2**. The map shows the locations of the six interceptor sewers that convey wastewater from the collection sewers to the advanced wastewater treatment facility. The map also shows the delineations and extents of the sewershed areas that discharge into each of the interceptors (the six colored areas).

The map shows the delineations and names of each of the individual catchment areas that discharge to the distinct points of connection to the interceptors. Most of these connection points have regulator structures that divert a controlled flow rate to the interceptor, and allow excess combined wastewater to be discharged to receiving waters.

Approximately 60 percent of contributing area within the City of Harrisburg is served by combined sewers that carry wastewater and stormwater in the same pipe. Approximately 40 percent of contributing area within the City is served by separate sanitary sewers, where stormwater is conveyed by CRW and other public (e.g. PennDOT, other State properties) MS4 systems which discharge to a stream. Approximately 12 percent of the City does not contribute wastewater or stormwater to CRW's system (e.g. railroad corridors, areas adjacent to streams).

In the CRW service area, there are five categories of catchment area types, distinguished by where the sanitary wastewater flows and the stormwater runoff flows are ultimately conveyed. There also are areas not served by CRW sewers. Tributary areas for each of the five categories of catchment types shown in **Figure 3-2** are provided in **Table 3-2**.

CRW's wastewater and stormwater collection and conveyance systems consist of the following components described and characterized in this report section.

- An advanced wastewater treatment facility (AWTF), with a permitted monthly average daily design capacity of 45 million gallons per day (mgd), that treats wastewater from the City of Harrisburg and the suburban communities

AWTF Hydraulic Capacity	
Headworks	80 MGD
Primary Clarifiers	80 MGD
Secondary Treatment	45 MGD
BNR	45 MGD
Disinfection	80 MGD
2017 Influent Flow to AWTF	
Average Daily Flow	20.9 MGD
Max Avg. Daily Flow	51.9 MGD
Max Monthly ADF	25.8 MGD
Peak Flow	74.1 MGD

[1] *Combined Sewer System Characterization Report, Version 2.0*, February 2018, available at **https://capitalregionwater.com/cbh2o**.

[2] *Separate Sanitary Sewer Capacity Assessment Report, Version 2.0*, February 2018, available at **https://capitalregionwater.com/cbh2o**.

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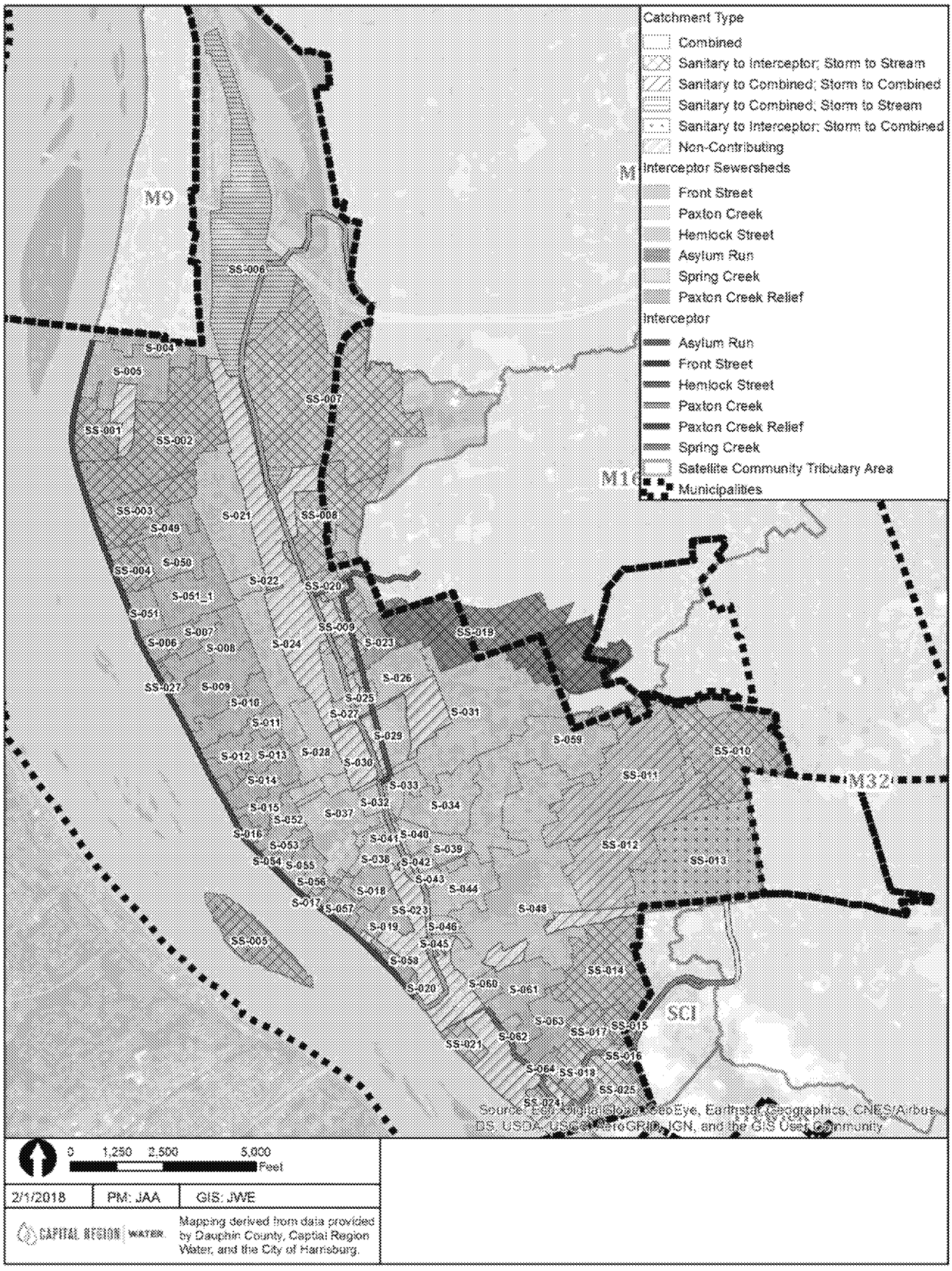

Figure 3-2: CRW Service Area Collection Sewer System and Catchment Areas

- A conveyance system consisting of:
  - 13.8 miles of interceptor sewer
  - Two major pumping stations and 1.3 miles of force mains that convey flow from the interceptors to the AWTF
  - 59 CSO regulator and 58 outfall structures (two regulators share a common outfall) that divert a controlled flow rate to the interceptor, and allow excess combined wastewater to be discharged to receiving waters
- A collection system consisting of:
  - Approximately 160 miles of separate and/or combined collection system sewers
  - Approximately 4,300 storm inlets and catch basins

Table 3-2: Catchment Area Types and Tributary Area Statistics

Sewershed	Combined Sewer System		Separate Sewer System					Non-Contributing Area (ac)	Separate Sanitary Outside City* (ac)
	[1] Combined Sewer Catchments (ac)	[2] Sanitary / Storm to Combined (ac)	[3] Sanitary to Combined; Storm to River		Sanitary to Interceptor				
					[4] Storm to Combined (ac)	[5] Storm to River			
			CRW MS4 (ac)	Other MS4 (ac)		CRW MS4 (ac)	Other MS4 (ac)		
Front Street	723	0	0	0	0	366	0	-	1
Paxton Creek	1,223	301	184	55	0	66	262	-	211
Hemlock Street	124	0	0	0	0	19	0	-	0
Paxton Creek Relief	16	0	0	0	0	0	0	-	0
Asylum Run	0	0	0	0	0	58	34	-	137
Spring Creek	0	0	0	0	169	367	0	-	5
Total	**2,086**	**301**	**184**	**55**	**169**	**876**	**295**	**561**	**354**
Percent of City	**46%**	**7%**	**4%**	**1%**	**4%**	**19%**	**7%**	**12%**	**-**
Percent of Contributing Area	**53%**	**8%**	**5%**	**1%**	**4%**	**22%**	**7%**	**-**	**-**

*Contributing area not tributary to a point of connection meter

Comprehensive inspection programs were successfully conducted for the CSO regulator structures, the interceptor system (both prior to and after cleaning), the pump stations and the force mains. These inspections provided the necessary information to properly understand the configuration, critical elevations, and maintenance conditions along the CRW Conveyance system. For the collection system, a Rapid Assessment Inspection was conducted at every known manhole and connecting pipe to quickly update the geographic information system (GIS) database and mapping, and to identify sewer segments with immediate structural or maintenance needs. These rapid assessment inspections are also being used to prioritize areas for systematic CCTV

inspections to better define and prioritize remedial maintenance and repair needs. Summary information is provided in the following report sections.

3.2.1 Advanced Wastewater Treatment Facility

CRW owns and operates the AWTF located at 1662 South Cameron Street in Harrisburg, PA. The AWTF is one of the largest publicly owned treatment facilities in the Commonwealth and currently the largest in Pennsylvania within the Chesapeake Bay Watershed. The AWTF employs biological nutrient removal technology in a High Purity Oxygen Activated Sludge (HPOAS) plant to achieve nitrogen and ammonia requirements. CRW's AWTF treats wastewater from the City of Harrisburg and the six suburban communities located within its service area. The 5-year average annual wastewater flow at the AWTF during 2013 to 2017 was 21.4 million gallons per day (MGD). The permitted design hydraulic capacity of the AWTF is 45 MGD. More detailed descriptions of the treatment facility, the treatment processes, and the individual process units are provided in Sections 3.3 and 3.4 of the March 2017 Combined Sewer System Characterization Report and Section 3.3 of the March 2017 CRW Wastewater Division, *Operations and Maintenance Manual*[3], which is updated annually. The wastewater and solids handling processes for the current AWTF are summarized below and illustrated on **Figure 3-3**.

In March 2014, CRW began upgrading its AWTF with biological nutrient removal to comply with the Chesapeake Bay Tributary Strategy and meet associated new NPDES permit discharge requirements. This $50 million project at the AWTF consisted of adding biological nutrient removal technology to the existing processes to achieve nitrogen and ammonia removal requirements. The process involved adding side stream treatment (nitrification) for the filtrate from the sludge dewatering process that, when returned to the main treatment process, will bolster performance. Multiple tanks and processes were modified to complete integration of the new process. The project was completed in 2016.

Influent Flows: The AWTF receives the wastewater flows from Front Street Pump Station and the Spring Creek Pump Station in a common force main, while flows from the Borough of Steelton are pumped directly to the AWTF. Wastewater flows are screened at the pump stations by mechanically-cleaned bar screens.

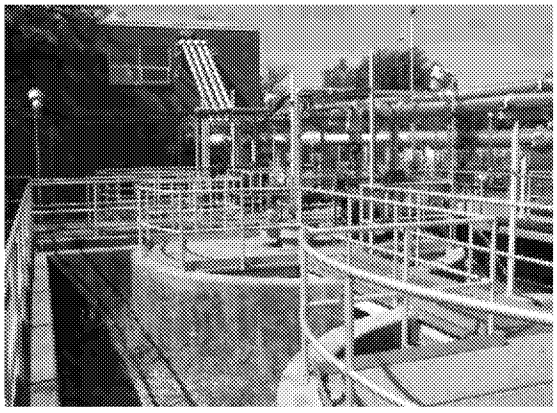

Figure 3-4: Vortex Grit Chambers at CRW AWTF

Headworks Facilities: Wastewater flow passes through the influent channel to four vortex grit removal units, shown in **Figure 3-4**. Effluent from the grit removal units flows through a venturi flow meter located in the 54-inch pipe in the Control Building which is used to measure total plant flow. Improvements to the headworks facility, which will increase the wet weather treatment capacity, have been designed and construction will continue through 2018.

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[3] *CRW Operation & Maintenance Manual, Version 2.0*, March 2017, available at **https://capitalregionwater.com/cbh2o**.

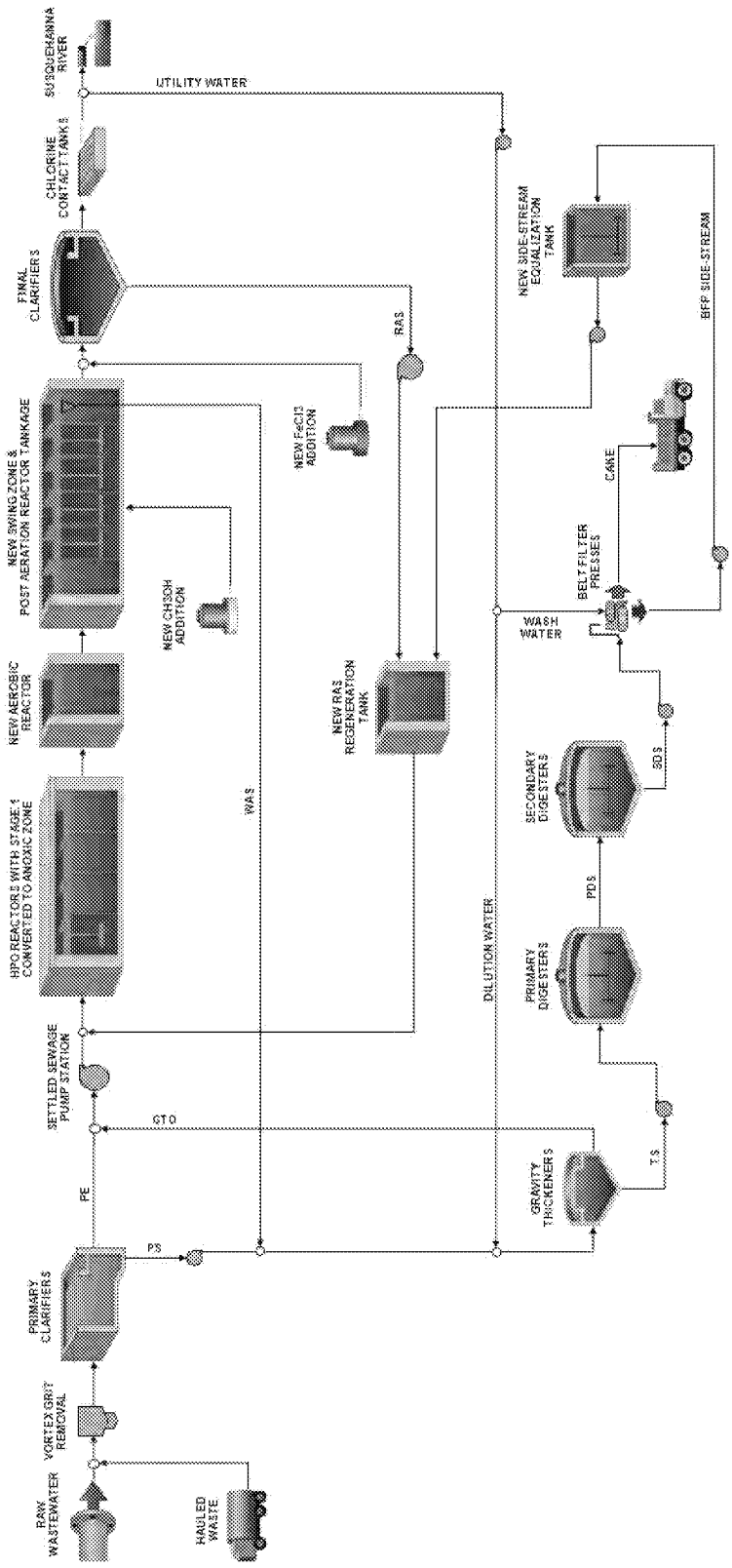

Figure 3-3: Process Flow Diagram for CRW AWTF Current Conditions
Source: Harrisburg Advanced Wastewater Treatment Facility Improvements Project. Basis of Design Report. Prepared by AECOM, February 2012

Primary Treatment Facilities: After the flow meter, wastewater is conveyed to the four primary clarifiers. Primary sludge is combined with waste activated sludge, and conveyed to the gravity thickeners. Stress testing was recently conducted to quantify the wet weather treatment capacity of the newly renovated and expanded facilities. The AWTF now has provisions for Chemically Enhanced Primary Treatment (CEPT). CEPT is used to improve total suspended solids (TSS) and biochemical oxygen demand (BOD) removal during peak loading periods.

***Advanced Treatment Facilities*:** Settled wastewater overflows the primary clarifiers' weirs to the Settled Wastewater Pump Station. All settled wastewater flow, up to 45 mgd, is pumped to the advanced process. Peak flows above 45 mgd are bypassed around the advanced process and directed to the chlorine contact tank for disinfection. The advanced treatment process is based on High Purity Oxygen Activated Sludge (HPOAS) technology wherein the Oxygenation Tanks are covered and aeration is achieved by high purity oxygen produced by the on-site cryogenic facility. The AWTF improvements project currently provides additional nitrogen removal capability by the conversion of the first stage of the HPOAS to a pre-anoxic zone and the addition of a Bioreactor between the HPOAS and final settling tanks.

The Bioreactor has the capability to alternate between aerobic and anoxic zones with methanol addition to complete the nitrogen removal process. Following the Bioreactor, there is a post-aeration channel to increase the dissolved oxygen concentration in the effluent to meet NPDES discharge permit conditions. Flow from the Bioreactor enters a mix tank where polymer can be added for Chemically Enhanced Secondary Treatment (CEST) to improve solids settling in the final settling tanks. Flow is equally distributed to the six, 102-feet square final settling tanks using weir gates and flow meters. Effluent from the final clarifiers is conveyed to the chlorine contact tanks, shown in **Figure 3-5**, where it is disinfected using chlorine gas and chlorinators prior to discharge to the Susquehanna River.

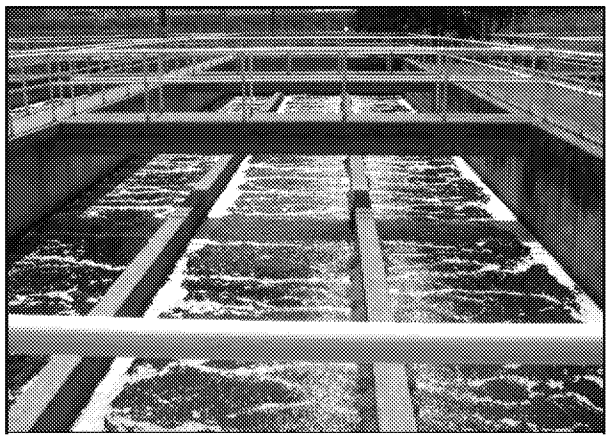

Figure 3-5: Chlorine Contact Tank at CRW AWTF

Sludge and Solids Handling Facilities: Return Activated Sludge (RAS) collected in the final settling tanks flows to the RAS pump station wet well where it is pumped to the RAS regeneration tank. This new side stream treatment process combines the filtrate from the sludge dewatering belt filter presses with RAS for nitrification treatment in the covered RAS regeneration tank using high purity oxygen. The overflow from the RAS regeneration tank is then distributed between the Oxygenation Tanks.

The gravity thickened primary and waste activated sludges are pumped to the two-stage anaerobic digesters. The thickened sludge is heated and gas mixed in the primary digester to reduce volatile solids content and stabilize the sludge for disposal. Sludge overflows the primary digesters to the secondary digesters which function as sludge storage tanks. The digested sludge is then dewatered by belt filter presses and disposed of via landfill or land application.

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Table 3-3: CRW AWTF NPDES Discharge Limits

Discharge Parameter	Unit	Minimum Value	Monthly Average Value	Weekly Average Value	Instantaneous Maximum Value
pH	-	6.0	-	-	9.0
Dissolved Oxygen	mg/L	5.0	-	-	-
Total Residual Chlorine	mg/L	-	0.5	-	1.6
Total Suspended Solids	mg/L	-	30	45	60
$CBOD_5$	mg/L	-	25	45	50
Ammonia-Nitrogen (May 1 – October 31)	mg/L	-	11	-	22
Total Phosphorus	mg/L	-	2.0	-	4.0
Fecal Coliform (May 1 – September 30)	Counts/100mL	-	200	-	-
Fecal Coliform (November 1 – April 30)	Counts/100 mL	-	2000	-	-

The AWTF discharges treated effluent to the Susquehanna River under a National Discharge Elimination System (NPDES) permit issued by the Pennsylvania Department of Environmental Protection (PA-DEP). The AWTF discharge limits under the NPDES Permit Number PA 0027197 are summarized in **Table 3-3**.

3.2.2 Interceptor System Characteristics and Inspections

For the early development of the Program Plan, an accurate and up-to-date understanding was needed of the existing CRW interceptor system. Comprehensive inspection programs were successfully conducted to obtain the necessary information to properly understand the alignment and conditions of the network of interceptor pipes, obtain the configurations and critical elevations of the regulator structures, develop the H&H model, and meet PCD requirements.

The CRW interceptor system consists of 13.8 miles of sewer pipe ranging in size and shape from 24-inch circular to 60-inch by 72-inch arch or rectangular pipe. Two of the interceptors, Asylum Run and Spring Creek convey separate sanitary flow. The other four interceptors are combined sewers. A map of the CRW interceptor sewers is provided in **Figure 3-6**. Pertinent information on the interceptor sewers is summarized in **Table 3-4**.

In 2014, CRW hired a contractor to inspect and assess the Asylum Run, Front Street, Hemlock Creek, Paxton Creek, Paxton Creek Relief, and Spring Creek Interceptor sewers. The technologies utilized to implement the inspections included closed circuit television (CCTV), sonar profiling, and laser profiling, which allowed full inspection of the pipes while maintaining full operation of the interceptor system and conveyance of the wastewater flow. Approximately 200 interceptor manholes were inspected, providing pan and tilt inspection images.

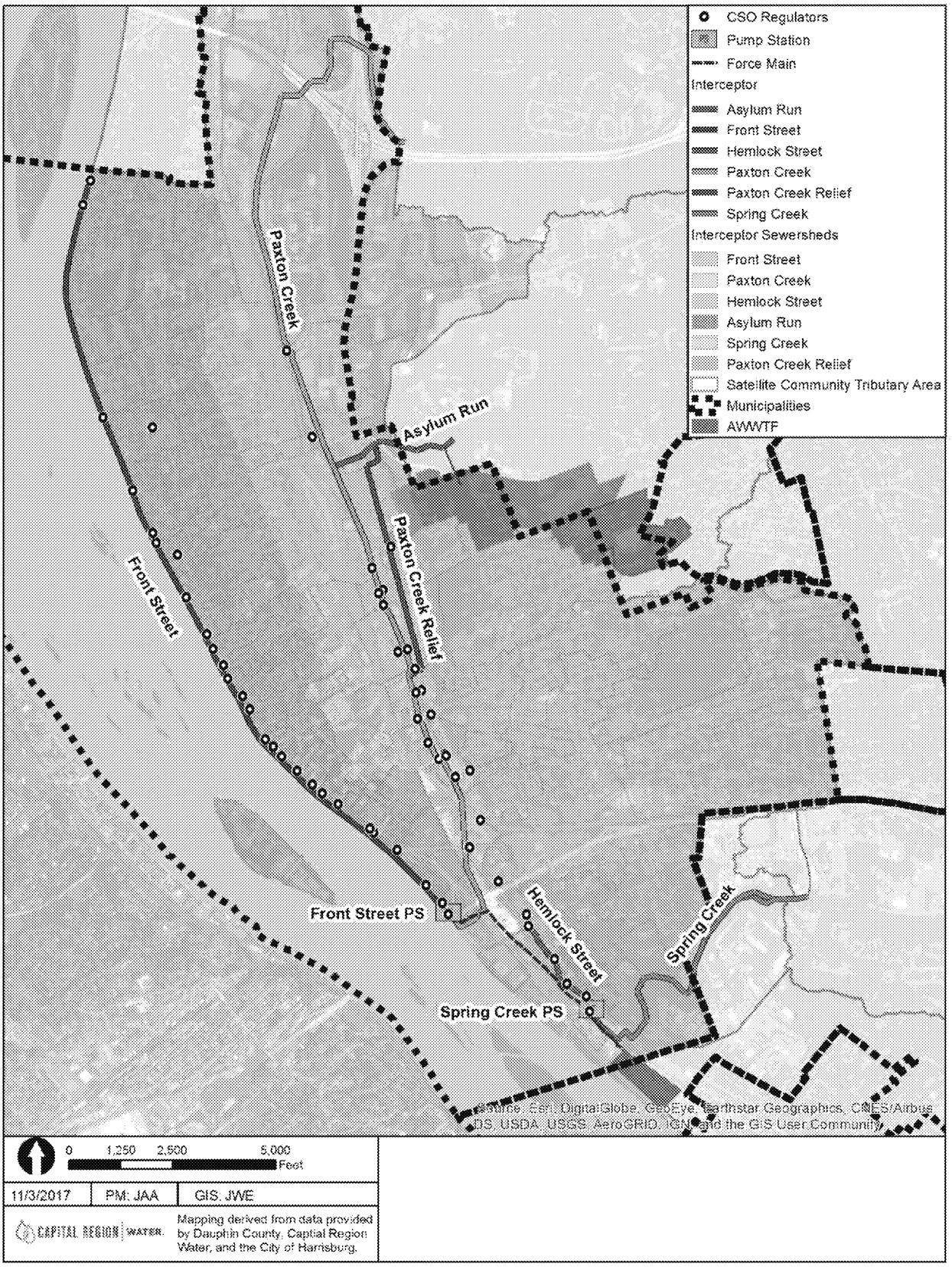

Figure 3-6: The CRW Interceptor Sewer System

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Table 3-4: Key Characteristics of Interceptors in the CRW Conveyance System

Interceptor	Type	Typical Cross-Section	Length (miles)	Slope %	Material	Number of CSO Outfalls
Asylum Run (ARI)	Separate	24" Round	0.67	0.61	Concrete, VCP	0
Front Street (FSI)	Combined	39"H x 36"	3.95	0.07	Concrete, VCP	28
Hemlock Street (HSI)	Combined	24" Round	0.52	0.18	Concrete, VCP	5
Paxton Creek (PCI)	Combined	59"H x 48"W; 60"H x 72"W	5.53	0.09	Concrete	25
Paxton Creek Relief (PCRI)	Combined	48" Round	1.15	0.11	Concrete	1
Spring Creek (SCI)	Separate	24"-30" Round, 34"H x 32"W, 39"H x 36"W	2.03	0.37	Concrete, CMP, DIP	0

The observations and results from the completed interceptor pipe inspections were documented digitally using the standardized protocols of the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP). The observations and results were also documented in a February 2015 memorandum.[4] The goal of using PACP standards is for CRW to organize the inspection data to create a comprehensive database to properly identify, plan, prioritize, manage and renovate their pipelines based on condition evaluation. The inspection results were reviewed and recommendations were developed for additional cleaning, further inspection, and anticipated rehabilitation requirements.

Plans and specifications were developed for the interceptor cleaning project, which was bid during September and October 2015, awarded in January 2016, and completed in early March 2017. A total of 35,700 linear feet of interceptor pipes were cleaned and approximately 1,500 cubic yards (1,800 tons) of debris were removed.

As the cleaning contractor completed its cleaning operations, each cleaned section of the interceptor was re-inspected using sonar and CCTV technologies, and the findings documented in a May 2017 memorandum[5], which superseded the February 2015 memorandum. The re-inspections verified that the pipes were sufficiently cleaned, documented the location and quantity of any residual solids depositions, and revealed hidden structural and/or maintenance defects and incorrect pipe cross sections.

Table 3-5 provides a summary of heavy cleaning that was completed during 2016 and 2017 (recommendations per the 2014 inspections) and the length of recommended rehabilitation for each interceptor.

[4] Technical Memorandum, *Summary and Recommendations for Cleaning and Rehabilitation of CRW Sewer Interceptors from the Review of Redzone CCTV, Laser and Sonar Data*, February 2015.

[5] Technical Memorandum, *CRW Interceptor Cleaning and Rehab Improvements Update Report,* May 2017.

Table 3-5: Summary of Recommended Interceptor Cleaning and Rehabilitation

Interceptor	Length of Heavy Cleaning Completed (feet)	Length of Recommended Rehabilitation (feet)
Asylum Run (ARI)	0	2,504
Front Street (FSI)	11,973	12,581
Hemlock Street (HSI)	1,143	0
Paxton Creek (PCI)	15,651	13,499
Paxton Creek Relief (PCRI)	6,312	0
Spring Creek (SCI)	655	5,117
Total:	**35,734**	**33,701**

3.2.3 Major Pump Station and Force Main Characteristics

Two sewage pump stations convey flow to CRW's AWTF. The Front Street Pump Station receives flow from the Front Street and Paxton Creek interceptors, while the Spring Street Pump Station conveys interceptor flow from the Hemlock Street and Spring Creek Interceptors. The Front Street Pump Station discharges to a 48-inch force main; the Spring Creek discharges to a 24-inch force main, which then discharges to the Front Street Pump Station force main. Immediately before reaching the AWTF, the force main expands to a 54-inch diameter. The Front Street pump station has four pumps, each pump is 10,000 gpm (two pumps are variable speed, and two pumps are constant speed). **Table 3-6** presents the operating level of each of these pumps. The Spring Creek pump station has three pumps; each pump is 8,350 GPM and all are variable speed. **Table 3-7** presents the operating level of each of these pumps. According to CRW's Nine Minimum Control Plan[6], both the Front Street and Spring Creek pump stations are over 50-years old, are nearing the end of their useful lives, and are in need of significant remedial maintenance and reconstruction within their existing buildings. A recent inspection of CRW's force main, however, did not identify any leaks, stable gas pockets, or priority anomalies.

Table 3-6: Front Street Pump Station Wet Well Operating Levels

Operating Condition	Rising Wet Well Levels (feet)	Dropping Wet Well Levels (feet)
Lead Variable Speed Pump	Start @ 294.0	Stop @ 291.0
1st Lag Variable Speed Pump	Start @ 295.0	Stop @ 292.0
2nd Lag Constant Speed Pump	Start @ 297.0	Stop @ 292.0
3rd Lag Constant Speed Pump	Start @ 297.1	Stop @ 295.0

Notes: 1. High Water Alarm = 297.0
2. Low Water Alarm = 291.5
3. Bottom of Wet Well = 286.0

[6] *CRW Nine Minimum Control Plan, Version 3.0*, August 2017, available at **https://capitalregionwater.com/cbh2o**.

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Table 3-7: Spring Creek Wet Well Operating Levels

Wet Well Parameters	Rising Wet Well Levels (feet)	Dropping Wet Well Levels (feet)
Lead Pump	Start @ 3.5	Stop @ 1.5
1st Lag Pump	Start @ 5.0	Stop @ 3.0

Notes: 1. High Water Alarm = 5.5
2. Low Water Alarm = 1.0
3. Levels referenced to bottom of wet well
4. The third pump must be placed into service manually

3.2.4 CSO Regulator Structure and Outfall Characteristics and Inspections

The CRW conveyance system includes 59 CSOs distributed along the four interceptor sewers plus an emergency overflow outfall at each of the two pumping stations. The locations of these CSO regulator structures are provided in **Figure 3-7**. To obtain the needed information for the Program Plan, CRW contracted for an inspection of every CSO regulator structure within the CRW interceptor system[7]. The systematic inspections were critical to documenting the configuration of each regulator, confirming key dimensions and elevations, and identifying potential structural or functional deficiencies. The inspection observation and measurement information and data for each individual regulator structure were documented in a five-page inspection form.

The configuration of a typical CSO diversion structure in the CRW system is provided in **Figure 3-8**. Combined wastewater enters the diversion chamber and under dry weather conditions, all the flow is diverted away from the trunk sewer and towards the interceptor sewer by a concrete diversion weir (also called a diversion dam). An example of a typical diversion weir is provided in **Figure 3-9**. During wet weather, the rate and volume of stormwater flow from the combined catchments increases significantly and can exceed the capacity of the regulators, downstream interceptor sewers and/or the treatment facility. When this occurs, the CSO regulator structures (sometimes called diversion structures) divert a controlled flow rate to the interceptor, while untreated excess combined wastewater is discharged to receiving waters.

There are two main categories of CSO regulator structures in the CRW system: regulators with variable control orifices and those with fixed orifice openings. Most of the CSO regulator structures in the CRW system have variable control orifices where the sizes of the control openings from the diversion chamber to the regulator chamber can increase and decrease under differing flow conditions, as determined by the mechanical Brown and Brown (B&B) type regulators. For most structures, under wet weather conditions, when the influent flow from the trunk line is high enough to approach the crest of the diversion weir, the wastewater level in the float chamber raises the float mechanism, triggering the control orifice to close. When the storm is over and the water level in the trunk sewer recedes, the float mechanism reopens the orifice to its fully open position. An example of a typical B&B mechanism is provided in **Figure 3-10**.

[7] *Regulator Infrastructure Inspection Report,* October 2013

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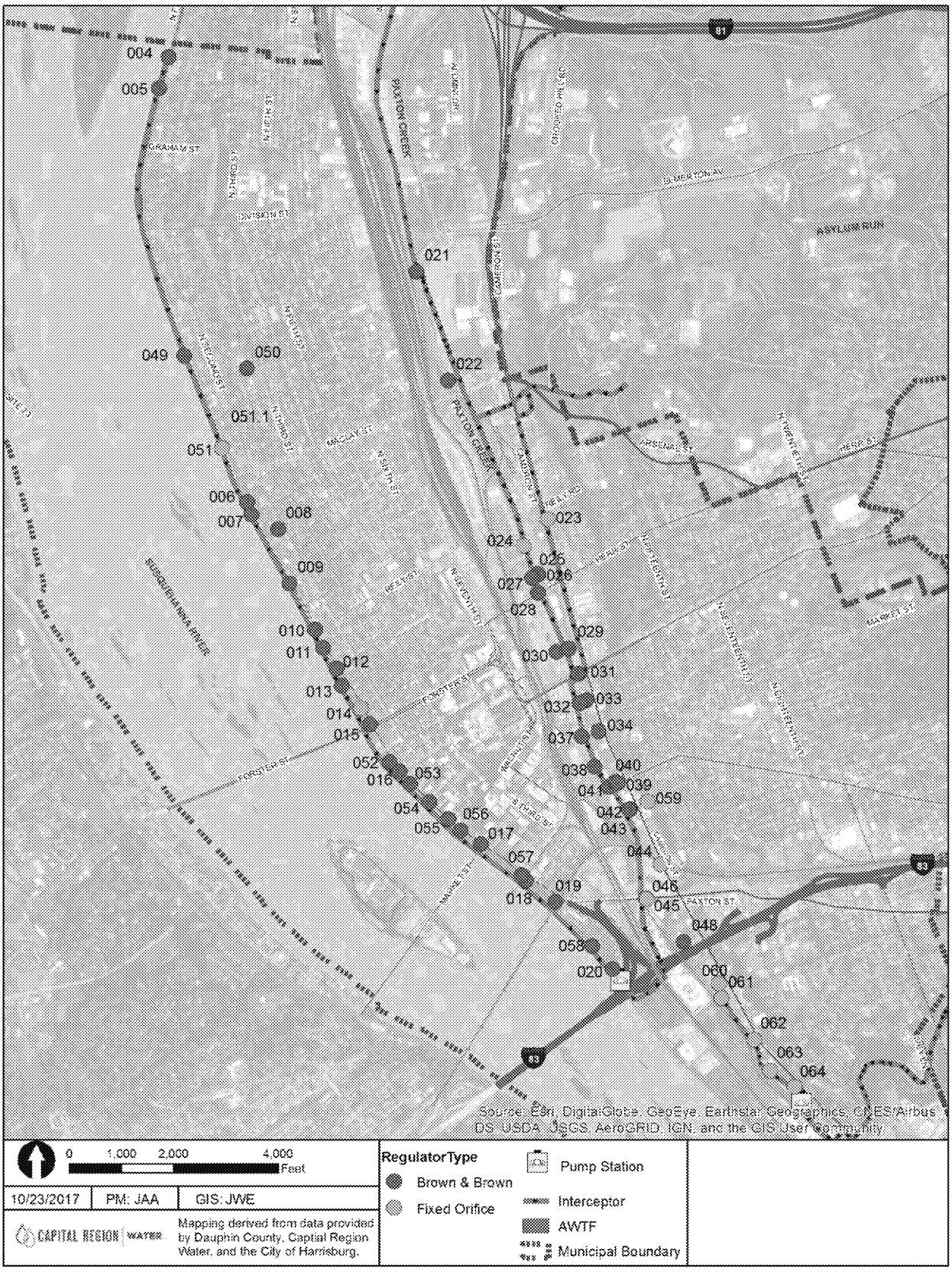

Figure 3-7: Locations of CSO Regulator Structures within the CRW System

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Thirteen of the CSO regulator structures have fixed control orifices and the size of the opening does not change under dry and wet weather conditions. The fixed orifice structures are similar to the variable orifice structures except that the size of control orifice openings are fixed and do not change. There is no float chamber in the structure and there is no B&B mechanical equipment. Some of the structures have a V-notch weir to control water surfaces in the chamber. Examples of fixed orifice controls are provided in **Figure 3-11**.

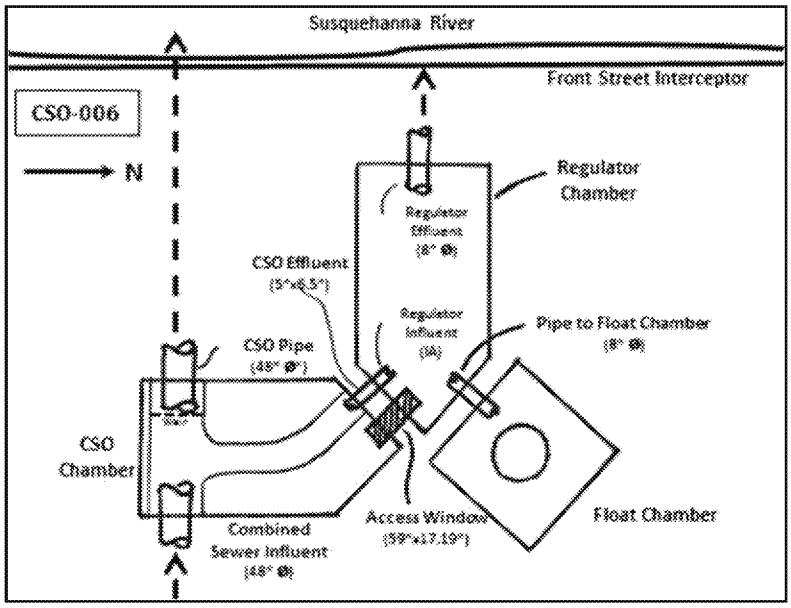


Figure 3-8: Configuration of a Typical CRW CSO Regulator Structure

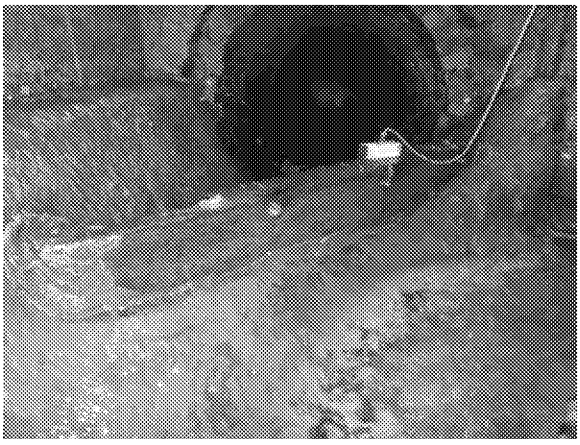


Figure 3-9: Example of a Diversion Dam

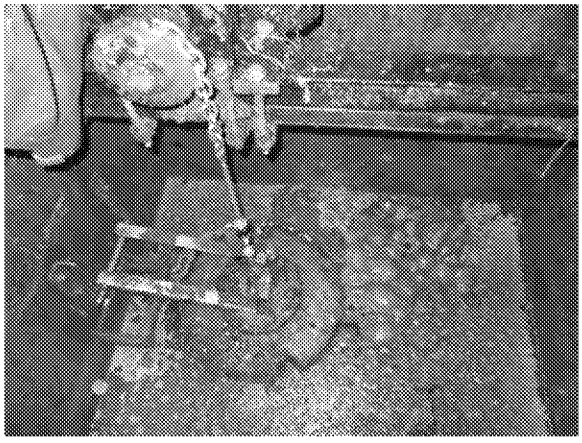
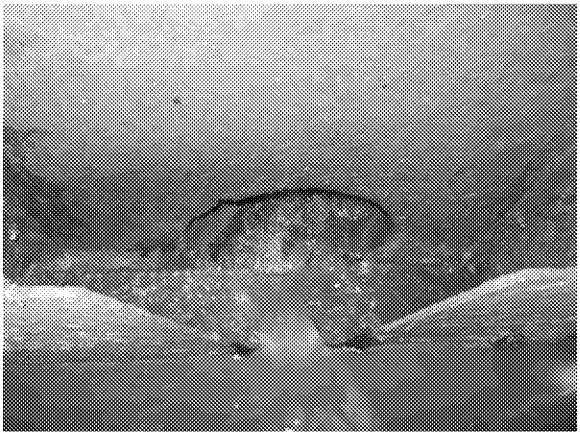


Figure 3-10: Brown and Brown Control Equipment



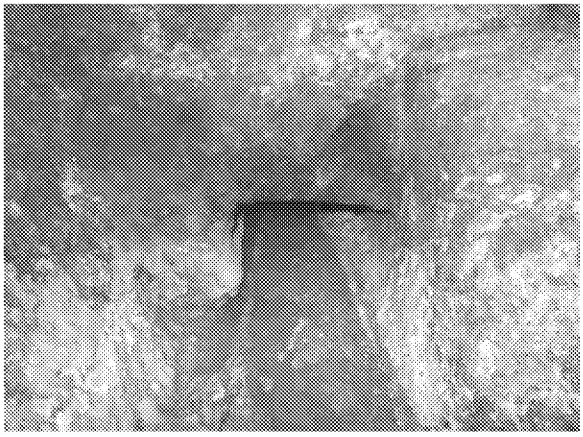


Figure 3-11: Examples of Fixed Orifice Controls

An emergency overflow structure and outfall serves each of the Front Street and Spring Creek Interceptors. They allow CSO discharges to occur if there were to be a mechanical failure at the pump station.

3.2.5 Collection System Characteristics and Inspections

In the initial stages of the City Beautiful H_2O Program Plan, CRW needed to quickly update its original GIS mapping of the configuration of the combined and separate sanitary sewer collection systems within the service area. It would not be possible to meet the PCD schedule and milestone deadlines by televising the entire system. Therefore, CRW elected to implement a Rapid Assessment Inspection Program, conducted via a pole camera inspection of every known manhole and connecting pipe within the collection system. The information gathered through the Rapid Assessment Inspection Program was successfully used to delineate the combined and separate sewer catchment areas within the CRW collection system. A map of the CRW collection system showing the catchment areas was previously provided in **Figure 3-3**.

CRW retained a contractor to perform the collection system Rapid Assessment Inspection Program in 2015 and 2016. **Table 3-8** provides a summary of the miles of pipe and the number of manholes and outfalls that were inspected. The inspection observations were divided between operations and maintenance (O&M) findings and structural findings.

Table 3-8: CRW Rapid Assessment Inspection Summary

Combined/Separate Sewer System	Miles of Pipe	Number of Manholes/Outfalls	Inspection Period
Collection System Trunk Sewers	31	713	2015-2016
Collection System Branch Sewers	92	2,087	2015-2016
Separate Storm Sewers	16	302	2016
Total	**139**	**3,102**	-

O&M findings consist of defects related to the operation of the sewer system. Defects such as root intrusions and debris and grease deposits are examples of O&M defects. Structural defects pertain to any issue that may jeopardize the structural integrity of the pipe or manhole. Cracks, fractures, holes, exposed rebar, and missing bricks are examples of structural defects. The rapid assessment inspections are being followed by an ongoing program of closed circuit television (CCTV) inspections that are described later in this Program Plan.

The zoom camera inspections allowed for a rapid assessment of the condition of the pipes within CRW's collection system. Since inspections were conducted from the manhole access points only, each pipe has an upstream and downstream video that was captured. By analyzing both the upstream and downstream videos, a general condition assessment was performed for the viewable portion of each pipe, and preliminary rehabilitation recommendations were made. If nothing was preventing visibility within the pipe, fifty feet or more of the pipe length was viewable from videos taken at both the upstream and downstream manholes, which was generally sufficient for providing a preliminary characterization of the pipe. However, for pipes

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with bends, partial obstructions, or long distances between manholes, the assessment was more limited.

Ongoing CCTV Inspections and Assessments: While the collected Rapid Assessment Inspection data were essential in meeting the PCD schedule, there were understood limitations to the information provided because conditions within the pipe segments beyond the manhole inspection limits could not be observed. Subsequently, CRW developed and is implementing a prioritized CCTV inspection program to fill in the information gaps at a pace within their capabilities.

CRW is in the process of conducting a prioritized remedial CCTV inspection of the entire collection system within the next five to seven years to eliminate risk associated with unknown defects, especially for critical sewers which have a high consequence of failure. To expedite the process, CRW has committed to purchasing a second CCTV truck and hiring additional staff to operate it. Outside contractors may also be used, as necessary, to supplement in-house CCTV capabilities. It is important to note that the CCTV inspection program is likely to identify additional defects not seen by the rapid assessment inspections which will elevate the condition score, and thus the recommendation priority, of many pipes. CRW is utilizing its Cityworks Asset Management System to document completed CCTV inspections, prioritize future CCTV inspections, and manage the pace at which inspections are conducted. Once the remedial CCTV inspections are completed on a system-wide basis. CRW will be able to transform its CCTV inspections from a remedial program to a preventative O&M program.

Updating of the GIS Database: The observations, findings, and relevant data from the completed Rapid Inspection Program were entered into the CRW geographic information system (GIS) database. The database updates included information such as pipe location, pipe size, and pipe condition, including the type and severity of any observed defects. The updated information facilitated the refinement of GIS-based maps of the CRW collection system. The GIS database is updated as new information is obtained through the ongoing CCTV inspections.

Ongoing Catch Basin Inspection and Repair: CRW is also in the process of conducting a comprehensive program of inspection, cleaning, and repair of its catch basins and storm inlets. The CRW collection system includes approximately 4,300 catch basins and inlets. CRW is utilizing its Cityworks Asset Management System to document completed inspections, prioritize and schedule any required remediation work, track completed rehabilitation activities, and manage the pace at which the activities are completed.

3.2.6 Prioritized Asset Management Program

Asset management is a systematic process of operating, maintaining, and upgrading assets cost-effectively. A Cityworks asset management and work order system has been successfully implemented to assist CRW in fulfilling its responsibility to provide sustainable services to their customers while maintaining their assets in a cost-effective manner. For quality assurance, sewer system inspections were conducted and documented using the criteria, standards and methodology of the National Association of Sewer Service Companies (NASSCO).

Cityworks Asset and Work Order Management: Cityworks provides CRW with a comprehensive public asset and work management tool for the operation and maintenance of infrastructure

facilities and other location-focused activities. The asset management program manages infrastructure capital assets to minimize the total cost of owning, operating, and maintaining assets at acceptable levels of service. Maintenance management involves two fundamental practices – reactive and scheduled maintenance. Cityworks logs and manages reactive maintenance activities such as when CRW crews conduct regulator structure inspections after a storm event, or respond to a citizen call reporting a sinkhole or clogged storm inlet. Cityworks manages scheduled maintenance or preventive maintenance activities to ensure the performance of CRW assets either individually or as a part of a larger system.

NASSCO Documentation Standards: The CRW conveyance and collection system inspections were conducted and documented using the criteria, standards and methodology of the National Association of Sewer Service Companies (NASSCO). Using the NASSCO protocols, and NASSCO-certified inspection supervisors, a standardized condition assessment score was assigned for each observed pipe or manhole defect to establish an overall level of severity. The protocols for the Pipeline Assessment Certification Program (PACP) were used for the sewer inspections. The standardization certification ensures that an assigned defect label and severity rating is consistent whether the inspection is conducted in Los Angeles or Harrisburg. The protocols for the Manhole Assessment Certification Program (MACP) were applied to the manhole inspections.

3.3 Regional Precipitation Characteristics

The Partial Consent Decree, in Section V-E, paragraph 15 requires CRW to develop and implement an *Initial Flow Metering and Monitoring Program Plan* (IFMMPP) [8]. The plan included a regional rain gauge network, and a gauge adjusted radar rainfall (GARR) system to collect precipitation data. The PCD also requires CRW to use the collected data to characterize precipitation over its service area. The long-term record data at the airport gauges were analyzed to develop a typical year rainfall dataset and a set of synthetic design storms for the CRW service area. The collected and analyzed precipitation data were sufficient to refine and validate the hydrologic and hydraulic (H&H) model.

3.3.1 Characterization of Precipitation Statistics and Patterns

The combined record from the two airport gauges provided a long-term historical record of 57 years. The average annual precipitation volume and the average annual number of storm events were determined, along with the associated standard deviations, for the extended precipitation record. The median annual rainfall for the Greater Harrisburg region for the 57-year record was 39.8 inches, and the standard deviation was 8.1 inches. The 68 percent confidence interval extends from 31.7 inches to 47.9 inches.

Figure 3-12 shows the average monthly distribution of precipitation volumes based upon the long-term precipitation record. Also shown on the figure are the plus and minus one standard deviation values, a measure of the statistical spread in the observed dataset. **Table 3-9** provides the information in tabular form.

[8] *Initial Flow Metering and Monitoring Program Plan,* July 2013.

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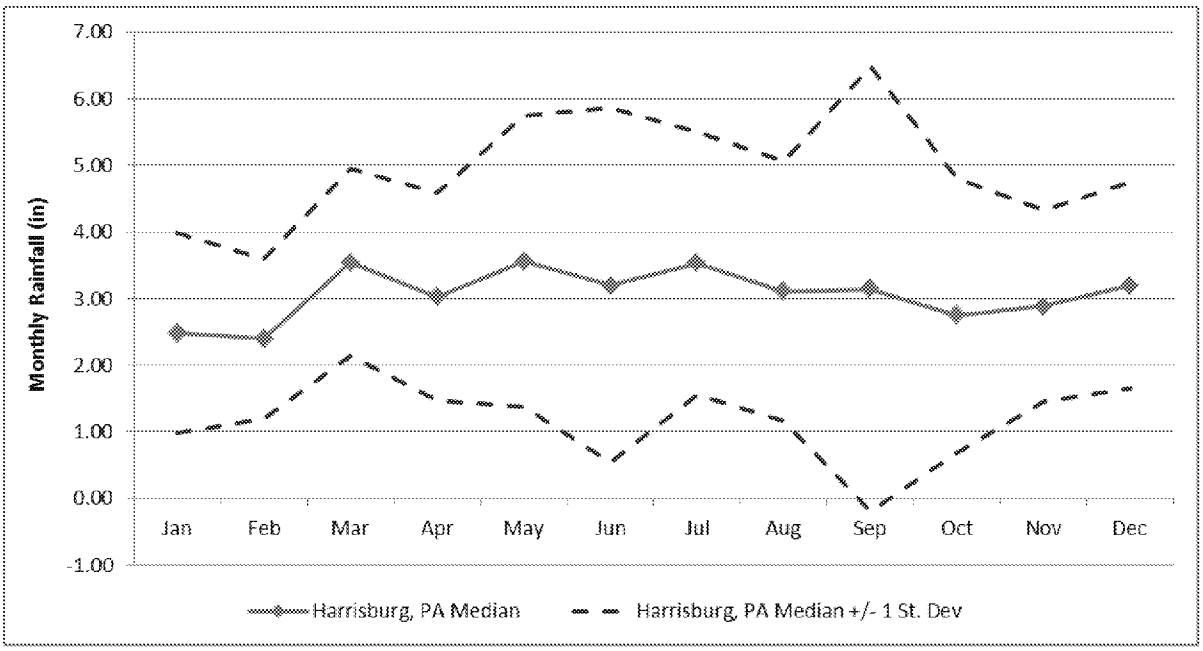

Figure 3-12: Median Monthly Precipitation Volumes in Harrisburg

Table 3-9: Median Monthly Precipitation Volumes in Harrisburg

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median	2.48	2.40	3.54	3.03	3.56	3.20	3.53	3.11	3.14	2.75	2.89	3.20
Standard. Deviation	1.50	1.20	1.40	1.56	2.19	2.65	1.97	1.95	3.34	2.05	1.44	1.55
Standard. Deviation. as %(2)	61%	50%	40%	51%	62%	83%	56%	63%	106%	75%	50%	49%
Median + 1 SD	3.98	3.60	4.94	4.59	5.75	5.85	5.50	5.06	6.48	4.79	4.33	4.75
Median – 1 SD	0.98	1.20	2.14	1.47	1.37	0.55	1.56	1.16	-0.20	0.70	1.45	1.65

(1)Note: All precipitation volumes are given in inches
(2)Note: Standard deviation as a percent of the median value

The analysis of the airport rainfall records indicated that the median annual number of significant precipitation events, events greater than 0.05 inches, over the long-term record was 86, and the standard deviation was 12.3 events. A minimum inter-event period of 6 hours was used for the analysis. The 68 percent confidence interval extends from 73.7 events to 98.3 events.

Figure 3-13 shows the average distribution of precipitation event frequency. Also shown on the figure are the plus and minus one standard deviation values to show the statistical spread in the observed dataset. The figure shows that the number of precipitation events in the greater Harrisburg area tend to be distributed evenly throughout the year, averaging from 6 to 9 events per month. **Table 3-10** provides the information in tabular form.

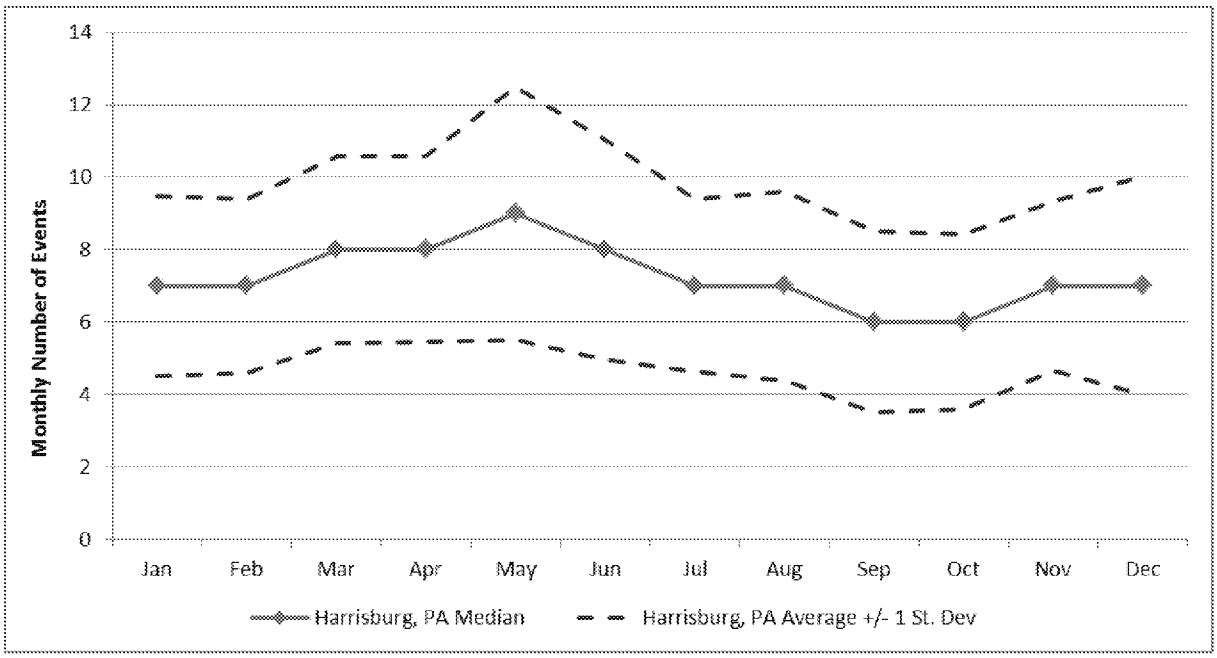

Figure 3-13 Median Number of Monthly Precipitation Events for Harrisburg

Table 3-10: Median Monthly Precipitation Events in Harrisburg

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median	7.0	7.0	8.0	8.0	9.0	8.0	7.0	7.0	6.0	6.0	7.0	7.0
Stand. Deviation	2.5	2.5	2.7	2.5	3.6	3.1	2.4	2.6	2.5	2.4	2.4	3.0
Stand. Dev. as %*	36%	35%	33%	32%	40%	38%	34%	37%	42%	40%	34%	43%
Median + 1 SD	9.5	9.5	10.7	10.5	12.6	11.1	9.4	9.6	8.5	8.4	9.4	10.0
Median – 1 SD	4.5	4.5	5.3	5.5	5.4	4.9	4.6	4.4	3.5	3.6	4.6	4.0

*Note: Standard deviation as a percent of the median value

3.3.2 Catchment Area Rainfall for H&H Modeling

To quantify and characterize precipitation patterns within the CRW service area, and support the development of the Program Plan, CRW successfully developed and implemented a precipitation gauge network consisting of eight tipping bucket rain gauges located throughout the service area. The gauge network recorded rainfall depths in 5-minute intervals with a minimum recorded depth of 0.01 inches. All the gauges are heated to allow for accurate measurement of frozen precipitation events during winter. Hourly rainfall data were also collected from the two National Weather Service gauges located at the Capital City Airport and at the Harrisburg International Airport. **Table 3-11** summarizes the rain gauge network and the respective gauge period of record while **Figure 3-14** shows the rain gauge network locations in relation to the City of Harrisburg and the communities receiving wholesale conveyance and treatment services from CRW.

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Table 3-11: Precipitation Monitoring Site Summary

Gauge Name /Number	Gauge Location	Period of Record	Data Collection Status	Data Analysis Status
ID COOP 363699	Capital City Airport	5/1/1948 - 1991	Completed	Completed
FAA_ Hourly-KCXY	Capital City Airport	1996 – Present	Ongoing	Ongoing
Harrisburg Int. Airport	Harrisburg Int. Airport	10/1/1991 – Present	Ongoing	Ongoing
RG1	Koons Park	9/3/2014 – Present	Ongoing	Ongoing
RG2	Market Street	8/1/2014 - Present	Ongoing	Ongoing
RG3	CRW AWTP	8/1/2014- Present	Ongoing	Ongoing
RG4	Swatara	9/5/2014 - Present	Ongoing	Ongoing
RG5	United Water	9/12/2014 - Present	Ongoing	Ongoing
RG6	Lower Paxton	9/9/2014 - Present	Ongoing	Ongoing
RG7	East Pennsboro	9/6/2014 – Present	Ongoing	Ongoing
RG8	Steelton	9/5/2014 - Present	Ongoing	Ongoing

Like any rain gauge network, the CRW system cannot quantify and characterize precipitation volumes, intensities, and patterns that occur between the gauge locations. To characterize the spatial variability of rainfall events over the CRW service area, gauge adjusted radar rainfall (GARR) data were obtained and used along with the gauge network data. GARR precipitation data were provided in 5-minute intervals within a high-resolution pixel grid comprised of 1-km by 1-km (0.6-mi by 0.6-mi) cells. A total of 586 pixel cells define precipitation patterns over the CRW service area, including the City of Harrisburg and the collection systems serving the suburban communities. **Figure 3-14** shows the GARR pixel grid in relation to the rain gauge network and municipal boundaries.

Radar reflectivity data were produced by the National Weather Service (NWS) Next Generation Radar (NEXRAD) system and were obtained from the KCCX radar site located near State College, Pennsylvania, approximately 62 miles from the City of Harrisburg. In the production of GARR, radar rainfall data were bias corrected through comparison with rain gauge accumulations. The high-resolution, spatially distributed GARR data over the entire CRW service area were used to characterize the response of combined and separate sanitary sewer collection systems to wet weather, support the calibration of the H/H models, and provide rainfall data for future system performance evaluations.

The radar rainfall data was applied to the delineated catchment areas within the CRW service area. This was done by intersecting the catchment area with the GARR pixel grid to determine the area from each pixel cell that falls within each tributary area. Once these areas are derived, an area-weighted precipitation value was calculated for each time step for each tributary drainage area. By doing this, a precipitation data set unique to each point of interest's tributary drainage area was produced.

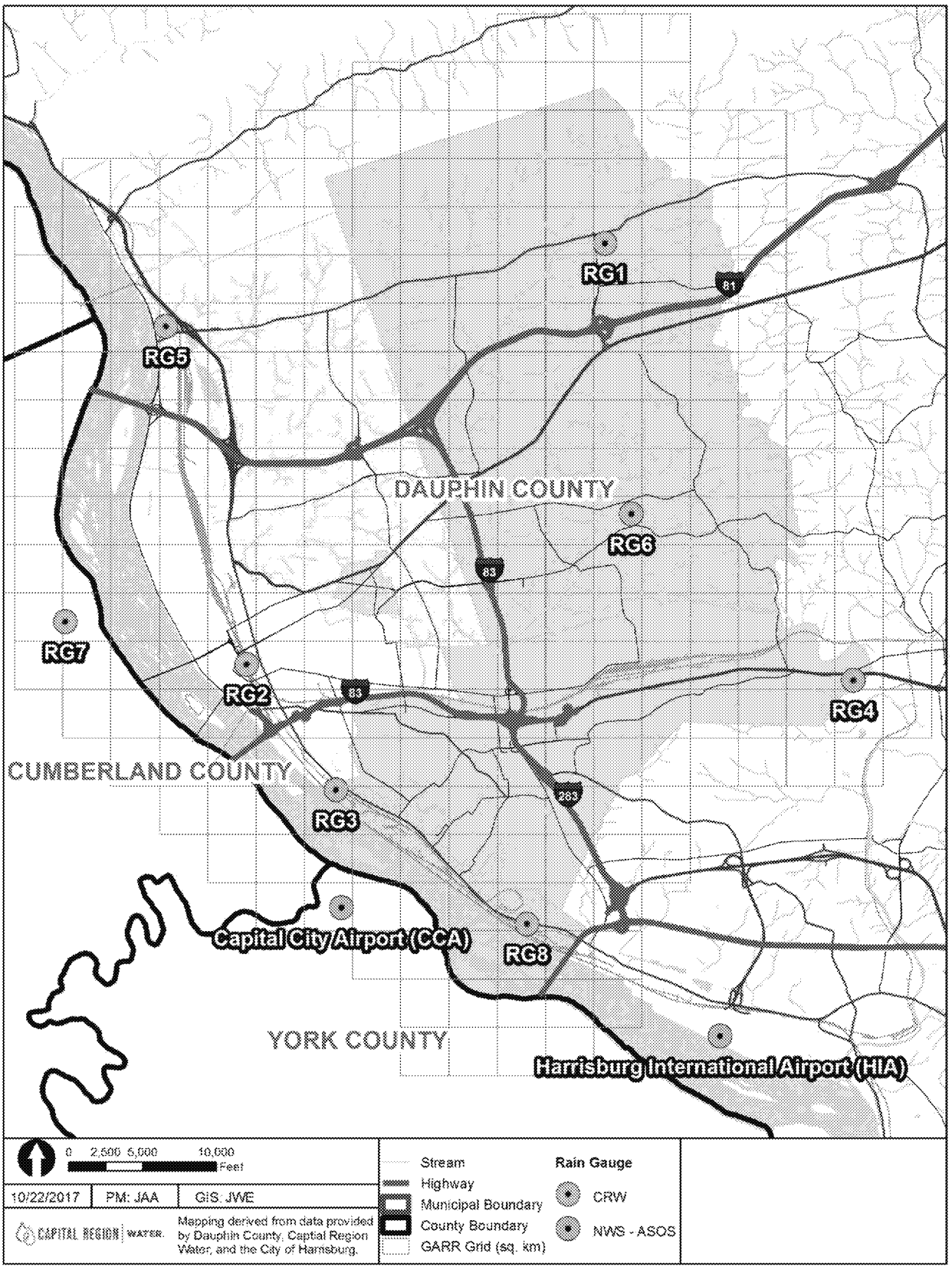

Figure 3-14 Precipitation Monitoring Sites and GARR Grid

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3.3.3 Development of the Typical Year Rainfall

A representative or typical year precipitation dataset for the CRW service area was created[9] for use with the H&H Model of CRW's conveyance system to establish the frequency, duration, and volume of CSO discharges; characterize their potential water quality impacts; and develop and assess alternative control strategies.

Point Precipitation Frequencies: The National Oceanic and Atmospheric Administration (NOAA) has conducted statistical analyses for long-term record precipitation record gauges across the country, and distributes the results on their internet site as NOAA Atlas 14. The Atlas provides precipitation frequency estimates for Harrisburg, based upon a partial duration frequency analysis of the long-term record. **Table 3-12** provides the analysis results for a one-year recurrence interval, including upper and lower bounds of the 90 percent confidence interval.

The completed analyses of the long-term precipitation record for the Harrisburg area established the following specific statistical criteria for the typical year rainfall.

- The average annual rainfall is 39.8 inches, and there is a 90 percent statistical confidence that the annual rainfall for the typical year should lie within a range extending from 31.7 inches to 47.9 inches.
- The average annual precipitation event frequency is 86 storms, and there is a 90 percent statistical confidence that the annual number of storms for the typical year should lie within a range extending from 74 to 98 events. A threshold value of 0.10 inches and an inter-event of six hours were used to define significant precipitation events.
- The desired monthly distribution of rainfall depths and event frequencies for the typical year, along with their associated confidence ranges, are shown on **Table 3-10.**
- The peak storm intensities for the typical year, along with their associated confidence ranges, are provided on **Table 3-12.**

Table 3-12: Point Precipitation Frequency Estimates* for Harrisburg for a 1-Year Recurrence Interval

Duration	Precipitation for 1 Year Recurrence Interval	Lower Bound 90% Confidence Interval	Upper Bound 90% confidence Interval
5-min	0.321	0.289	0.356
10-min	0.511	0.46	0.567
15-min	0.639	0.575	0.709
30-min	0.874	0.786	0.969
60-min	1.09	0.979	1.21

*Note: all precipitation frequency estimates are given in inches

The representative typical year precipitation record, developed for the Program Plan and input into the validated H&H model, meets these criteria. Therefore, the dataset should accurately

[9] Technical Memorandum, *Typical Year Report,* July 2015.

represent the long-term precipitation record for the CRW service area. When the typical year precipitation dataset is input into the existing condition H&H models, the simulated annual CSO statistics for annual event frequency, volume, and duration should closely match corresponding statistical averages of the long-term historical record, establish existing baseline conditions, and facilitate the development and evaluation of wet weather control alternatives.

Impacts of Climate Change: Both the National CSO Policy and the US-EPA guidance for the preparation of a LTCP clearly states that control alternatives are to be developed based upon an "average annual basis." Therefore, rainfall analyses are implemented from the typical long-term rainfall record. CRW implemented written US-EPA guidance when developing and assessing alternatives, and utilized the typical year precipitation analysis approach. Sensitivity runs were subsequently conducted and considered to quantify performance under a range of precipitation conditions, including those imposed by climate change trends. While CRW could consider climate change in sizing facilities, the level of control (and the associated sizing of facilities) provided by the CRW Program Plan is guided by the financial capability constraints of the service area rate payers (see Section 8.0). The impacts of climate change would require a significant extension to the implementation schedule for the Program Plan, well beyond that of a traditional Consent Decree timeframe. Therefore, the possible long-term effects of climate change will potentially impact the level of service provided by the Program Plan, but not impact the recommended control facilities.

3.3.4 Development of Synthetic Design Storm Rainfall

The Program Plan is intended to prevent separate sanitary sewer overflows (SSOs) and control unauthorized releases from the combined sewer system, along with controlling CSO discharges. To quantify and characterize specific locations with the potential for SSOs and unauthorized combined sewer releases to occur within the CRW service area, a series of synthetic design storms were developed and applied to the H&H models. The analyses complied with the requirements specified in the PCD that require CRW to conduct a capacity assessment study of the Harrisburg sewer system under current conditions during peak dry weather flow conditions and the 2-year, 5-year, and 10-year 24-hour storm events[10].

CRW obtained and utilized rainfall intensity-duration-frequency statistics for Harrisburg published in NOAA Atlas 14 to define 24-hour rainfall volumes for the recurrence interval storm events. Design rainfall hyetographs were developed by fitting these volumes to the SCS-Type II distribution, which embeds the intensity of storms with durations less than 24 hours, allowing the calculation of runoff statistics across drainage areas of varying size, slope, and storage characteristics. This distribution properly estimates peak flows from drainage catchments over a range of times of concentration shorter than 24-hours.

The SCS-Type II distribution is considered a stacked distribution, where approximations of the 5-minute, 10-minute, 15-minute, 30-minute, 1-hour, 2-hour, 6-hour, and 12-hour storm volumes are superimposed roughly symmetrical around the twelfth hour of the synthetic storm. This temporal distribution has been widely implemented by water resources professionals to calculate frequency duration volumes and peak intensities applicable to a wide range of catchment and

[10] *Separate Sanitary Sewer Capacity Assessment Report, Version 2.0,* Section 4, February 2018, available at **https://capitalregionwater.com/cbh2o**.

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sewershed areas and times of concentration. Hyetographs, or graphical bar-chart representations, of the resulting design storm rainfall distributions are provided in **Figure 3-15** through **Figure 3-17**.

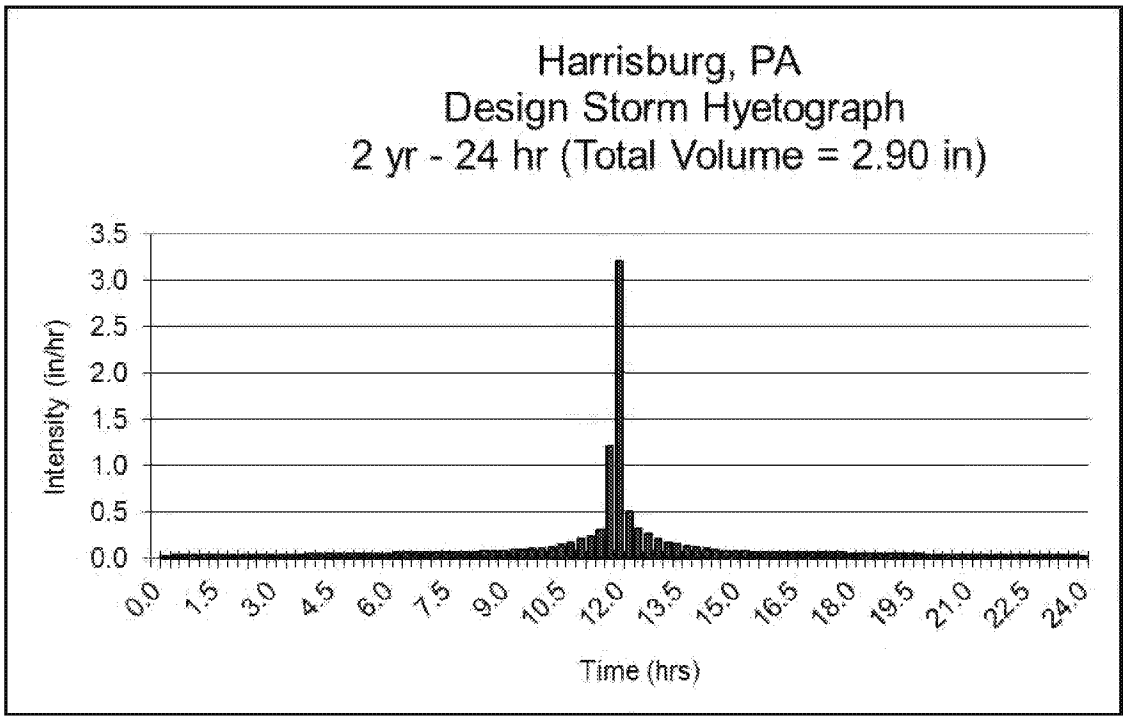

Figure 3-15: Hyetograph for a 2-Year, 24-Hour Synthetic Design Storm

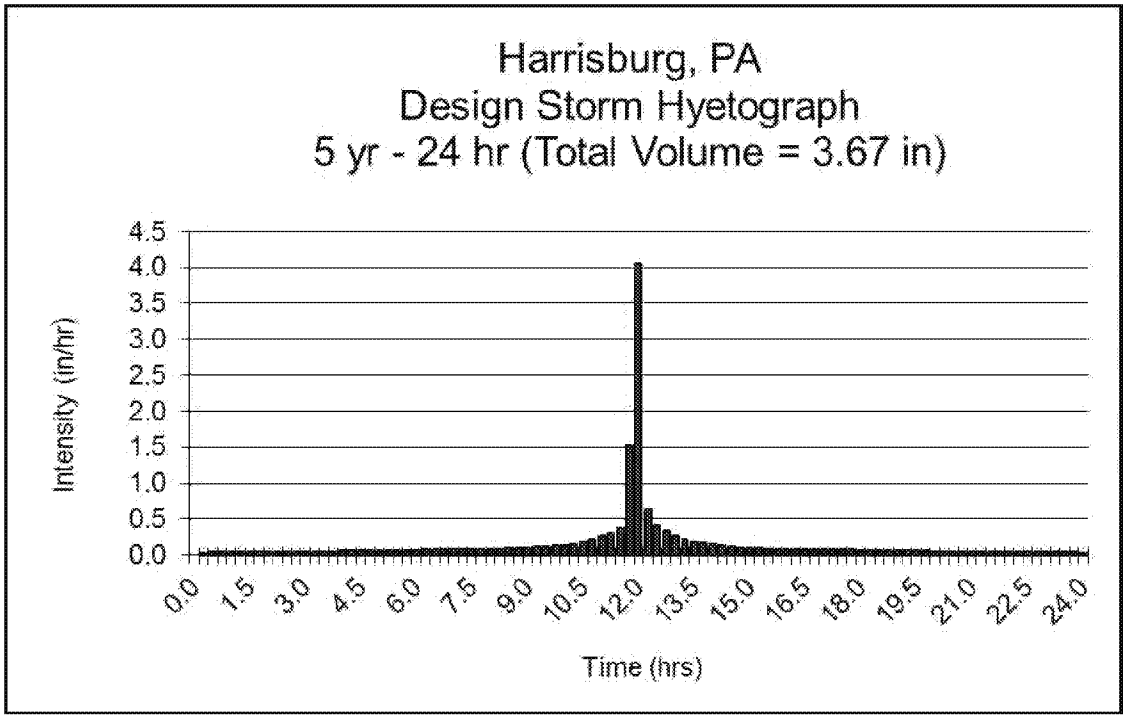

Figure 3-16: Hyetograph for a 5-Year, 24-Hour Synthetic Design Storm

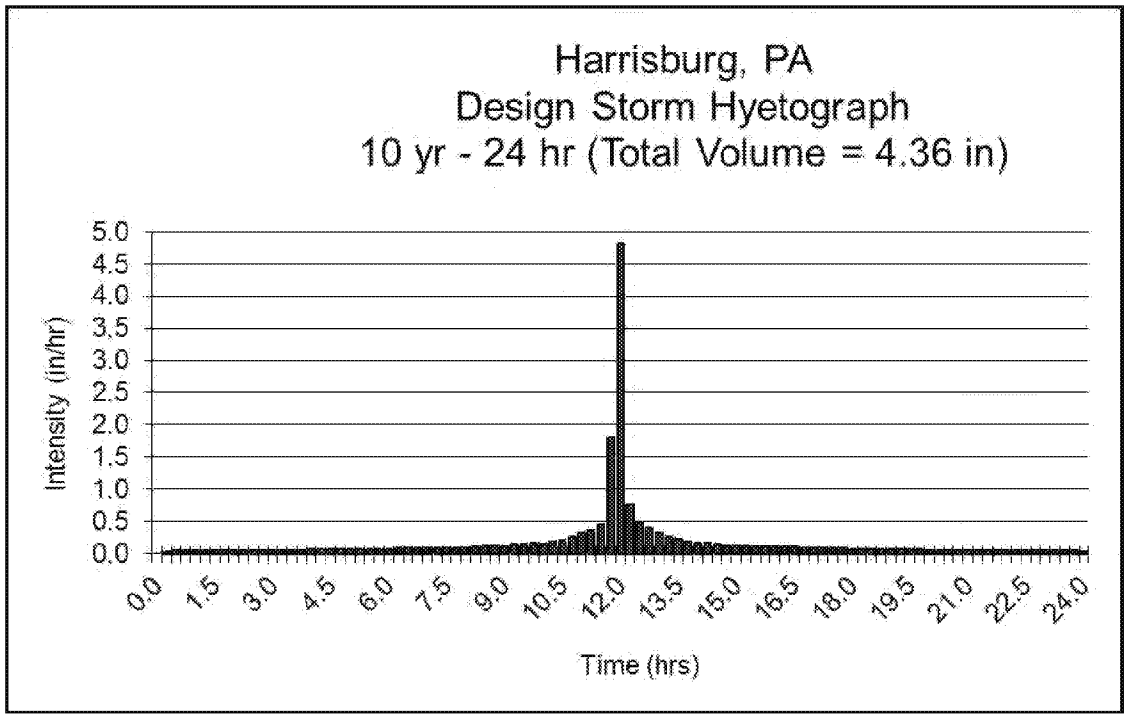

Figure 3-17: Hyetograph for a 10-Year, 24-Hour Synthetic Design Storm

NOAA Atlas 14 includes figures that show the analysis results for monthly precipitation exceedance values for the 60-minute and 24-hour duration storms. A copy of these figures is provided in **Figure 3-18** and **Figure 3-19**. The results indicate that 60-minute duration design storms, typically associated with intense thunderstorm activity, are most likely to occur during the months of July and August (with the highest probability bar values in the graph). The 24-hour duration design storms, typically associated with large frontal systems, are most likely to occur during the months of August and September (again, with the highest probability bar values in the graph). The analysis figures indicate it would be unlikely that these design storms would occur during the winter season or during times of high seasonal ground water that occur during the months of February, March and April. The probability bar values in the NOAA Atlas 14 graph are much smaller during these months, indicating a much lower probability of occurrence. Artificially imposing these design storms on spring time hydrologic conditions would invoke statistical joint probability principles that would result in unrealistically low joint probabilities and unrealistically high return interval estimates.

The CRW analyses match the design storms to the seasonal hydraulic conditions that would most likely be encountered. For the 60-minute and 24-hour durations, the design storms would most likely occur during the month of August. Therefore, GWI values and RDII values for the month of August were selected for the model simulations.

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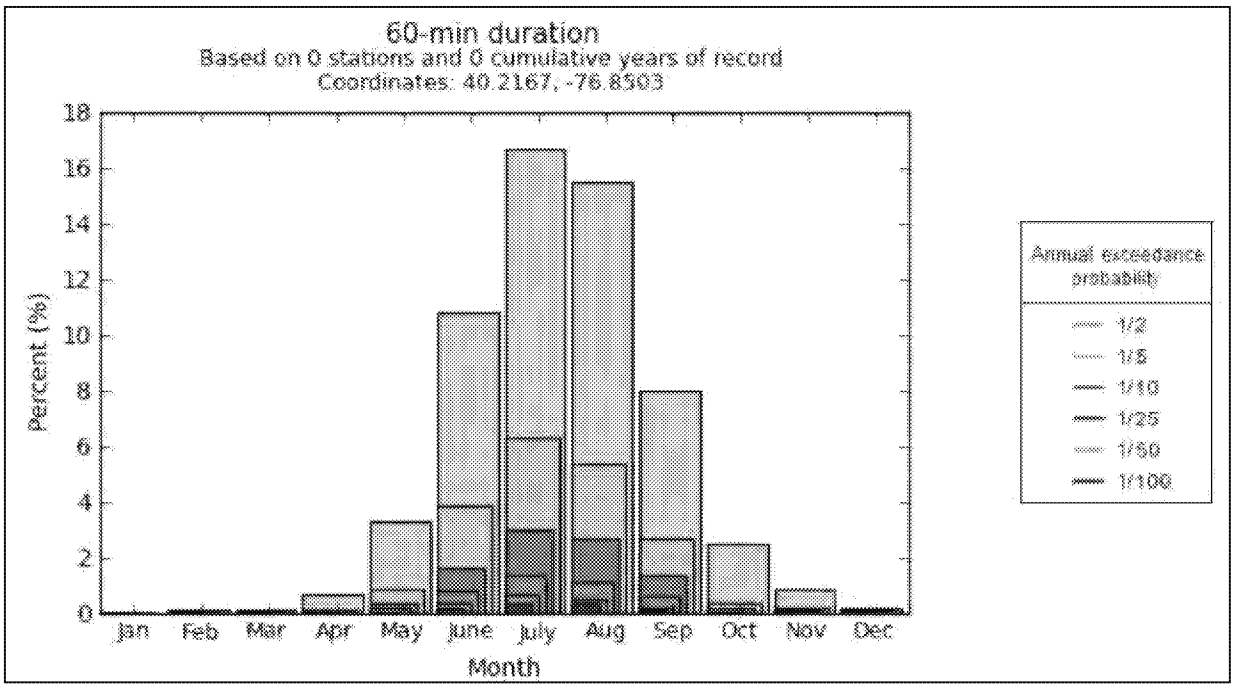

Figure 3-18: Monthly Storm Probability for 60-Minute Rain Durations from NOAA Atlas 14

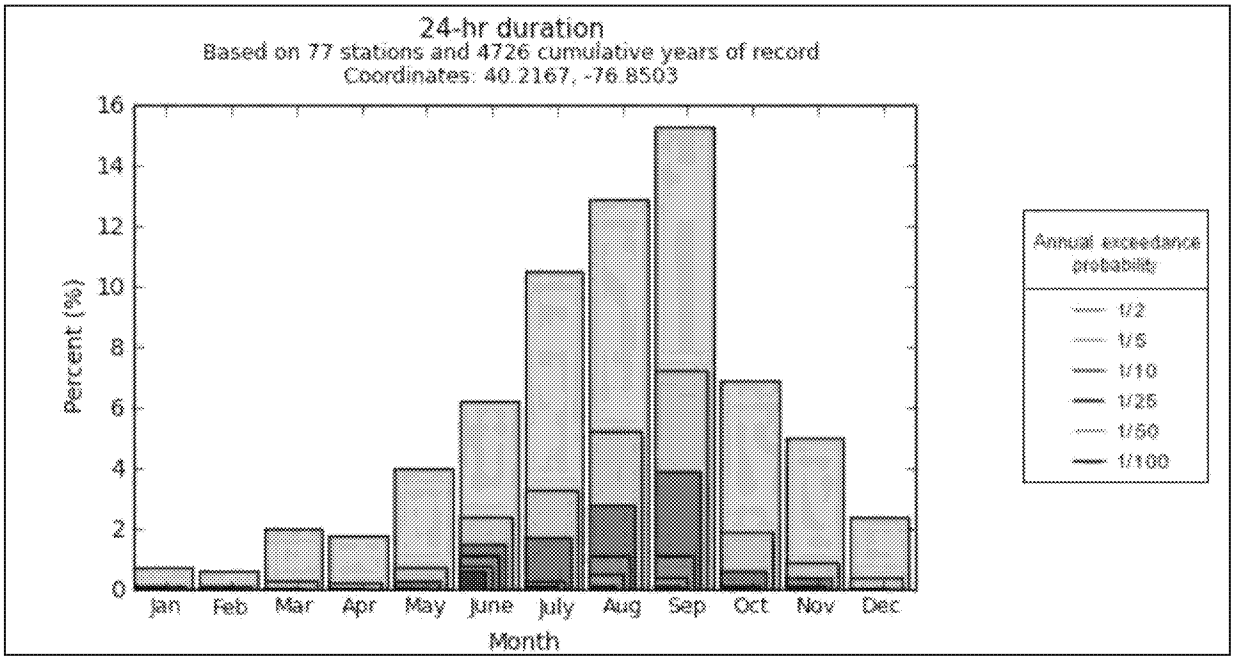

Figure 3-19: Monthly Storm Probability for 24-Hour Rain Durations from NOAA Atlas 14

3.4 Wastewater and Stormwater Flow Characteristics

CRW incorporated the sewer system information obtained through its completed facility inspection programs (Section 3.2) to update and refine its hydrologic and hydraulic (H&H) model of the CRW conveyance system. CRW also performed extensive precipitation monitoring (see Section 3.3) and flow monitoring to properly calibrate and validate its H&H model. The model was used to develop a thorough understanding of the wastewater and stormwater flow characteristics of its sewer system in response to precipitation events of varying duration and intensity; to characterize hydraulic capacity, sewer system overflows, and unauthorized combined sewer system discharges; and to support the development of the Program Plan.

3.4.1 Regulatory Context and Requirements

The Partial Consent Decree, in Section V-E, paragraph 15 requires CRW to develop and implement an *Initial Flow Metering and Monitoring Program Plan* (IFMMPP) [11]. The IFMMPP defined a precipitation and flow monitoring program to collect the data needed to characterize the CRW system and to refine and validate the hydrologic and hydraulic (H&H) model, as described in this Section.

Section V-E, paragraphs 15g and h of the Partial Consent Decree (PCD) require CRW to prepare, calibrate, and verify a hydrologic and hydraulic (H&H) model of the CRW conveyance system. CRW developed and calibrated an updated model and on April 1, 2016, CRW submitted a *Sewer System H&H Model Report*[12] to US-EPA and PA-DEP documenting the completed model. The collected and analyzed precipitation data were sufficient to refine and validate the hydrologic and hydraulic (H&H) model[13], [14].

PCD Section V-C, paragraph g-vi requires CRW to utilize the calibrated H&H model to characterize the frequency, duration, and volume of CSO discharges from the CRW sewer system under existing condition Typical Year precipitation conditions and under existing condition, actual monitored precipitation conditions. CRW has successfully utilized the H&H model for quantifying CSO discharges under typical year precipitation, and the results are documented in Program Plan Section 4.3. On a six-month frequency schedule, CRW applies high-resolution, spatially-distributed GARR precipitation data to the H&H model to quantify existing condition CSO discharges. Semiannual CSO discharge reports are submitted to US-EPA and PA-DEP.

3.4.2 Summary of the Hydrologic and Hydraulic Model

The CRW hydrologic model simulates dry and wet weather flow and represents all catchment areas within the City of Harrisburg contributing to the conveyance system, and trunk sewers within the collection system, for both separate and combined sewer systems. The hydraulic model simulates how the flows are conveyed through the sewer system and represents the CRW

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[11] *Initial Flow Metering and Monitoring Program Plan,* July 2013.

[12] *Sewer System H&H Model Report,* Sections 2.4 and 2.5, April 2016.

[13] *Combined Sewer System Characterization Report Version 2.0,* Sections 2.0 and 5.3, February 2018, available at **https://capitalregionwater.com/cbh2o**.

[14] *Separate Sanitary Sewer Capacity Assessment Report Version 2.0,* Section 3.1.3, February 2018, available at **https://capitalregionwater.com/cbh2o**.

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conveyance and trunk sewer systems.

The XP-SWMM hydraulic model developed to support preparation of the CSO LTCP in 2005 was converted into SWMM5 and used as the starting point to update and refine the conveyance system model. This model was then calibrated with the flow and rainfall data collected between September 2014 and November 2015 using the WaPUG[15] calibration criteria. The calibrated conveyance system/trunk sewer model was used to develop the typical year overflow statistics reported in **Section 4.3** of this Report.

Model of CRW's Conveyance System: The hydraulic model of the conveyance system consists of the following components:

- ***Interceptor system***: upstream and downstream inverts, diameter or size, shape, and depth of sediment were refined using data collected for CRW's GIS development program.
- ***Regulator and CSOs***: physical parameters and the operational schedules were collected from field inspection and interviews with CRW Field Operations personnel.
- ***Pump Stations***: Pump capacity, pump curves, wet well level time series and operational schedules were collected during preparation of CRW's Operation & Maintenance Manual.

Model of CRW Trunk Sewers: According to the requirements of the Partial Consent Decree (PCD) Paragraphs E(15)(g) and E(30)(b)(i), the hydraulic model was extended into the collection system trunk sewers, defined as 15 to 20 percent of the pipes within CRW's collection system meeting the following criteria:

- All combined sewers 42" or greater,
- All separate sanitary sewers 18" or greater that drain into the combined sewer system, and
- Additional sewers necessary to represent the downstream portion of the collection system, including major flow split manholes within the collection system.

Table 3-13 provides a summary of the CRW interceptor and collection systems included in the H&H model, while **Figure 3-20** provides a map of the modeled sewers.

Table 3-13: Characteristics of CRW's Collection/Trunk Sewer Model

Features	Characteristics
Number of Catchments	482
Number of Pipes	2,148
Number of CSOs	59
Number of Wastewater Pumping	2 (Front Street and Spring Creek Pump Stations)
Inflow from Suburban Communities	4 (M9, M13, M32, M167)
Six Interceptor Systems: (1) Front Street Interceptor; (2) Paxton Creek Interceptor; (3) Paxton Relief Interceptor; (4) Spring Creek Interceptor; (5) Hemlock Creek Interceptor; (6) Asylum Run Interceptor	

[15] Wastewater Planning Users Group, a not-for-profit organization established to promote best practice in the wastewater industry.

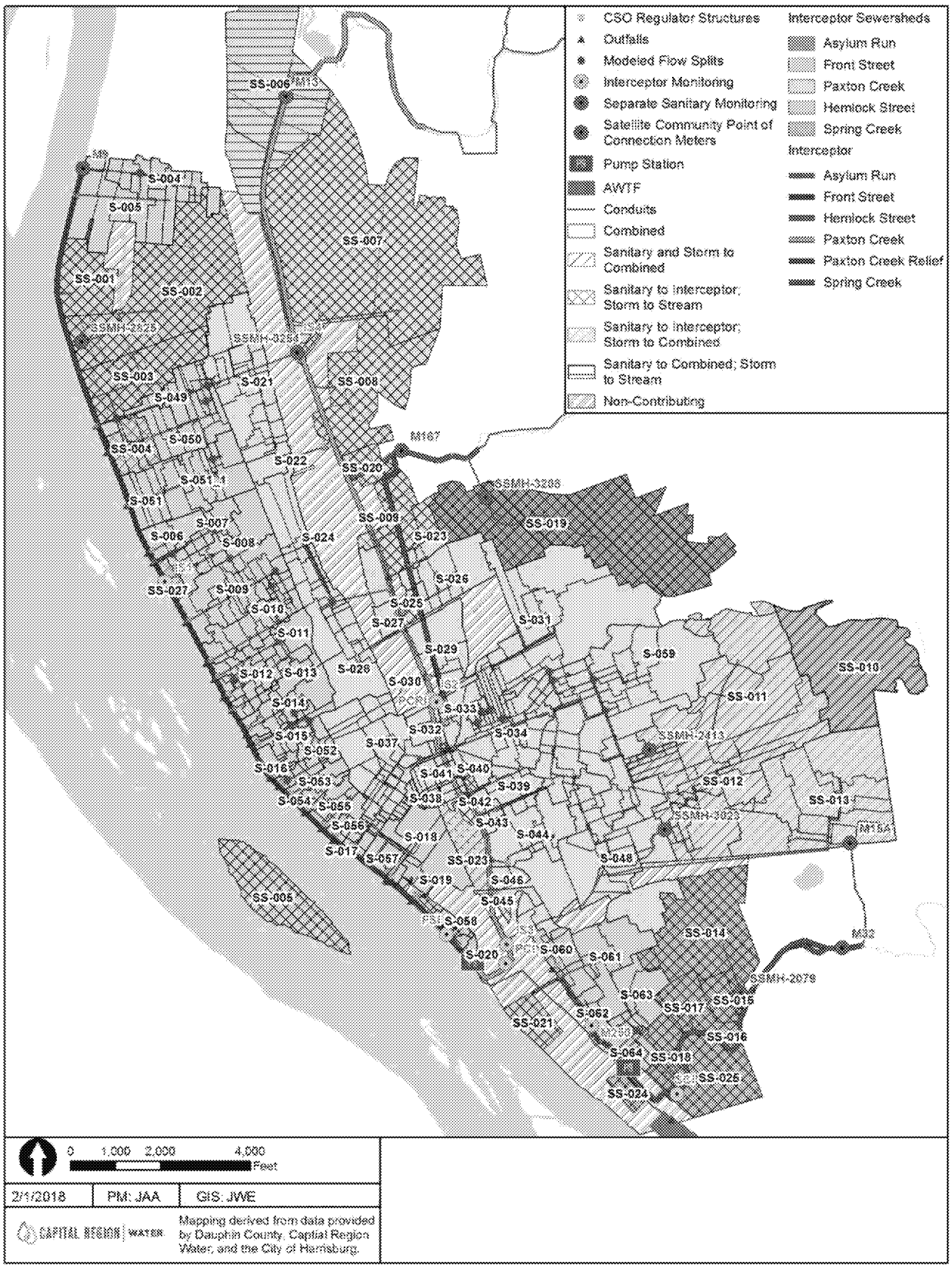

Figure 3-20: Interceptor and Major Trunk Sewers Represented by the H&H Models

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Hydrologic Model: The hydrologic model uses data about each catchment and internal calculations to determine the amount of flow entering the major trunk sewer system:

- ***Sewershed / catchment delineation*** was refined using collection system data recently collected in the field and from record drawings as part of CRW's GIS development program.
- ***Catchment Base Wastewater Flow (BWF)*** consists of average existing dry weather flows with the appropriate diurnal pattern, derived from the flow monitoring data.
- ***Catchment Seasonal Groundwater Infiltration (GWI)*** was estimated from long-term flow monitoring data and distributed to model catchments representing specific geographic areas tributary to the modeled sewers.
- ***Separate/Combined Stormwater Catchment hydrologic properties***: Aerial photographs collected in 2013 were used to refine the impervious area of each catchment. Other hydrologic parameters (e.g., width, slope, infiltration parameters) were established through standard hydrologic protocol and refined through model calibration, as described later in this section.
- ***Separate Sanitary Catchment Rainfall-Dependent Infiltration/Inflow (RDII)*** is characterized by a set of unit hydrograph parameters that relate precipitation to infiltration/inflow to separate sanitary sewers, derived from analysis of precipitation and flow monitoring data for a wide range of wet weather events.

The hydrologic model developed to support calibration of the conveyance system model[16] used a single catchment to represent flow draining to each CSO regulator. Following model calibration, these catchments were further divided to properly allocate flow to the trunk sewers in the model. The hydrologic parameters and dry weather flows defined for each CSO catchment in the calibrated model were distributed and/or assigned to its subdivided catchments in the trunk sewer model, and model results were checked for consistency with the calibrated model[17][18].

3.4.3 Summary of Monitoring Data used to Support the H&H Model

An accurate and up-to-date understanding was needed of existing wastewater flow along the CRW sewer conveyance and generated within CRW's separate and combined catchments under dry and wet weather conditions. An *Initial Flow Metering and Monitoring Program Plan* (IFMMPP)[19] was developed and implemented to collect the precipitation and flow monitoring data needed to characterize the CRW system and to refine and validate the hydrologic and hydraulic (H&H) model. Flow monitoring was performed at the following locations:

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[16] *Sewer System H&H Modeling Report*, April 2016.

[17] *Combined Sewer System Characterization Report Version 2.0*, Sections 2.0 and 5.3, February 2018, available at **https://capitalregionwater.com/cbh2o**.

[18] *Separate Sanitary Sewer Capacity Assessment Report Version 2.0*, Section 3.1.3, February 2018, available at **https://capitalregionwater.com/cbh2o**.

[19] *Initial Flow Metering and Monitoring Program Plan*, July 2013.

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- At the four major points of connection (POCs) where wastewater flows from the suburban community collection systems are conveyed to the CRW system.
- At selected City separate sanitary sewer catchment areas to characterize base wastewater flow (BWF), groundwater infiltration (GWI), and rainfall dependent infiltration/inflow (RDII),
- At selected CSO regulator structures to characterize the hydrology of their tributary catchment areas, and
- Along selected points along the CRW interceptor system to calibrate/validate hydraulic model of the conveyance system.

Comprehensive protocols and standards for field activities were implemented to execute the flow monitoring program to maximize the collection of high quality data. CRW successfully implemented quality assurance and quality control (QA/QC) measures necessary to confirm that the network of flow monitoring equipment provided representative, accurate and reliable data, and that the data quality is sufficient for use in the development of the H&H models for the Program Plan.

3.4.3.1 Interceptor Flow Monitoring and Characterization

The IFMMPP identified nine critical monitoring locations along the CRW interceptor system. CRW successfully installed and maintained flow monitors at these sites to provide the necessary data to successfully quantify and characterize the distribution of wastewater flow along the CRW interceptor sewer system, provide the necessary data to calibrate and verify the H&H model, and meet PCD requirements. The monitors collected and recorded redundantly monitored wastewater depth, monitored velocity, and calculated flow in 5-minute time-step increments. The monitoring site information and status are summarized in **Table 3-14** and the monitoring locations are provided in **Figure 3-21**.

Table 3-14: Interceptor System Monitoring Site Summary

Monitor ID	Interceptor System	Pipe Diameter (inches)	Data Collection Initiated	Data Collection Status	Data Analysis Status
IS1	Front Street	35.5 H x 30.5 W	8/01/2014	Ongoing	Ongoing
FSI	Front Street	41 H x 42.5 W	8/01/2014	Ongoing	Ongoing
PCI	Paxton Creek	60 diameter	8/01/2014	Ongoing	Ongoing
PCRI	Paxton Creek	48 diameter	8/13/2014	Ongoing	Ongoing
IS2	Paxton Creek	48 H x 59 W (arch)	8/21/2014	Ongoing	Ongoing
IS3	Paxton Creek	60 diameter	8/22/2014	Ongoing	Ongoing
IS4	Paxton Creek	42 diameter	8/18/2014	Ongoing	Ongoing
M250	Hemlock Street	24 diameter	8/01/2014	Ongoing	Ongoing
SCI	Spring Creek	34 H x 32.5 W	8/13/2014	Ongoing	Ongoing

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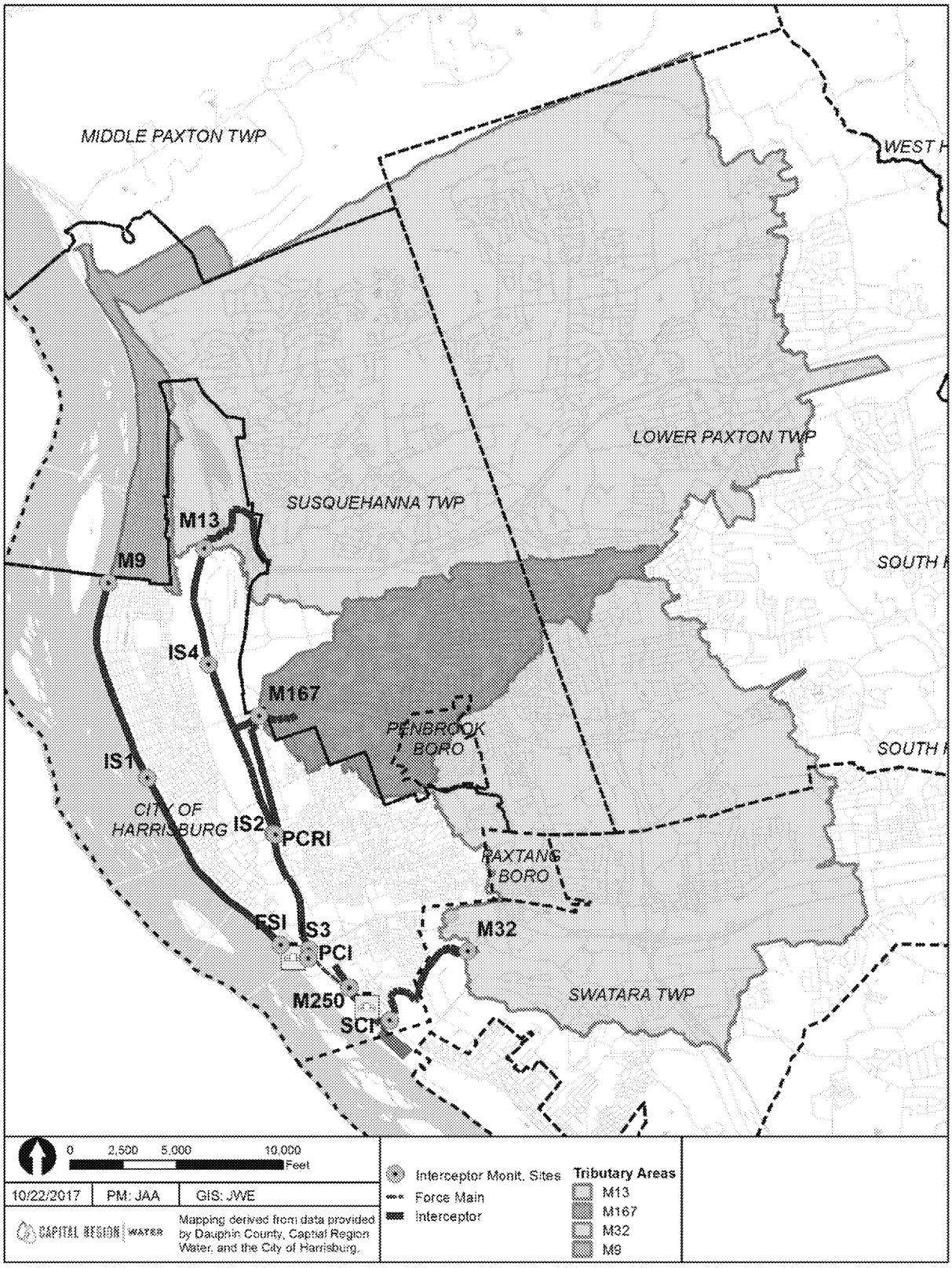

Figure 3-21: Interceptor and Suburban Community Point of Connection Monitoring Sites

3.4.3.2 Suburban Community Flow Monitoring and Characterization

The IFMMPP also identified the four points of connection (POCs) where wastewater flows from the suburban community collection systems are conveyed to the CRW system. CRW installed and maintained flow monitors at each of these POC sites to quantify and characterize dry and wet weather flow from the suburban community separate sanitary sewer systems. The monitors collected and recorded redundantly monitored wastewater depth, monitored velocity, and calculated flow in 5-minute time-step increments. The monitoring site information and status are summarized in **Table 3-15** and the monitoring locations are provided in **Figure 3-21**.

Table 3-15: Suburban Community POC Monitoring Site Summary

Monitor ID	Pipe Diameter	Catchment Area (acres)	Data Collection Initiated	Data Collection Status	Data Analysis Status
M9	24 inches	847	8/01/2014	Ongoing	Ongoing
M13	42 inches	12,602	8/15/2014	Ongoing	Ongoing
M32	34 inches	6,716	8/14/2014	Ongoing	Ongoing
M167	24 inches	2,334	8/14/2014	Ongoing	Ongoing

3.4.3.3 Combined Collection System Flow Monitoring and Characterization

CRW successfully characterized flows generated within 13 selected catchments of CRW's combined sewer system. This was done by monitoring depth and velocity at the influent to each associated combined sewer overflow (CSO) regulator structure. Detailed analyses in Addendum #3 to the IFMMPP[20] identified these sites as providing a representative sampling of the types of combined sewershed areas within the City of Harrisburg. Monitoring at each CSO regulator site had a duration of 12 months to quantify and characterize seasonal variations in wastewater and stormwater flow and monitor a sufficient number of storm events throughout the year. The monitoring equipment recorded data in 5-minute time-step increments. Two categories of monitoring sensors were installed and two categories of data were collected:

- The first category was the monitored wastewater depth and flow from the influent trunk sewer to the regulator structure. The data were used to successfully quantify and characterize wastewater flow from each tributary catchment for use in calibrating the hydrologic parameters of CRW's H&H model.
- The second category was the monitored depths of CSO discharges over the diversion weirs. The diversion weirs and the regulator structures direct all the dry weather wastewater and a portion of the wet weather flow to the interceptor system for conveyance and treatment. The data, along with the daily observations of CSO activation by CRW maintenance staff, were used to calibrate the H&H model representation of regulator hydraulics and Brown and Brown regulator operational rules.

The collection system characterization monitoring sites, characteristics, and status are summarized in **Table 3-16** and illustrated in **Figure 3-22**, along with their respective catchments.

[20] *Initial Flow Metering and Monitoring Program Plan,* Addendum #3, December 2014.

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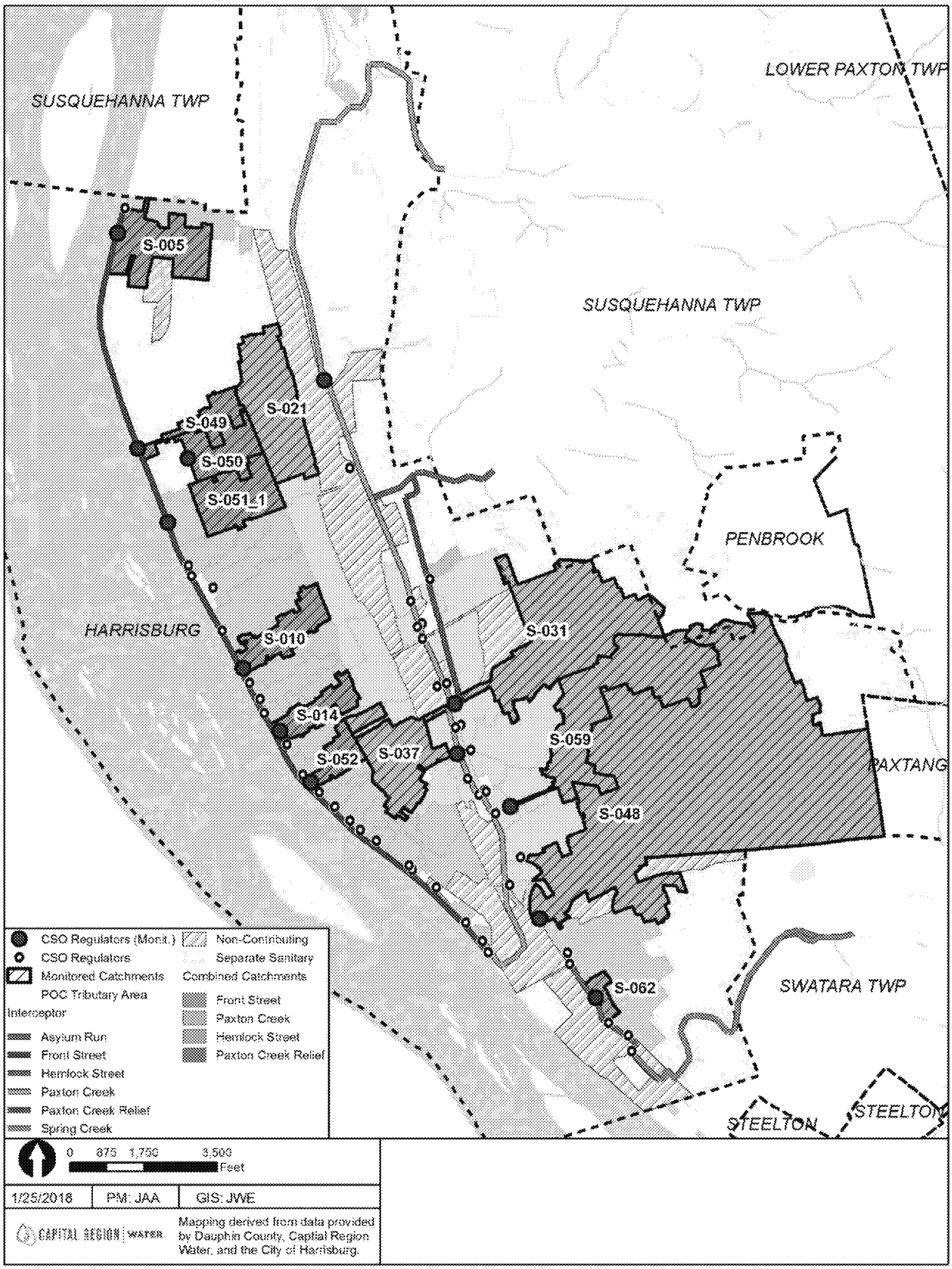

Figure 3-22: Combined Trunk Sewer and CSO Regulator Monitoring Sites

Table 3-16: Combined Collection System Flow Characterization Monitoring Site Summary

Monitored Catchment ID	Catchment Area (acres)	Monitored CSO Regulator ID	Pipe Size H x W or Diameter (inches)	Data Collection Initiated	Data Collection Status	Data Analysis Status
S-005	69.5	CSO-005	61 H x 48 W	7/31/2014	Completed	Completed
S-010	41.8	CSO-010	36	8/04/2014	Completed	Completed
S-014	29.9	CSO-014	34.5	8/05/2014	Completed	Completed
S-021	149.3	CSO-021	51 and 24	7/31/2014	Completed	Completed
S-031	220.0	CSO-031	60 H x 48 W	7/23/2014	Completed	Completed
S-037	74.2	CSO-037	66 H x 48 W	9/25/2014	Completed	Completed
S-048	766.5	CSO-048	66 H x 60 W	7/22/2014	Completed	Completed
S-049	27.8	CSO-049	54	7/22/2014	Completed	Completed
S-050	41.8	CSO-050	48	8/01/2014	Completed	Completed
S-051.1	57.0	CSO-051.1	54 H x 44 W	9/30/2014	Completed	Completed
S-052	21.9	CSO-052	30 H x 36 W	8/06/2014	Completed	Completed
S-059	149.7	CSO-059	54 H x 45 W	8/28/2014	Completed	Completed
S-062	10.4	CSO-062	15	8/05/2014	Completed	Completed

3.4.3.4 Separate Sanitary Collection System Flow Monitoring

CRW successfully monitored seven key separate sanitary catchments within the City of Harrisburg collection system. Two of these seven catchment monitoring sites, SSMH-2413 and SSMH 3023, monitor flow from separate sanitary catchments that discharge into a CRW combined sewer upstream of the CSO 048 regulator, and are thus considered to be part of CRW's combined sewer system. The remaining five metering sites monitor flow from separate sanitary catchments that discharge directly to the interceptor system, and are thus considered to be part of CRW's separate sanitary sewer system.

All seven monitoring sites provided the necessary data to successfully quantify and characterize dry and wet weather flow from CRW's separate sanitary catchments. The monitors collected and recorded redundantly monitored wastewater depth, monitored velocity, and calculated flow in 5-minute time-step increments. Over 12 months of data were collected and utilized for the analyses, which permitted the model to account for seasonal variability of ground water and the response of the separate sanitary catchments to wet weather. Separate sanitary sewer catchment monitoring locations are provided in **Figure 3-23** and the monitoring site and status information are summarized in **Table 3-17**.

Figure 3-23 and **Table 3-17** depict and include two separate sanitary catchments (SSMH-2413 and SSMH-3023) that discharge into a downstream combined sewershed area (S-048). The catchments were monitored and modeled as separate sewers, but classified as being part of the combined collection system to be consistent with Partial Consent Decree definitions.

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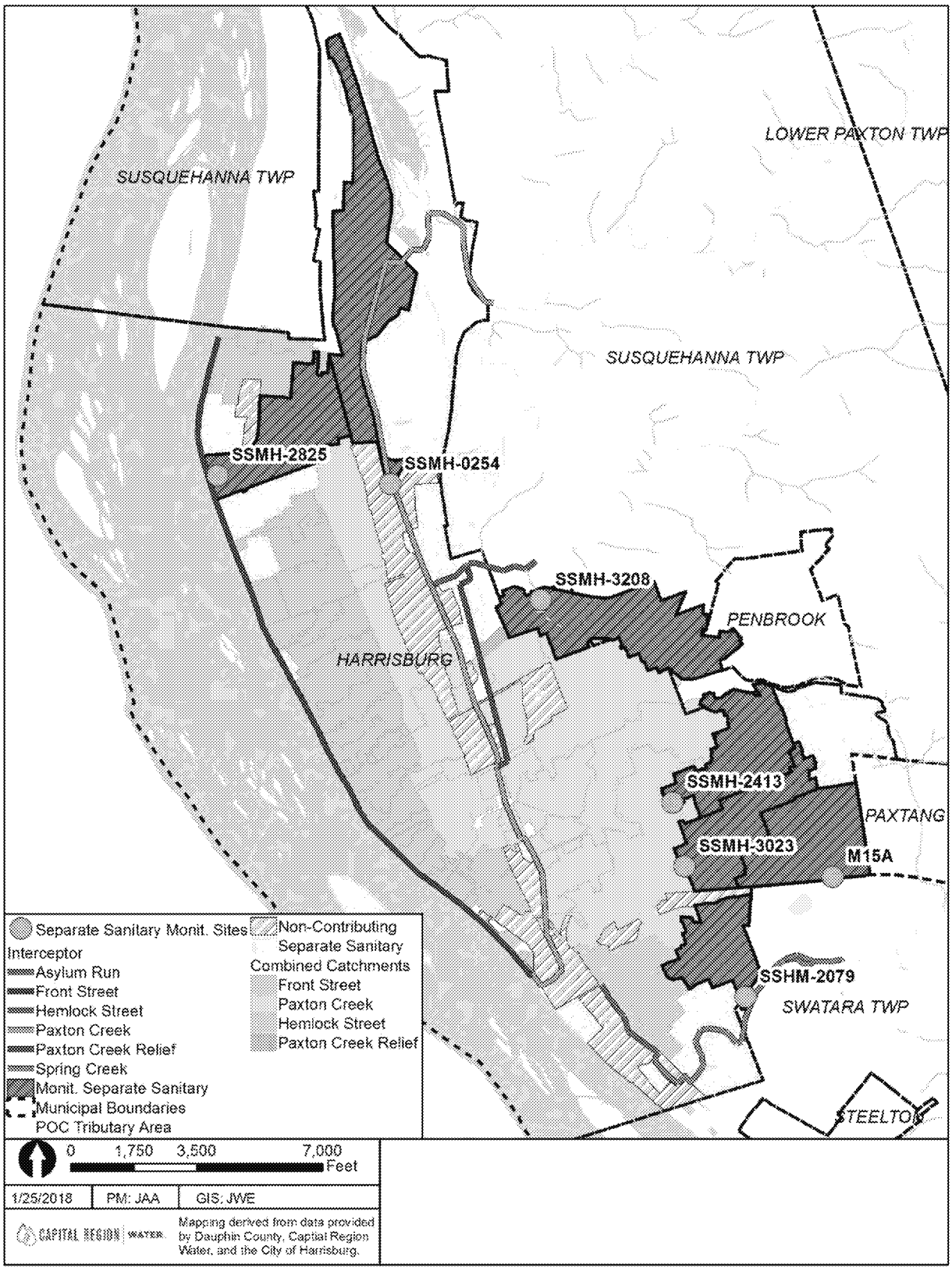

Figure 3-23: Separate Sanitary Catchment Monitoring Sites

Table 3-17: City of Harrisburg Separate Sanitary Sewer Data Collection Site Summary

Monitored Catchment ID	Catchment Area (acres)	Monitor Location	Pipe Diameter (inches)	Interceptor	Data Collection and Analysis Status
M15A	169	South 26th Street	18 dia.	Spring Creek	Completed
SSMH-0254	276	Industrial Road	15 dia.	Paxton Creek	Completed
SSMH-2079	109	South 19th Street	14 dia.	Spring Creek	Completed
SSMH-2413	156	Darlington and 19th	20 dia.	Paxton Creek	Completed
SSMH-2825	166	Front and Shamokin	18 dia.	Front Street	Completed
SSMH-3023	139	Brookwood and 17th	48 dia.	Paxton Creek	Completed
SSMH-3208	229	Arsenal Boulevard	24 dia.	Asylum Run	Completed

3.4.3.5 Characterization of Dry Weather Flow (DWF)

For each of the selected suburban community and City separate sanitary sewer system monitoring sites, monitored storm flows were analyzed to characterize wet weather hydrology within separate sanitary sewer systems. The flow quantification analyses were conducted using the Environmental Protection Agency (EPA) Sanitary Sewer Overflow Analysis Program (SSOAP). The SSOAP program divided the total monitored wastewater flow into its three components, base wastewater flow (BWF), ground water infiltration (GWI), and rainfall dependent infiltration and inflow (RDII). These components of wastewater flow are depicted in **Figure 3-24**.

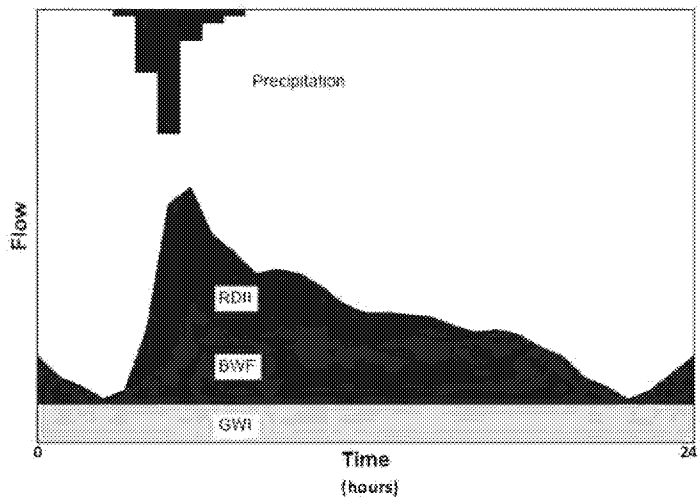

Figure 3-24: Typical Flow Characterization in a Separate Sanitary Sewer System

The quantified BWF represents the monitored residential, commercial, institutional, and industrial flow that was discharged to the sanitary sewer system for collection and treatment. The quantified GWI represents the monitored infiltration of ground water that entered the collection system through leaking pipes, pipe joints, and manhole walls. Dry weather flow (DWF) is the sum of BWF and GWI.

A suitable DWF characterization period is preceded by at least three days without rainfall of 0.1 inches or larger. During the monitoring period from September 2014 through August 2015, the longest period of DWF meeting these criteria occurred between November 7, 2014 and November 15, 2014. The calibration of DWF involved was performed in the following manner.

- ***Establish Boundary Conditions***: The boundary condition of the model was established by determining average DWF and diurnal hydrographs from the suburban communities at monitoring sites M9, M13, M167 and M32.

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- ***DWF from CRW's Service Area***: Average DWF (per acre) and diurnal patterns measured with the 13 meters located at the influent to the CSO regulators and seven meters characterizing flow from CRW's separate sanitary sewers were used to determine the representative DWF for the catchments within CRW's service area.
- ***Calibrate at Interceptor Monitoring Stations:*** DWF calibration was performed by comparing DWF generated with the H&H model with measured flow data at interceptor monitoring stations IS1, FSI, IS4, IS2, PCRI, PCI and SCI.

Table 3-18 summarizes the DWF calibration findings obtained using this methodology, the average DWF generated within each major sewershed of CRW's service area, and monthly variability of DWF.

Table 3-18: Estimated Dry Weather Flow Measured Within CRW's Conveyance System.

Condition	Estimated Flow at Flow Meters in the Interceptor (MGD)													Total To AWTF
	Front Street			Asylum/ PCRI		Paxton Creek				Hemlock	Spring Creek			
	M9	IS1	FSI	M167	PCRI	M13	IS4	IS2	IS3	M250	M32	M15A	SCI	
Average Dry Weather Flow (DWF)	0.37	1.24	2.37	2.12	2.28	4.16	4.43	9.96	11.89	0.17	0.25	4.59	5.19	19.62
Minimum Nighttime Flow (MNF)	0.10	0.42	0.53	1.06	1.19	1.17	1.48	2.71	3.18	0.03	0.06	1.92	2.23	5.97
Groundwater Infiltration (GWI)	0.09	0.38	0.48	0.95	1.07	1.05	1.34	2.44	2.86	0.02	0.05	1.73	2.00	5.36
Base Wastewater Flow (BWF)	0.28	0.86	1.89	1.17	1.21	3.11	3.09	7.52	9.03	0.14	0.20	2.86	3.19	14.25

3.4.3.6 Characterization of Rainfall-Dependent Infiltration/Inflow

The inflow component of RDII is the water that entered the sanitary sewer system directly via leaky manhole lids and frames, roof drain connections, sump pumps, foundation drains, and cross connections. The infiltration portion of RDII refers to rainfall runoff that filters through the soil before entering a sanitary sewer system through damaged pipe sections, leaky joints, etc. These defects can occur in both the public right-of-way portions of the sewer system or in individual service laterals on private property.

The SSOAP program was used to quantify the RDII associated with each successfully monitored storm and develop a series of input values for use by the H&H models. The calculated volume of RDII for each monitored storm was divided by the corresponding volume of rainfall over the catchment or sewershed area and expressed as a percentage or R-value. This R-value represents the fraction of monitored rainfall that fell over the tributary catchment/sewershed area that entered the sanitary sewer system. The SSOAP program was used to distribute the calculated RDII volumes and develop a series of three triangular unit hydrographs to represent the fast, medium and slow responses of the catchment/sewershed collection systems to each of the monitored storms, as depicted in **Figure 3-25**.

These hydrographs represent the magnitude and timing of the RDII hydrology of the monitored separate sanitary catchment areas. Selected individual storm hydrographs were averaged together on a monthly basis to represent seasonal variability. These monthly unit hydrographs

were used as input into the H&H model for monitored areas, and extrapolated values were derived for unmonitored areas. For each storm within each separate sanitary catchment area, the model applied the appropriate monthly-average unit hydrographs to the monitored rainfall so that the model-simulated sewer system responses correlated well to the monitored RDII flow.

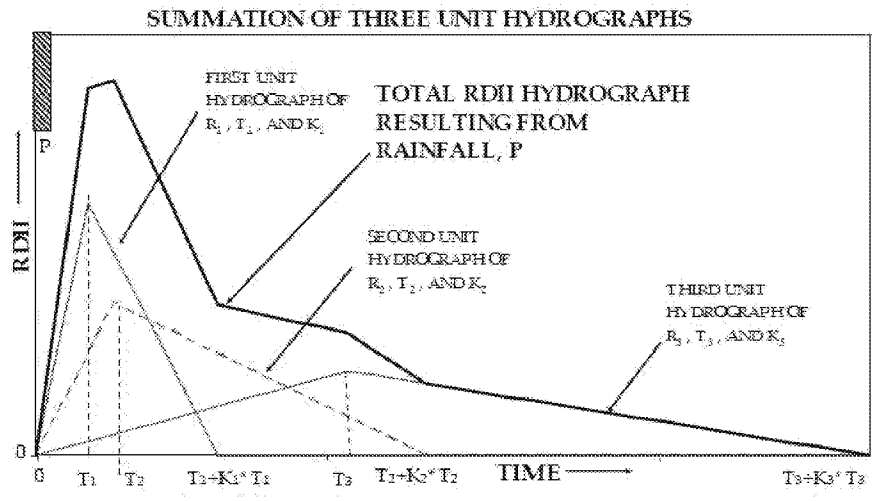

Figure 3-25: Unit Hydrograph Parameters Derived from SSOAP Toolbox

Representative analysis results are illustrated in **Figure 3-26** and **Figure 3-27**. The short-term (R1) RDII responses, medium-term (R2), and long-term (R3) responses are depicted for the monitored SSMH-2079 and SSMH-0254 catchment areas. The analysis results revealed that the SSMH-2079 catchment area demonstrated significant seasonal variability, and total RDII flows during the winter and early spring seasons are more than twice those experienced during the summer and fall. Conversely, the SSMH-0254 catchment area demonstrated minimal seasonal variability where RDII flows were consistent throughout the year, except for an observed 20 percent reduction during the fall season. Both catchment areas had relatively low total R-values, indicative of a "tight" collection system, despite the differences in the seasonality of the RDII responses.

Individual RDII analysis results for each of the monitored and analyzed City separate sanitary sewer catchment areas are provided in **Table 3-19**. The seven selected City catchment areas were previously shown in **Figure 3-23**. The short-term (R1), medium-term (R2), and long-term (R3) RDII responses, along with the total RDII response are provided. Also included is the GWI ratio, which reflects the magnitude of observed GWI component of the monitored average daily dry weather flow. The total R-values ranged from 0.99 percent to 4.19 percent, indicating the fraction of monitored rainfall over the catchment area that entered the sanitary sewer system.

Low values typically indicate a tighter sewer system with minimal extraneous flow. On the contrary, high values indicate high quantities of extraneous flow. Low total R-values are generally below 2 percent, while average total R-values range from 2 percent to 6 percent. Moderately high total R-values range from 6 percent to 10 percent, and high values are generally over 10 percent. These assessment results indicate that a comprehensive RDII reduction program would not be cost-effective for CRW, since the existing sewer collection systems are relatively tight. However, the high GWI ratio monitored at site SSMH-0254, located along Industrial Road and adjacent to Paxton Creek and Wildwood Lake, indicate that the trunk sewer could be a cost-effective candidate for a sewer lining project.

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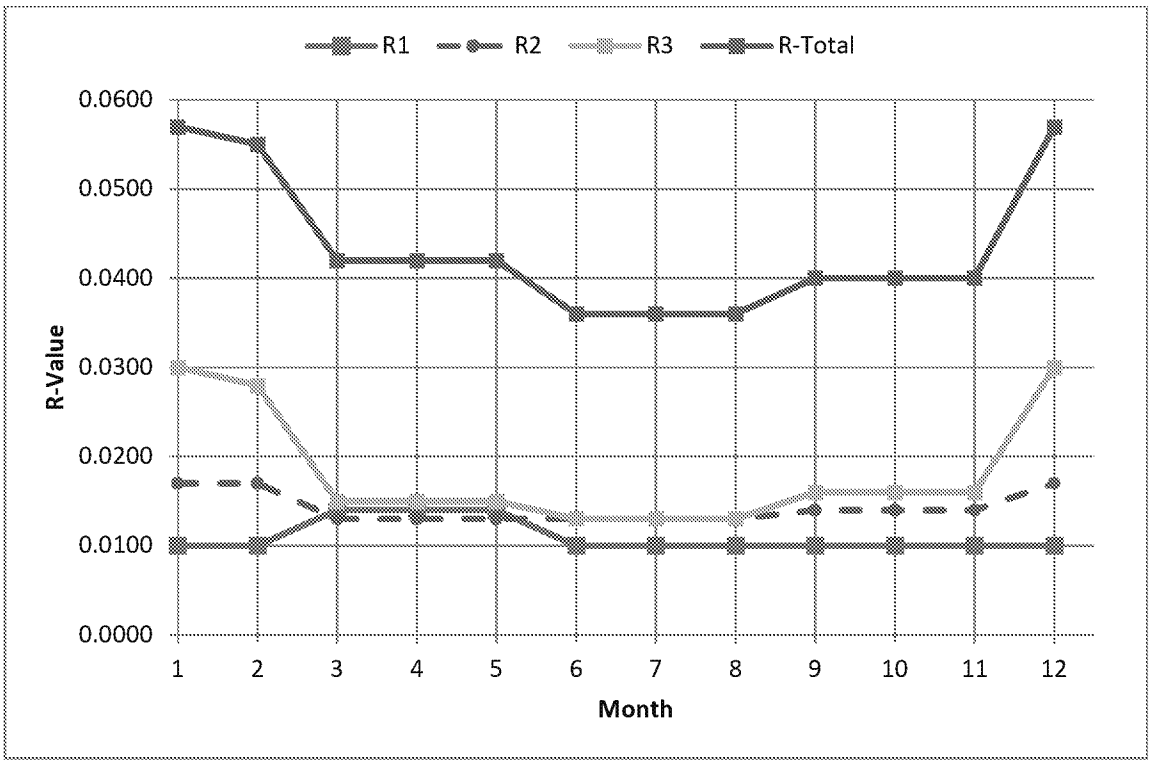

Figure 3-26: Monthly Varied R Values at SSMH-2079 (Significant Seasonal Variation)

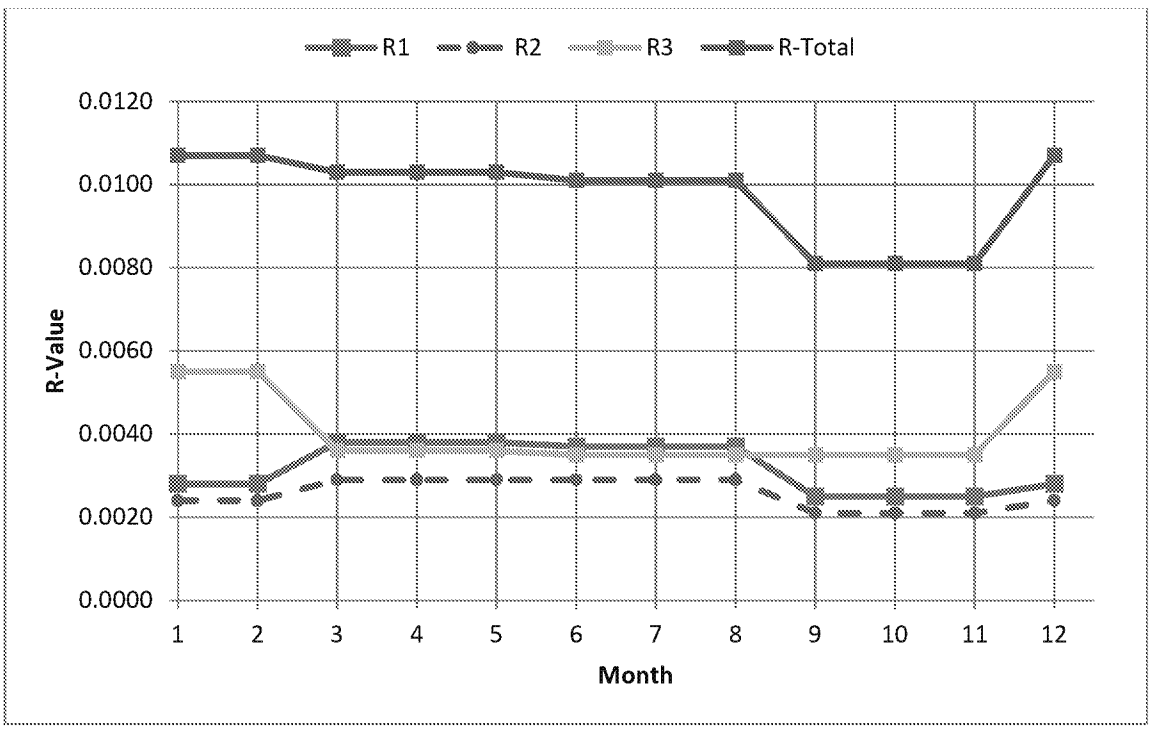

Figure 3-27: Monthly Varied R Values at SSMH-0254 (Minimal Seasonal Variation)

Table 3-19: Summary RDII Analysis Results for CRW Separate Sanitary Sewer Catchment Areas

Monitoring Site	R1	R2	R3	Total R	GWI Ratio
SSMH-0254	0.0033	0.0026	0.0040	0.0099	0.93
SSMH-2079	0.0095	0.0137	.0187	0.0419	0.63
SSMH-2413	0.0093	0.0073	0.0071	0.0236	0.77
SSMH-2825	0.0117	0.0070	0.0055	0.0242	0.72
SSMH-3023	0.0108	0.0074	0.0087	0.0270	0.82
SSMH-3208	0.0105	0.0098	0.0130	0.0333	0.78
SSMH-M15A	0.0144	0.0118	0.0115	0.0376	0.64

Individual RDII analysis results for each of the monitored and analyzed suburban community separate sanitary sewer catchment areas are provided in **Table 3-20**. The four point of connection catchment areas were previously shown in **Figure 3-21**. The total R-values ranged from 0.87 percent to 2.16 percent, indicating the fraction of monitored rainfall over the catchment area that entered the sanitary sewer system. These assessment results indicate that a comprehensive RDII reduction program would not be cost-effective for the suburban communities, since the existing sewer collection systems are relatively tight.

3.4.3.7 Wet Weather Flow Calibration

The CRW model was calibrated during wet weather conditions using the monitored precipitation and flows for the selected calibration periods and events. To calibrate and verify the CRW H&H model, four events were selected: three for calibration and one for validation. **Table 3-21** summarizes the four selected events. Two events were selected for model calibration from the top ten storm events; one representing a high intensity storm event (i.e., July 26, 2015), and one representing a large volume, medium intensity event (i.e., June 1, 2015). The remaining calibration event (i.e., March 13, 2015) represents hydrologic conditions during small to moderate storm events. This last event was selected in order to properly represent average annual and seasonal conditions and CSO statistics, as well as be appropriate for evaluation of green infrastructure alternatives that promote infiltration and evapotranspiration. This third calibration event also represents springtime conditions when soils are more saturated. The validation event (November 23, 2014) represents average conditions, as well as conditions during a third season (autumn). Review of the flow monitoring data during these events indicates that they are accompanied by flow monitoring data of good quality to support calibration/validation.

Table 3-20: Summary RDII Analysis Results for Suburban Separate Sanitary Sewer Catchment Areas

Monitoring Site	R1	R2	R3	Total R	GWI Ratio
POC M9	0.0018	0.0018	0.0051	0.0087	0.63
POC M13	0.0018	0.0023	0.0068	0.0109	0.54
POC M32	0.0022	0.0022	0.0094	0.0138	0.72
POOC M167	0.0039	0.0039	0.0138	0.0216	0.78

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Table 3-21: Selected Storm Events for H&H Model Calibration and Validation

No.	Storm Event Date	Averaged Total Rainfall Volume (in.)	Average Peak Rainfall Intensity (in./hr.)	Rainfall Duration (hr.)	Purpose
1	June 1, 2015	1.35	0.36	8.92	Calibration – Large Volume
2	July 26, 2015	0.91	0.81	4.42	Calibration – High Intensity
3	March 13, 2015	0.63	0.11	10.42	Calibration – Moderate Event
4	November 23, 2014	0.58	0.24	6.92	Validation– Moderate Event

Monitored flow during three calibration events were compared with modeled flow at the sites of the meters along the interceptor system to demonstrate that CRW's H&H Model provides accurate and reliable estimates of conveyance system performance over a range of events representative of CSOs and the likely range of CSO control. While the goal is to meet WaPUG[21] criteria at every meter during each calibration event, occasional outliers may occur that are attributable to one or more of the following situations:

- ***Event-specific monitoring excursions.*** If model and monitor results align well for other events and/or adjacent meters, an event specific excursion in measured flow may be attributable to potential short-term blockages or hydraulic transients during the event. Severe levels of debris exist in the interceptor and are known to periodically but temporarily affect flow monitor accuracy.
- ***Uncertainty in pump operating rules.*** Both the Front Street and Spring Creek pump stations are over 50 years old and scheduled for major overhauls in the next few years. Review of flow data indicates some uncertainty in pump station operation which, when coupled with backwater conditions in the interceptor, are difficult to model. Modeling in support of the Program Plan focuses on new pump stations / operating rules, since station replacement/repair is expected to occur before implementation begins.
- ***Uncertainty in wet weather response from suburban communities.*** Wet weather flows from suburban communities estimated using the RTK parameters derived from flow monitoring data and US-EPA SSOAP analysis represent large upstream areas and local phenomena within suburban systems that may influence monitored flows in CRW's system.

Detailed information on the development, calibration, and verification of the H&H model, as well as a series of plots depicting simulated versus observed wastewater total volume, peak flow, and maximum depth are provided in the 2016 *Sewer System H&H Model Report*[22].

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[21] Wastewater Planning Users Group – Code of Practice for the Hydraulic Modeling of Sewer Systems, Version 3.001, December 2002, http://www.ciwem.org/wp-content/uploads/2016/05/Code-of-Practice-for-the-Hydraulic-Modelling-of-Sewer-Systems.pdf

[22] *Sewer System H&H Model Report*, Sections 2.4 and 2.5, April 2016.

Section 4
Problem Analysis and Priorities

Capital Region Water's (CRW) *City Beautiful H_2O Program Plan* (Program Plan) seeks a balanced, affordable approach to addressing the following problems with its separate and combined wastewater/stormwater collection, conveyance, and treatment systems:

- Equipment failure and structural/operational deficiencies attributed to decades of deferred maintenance at the Advanced Wastewater Treatment Facility (AWTF).
- Structural/operational deficiencies and debris buildups attributed to decades of deferred maintenance along the conveyance and collection systems.
- Water quality degradation attributed to wet weather sewer discharges from combined sewer overflows (CSOs) and municipal separate storm sewer system (MS4) discharges to receiving waters.
- Separate sanitary sewer overflows (SSOs) and unauthorized releases from combined sewers attributed to hydraulic capacity limitations.

This section summarizes the nature and severity of each of these four problem types, followed by a statement of CRW's approaches and priorities for resolving each.

4.1 Overview of Problem Analysis and Priorities

Program Plan Section 3.2 described the inspection and characterization activities conducted at the AWTF and along the conveyance and collection systems. This section summarizes the problematic conditions that were observed and the specific priorities established by this Program Plan.

Section 4.2 provides summaries of the structural and operational deficiencies and debris buildups, attributed to decades of deferred maintenance, at the AWTF, and along the conveyance and collection systems.

AWTF Risks and Priority Repairs: Recent evaluations reveal that most treatment processes are in fair overall physical condition, but require priority capital replacement investments and additional O&M expenditures to protect against the risk of major failure. The AWTF currently has no screening facilities, and the design and installation of a screen system has commenced. Design has also begun for the rehabilitation of the existing primary clarifiers.

Conveyance System Risks and Priority Repairs: The CSO regulators and outfalls were inspected in 2013, and subsequent analysis in 2016 found 15 CSO outfall pipes in need of repair and 40 CSO structures subject to potential river intrusion during a 2-year flood event or less. The interceptors were inspected in 2014, and in 2016 a cleaning program was implemented where 1,500 tons of debris were removed and the pipes were re-inspected to confirm cleaning effectiveness and the structural condition assessments. A scheduled interceptor system rehabilitation program was

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developed and is being implemented, and a 5-year cycle of re-inspection and cleaning has been recommended. Specific rehabilitation measures and upgrades have been recommended for the Front Street and Spring Creek wastewater pumping stations and the Market Street stormwater pump station.

Collection System Risks and Priority Repairs: CRW retained a contractor to perform the collection system Rapid Assessment Inspection Program in 2015 and 2016. CRW subsequently evaluated the collected data to assign condition scores to assets. The results indicated that 17 percent of the inspected pipes were in excellent condition, 19 percent in good condition, 25 percent in fair condition, 21 percent in poor condition, and 17 percent in very poor condition. There were understood limitations to the information provided, so subsequently, CRW developed and is implementing a prioritized CCTV inspection program to fill in the information gaps at a pace within its financial capabilities. CRW has also implemented a stormwater inlet and catch basin cleaning and repair program, scheduled to be completed in 2021, to address inlets that are blocked with debris and those that require complete reconstruction when cleaned.

Section 4.3 describes the magnitude and frequency of wet weather sewer discharges from CSOs and MS4s to receiving waters.

Combined Sewer Overflow Risks: The calibrated hydrologic and hydraulic (H&H) model indicates the existing system, on average, captures and treats 53 percent of the combined wastewater volume, overflows from 9 to 95 times a year, depending on regulator structure, and discharges approximately 860 million gallons into receiving waters under typical year precipitation conditions. The annual frequency, duration and volume of CSO discharges are provided for each CSO regulator structure in the CRW system.

Municipal Separate Storm Sewer System Risks: MS4s serve a small portion of Harrisburg and are subject to Pennsylvania Department of Environmental Protection (PA-DEP) MS4 permitting requirements. An individual permit application submitted in September 2017 defined the area served by CRW's MS4s, known MS4 outfalls, and minimum control measures (MCMs) that will be implemented consistent with similar elements of the CSO NMC Plan. The permit application also included a Joint Pollution Reduction Plan (PRP) that indicates how CRW, Lower Paxton Township, and Susquehanna Township will collaborate to meet the Paxton Creek sediment TMDL (largely through streambank stabilization measures), as well as achieve initial PRP requirements for Wildwood Lake, an unnamed tributary of Spring Creek, and the Chesapeake Bay.

Section 4.4 provides the results of the hydrologic and hydraulic (H&H) modeling analyses that were conducted to identify specific locations where wet weather flows resulting from large design storms exceeded the capacity of the combined trunk sewers (described in Section 3.2.5), increasing the risk of unauthorized releases (e.g. surface flooding from surcharged manholes.) These locations are provided in a series of maps.

Section 4.5 defines the projected probability and locations of potential SSO discharges, including water in basements, within the CRW separate sanitary sewer system. Summary tables show how full the collection system pipes are flowing under a range of design storms characterizing the risk of an SSO discharge. Field reconnaissance and geographic information system (GIS) investigations

were conducted to identify structures with the potential for basement flooding from sanitary sewer backups.

Section 4.6 summarizes the results of the receiving water depth monitoring and flooding frequency analyses that were conducted. It also describes the extensive water quality monitoring and analysis activities that have been conducted over the past 10 years on the two waterbodies receiving direct discharges from CRW CSOs and MS4s, the Susquehanna River and Paxton Creek. Analysis led to the conclusion that bacteria is the pollutant of concern for the Susquehanna. Along Paxton Creek, sediment, dissolved oxygen and bacteria are the three pollutants of concern. Due to the distribution of the 58 CRW outfalls along the receiving waters and the flow regimes of the receiving waters, there are no Sensitive Areas as defined in the National CSO Policy in the receiving waters that would directly require more attention than others in evaluating LTCP options. However, US-EPA has requested that priority be given to the Susquehanna River[1].

Section 4.7 provides a regulatory compliance framework that outlines the priorities and obligations for addressing each of these problems.

- A risk-based assessment of the condition and criticality of CRW's assets to support investment decisions into their rehabilitation and renewal, to address priority risks, and achieve an appropriate level of resiliency while meeting other objectives and obligations.
- The technology and water quality based requirements of the Clean Water Act, with investment decisions for CSO and MS4 discharge controls and in-stream erosion/habitat enhancements (required to address the Paxton Creek TMDL and other pollution reduction requirements under PA-DEP's MS4 permitting program). This framework could also lead to a reassessment of water quality objectives and designated uses (e.g., in recognition of hydromodification to Paxton Creek within Harrisburg).
- A risk-based evaluation of the frequency and impact of wet weather SSOs and unauthorized releases from the combined sewer system, considering public health, safety and property damage considerations.

4.2 Structural/Operational Deficiencies and Debris Buildup

Section 3 summarized CRW's wastewater / stormwater infrastructure and the investigations conducted to define its current condition. CRW's most recent Consulting Engineer's Annual Report (CEAR) includes a limited condition assessment of the key components of the CRW Wastewater System based upon available condition assessment summaries, discussions with CRW staff, and visual observations[2]. Facilities were rated according to their risk of failure in five categories: visual appearance, reliability, O&M performance, capacity, and regulatory compliance, concluding that existing system conditions present a moderate overall risk (e.g. aged or worn but generally in good operating condition). This section summarizes the known structural/ operational deficiencies and debris buildup that affects near and long-term system reliability.

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[1] USEPA, Technical Memorandum, *Sensitive Areas/Priority Areas in the Harrisburg Receiving Waters*, September 2016.

[2] Arcadis, *Consulting Engineer's Annual Report (CEAR), Wastewater System*, September 29, 2017.

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4.2.1 Advanced Wastewater Treatment Facility Problems

4.2.1.1 Overview of the Advanced Wastewater Treatment Facility

CRW owns and operates one Advanced Wastewater Treatment Facility (AWTF) that receives all combined sewage conveyed through CRW's interceptors and pumping stations. The AWTF also receives the combined sewage from Steelton Borough, which is pumped directly to the facility. Combined sewage is treated by a series of unit processes including: grit removal, primary clarification, oxic/anoxic biological treatment, chemical addition, final clarification, and disinfection prior to discharge to the Susquehanna River. Waste biosolids are stabilized via anaerobic digestion, and dewatered by belt filter press prior to agricultural land application as Class B residuals. CRW completed major improvements to the biological treatment and final clarification processes at the AWTF in 2016 that enable compliance with effluent limits for nutrient removal.

4.2.1.2 Known Advanced Wastewater Treatment Facility Problems

Recent assessments and evaluations have revealed that numerous components of the AWTF have exceeded their life expectancies. In February 2017, a Biosolids Facilities Existing Conditions Report[3] provided an assessment of the current conditions of the solids treatment and handling systems at the AWTF, concluding that nearly all of the facilities and equipment, except the dewatering process equipment, are original equipment that have exceeded their useful design life, and are in need of replacement to increase reliability and reduce energy costs. In June 2017, a Biosolids Facilities Improvement Plan report[4] recommended rehabilitation and improvements projects for primary and secondary anaerobic digestion, gravity thickening, cogeneration and hauled waste processing. CRW is evaluating alternate approaches that will prove more affordable while maintaining efficient operations. Design has begun for a rehabilitation of CRW's existing primary clarifiers[5], including the repair and/or rehabilitation of each primary clarifier, its mechanical systems, and associated piping, pumping, and valves.

A listing of the recommended priority repairs at the AWTF is provided in **Table 4-1**. These necessary repairs have been identified as high priority needs to reduce the risk of hydraulic or treatment process failures, at an estimated opinion of probable cost in excess of $70 million (escalated cost) or $61 million (2017 dollars). It has been recommended that these high priority repairs be implemented over the next five to ten years.

Two of the recommended priority projects at the AWTF, a new headworks screening facility and primary clarifier improvements and repairs, would provide two strategic functions:

- Protect the integrity of the existing treatment processes and ensure NPDES permit effluent limits are consistently met, and
- Provide the needed hydraulic capacity in the primary treatment processes.

The hydrologic and hydraulic (H&H) model used for the Program Plan to develop and evaluate alternative levels of wet weather control assumed a primary treatment capacity of 80 mgd would

[3] Whitman, Requardt & Associates, LLP, *Biosolids Facilities Existing Conditions Report*, February 2017.
[4] Whitman, Requardt & Associates, LLP, June 2017, *Biosolids Facilities Improvements Plan, Draft.*
[5] Whitman, Requardt & Associates, LLP, *Primary Clarifier 30% Design*.

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be available to provide the needed quantity of wet weather treatment. Stress testing was performed to check the hydraulic capacity of the primary treatment facilities and the corresponding treatment effectiveness.

Table 4-1: Recommended High Priority Rehabilitation Projects at the AWTF

Rehabilitation Project Description	Wet Weather Benefit?
Headworks Screening Design/Construction	Yes
Anaerobic Digester Roof Repair/Primary Digester Facilities	No
WAS Thickening & Hauled Waste Improvements	No
Cogeneration (CHP) Improvements	No
Gravity Thickeners	No
Acid Phase Digester & Secondary Digester Conversion	No
Primary Clarifier Improvements and Repairs	Yes
Dewatering Improvements - Design Phase	No
Trucked-In Waste Receiving Station	No

The 2017 Biosolids Facilities Improvement Plan also recommended replacement of other aging equipment and implementation of process changes to reduce operating costs and improve digester gas production and utilization via cogeneration (combined heating and power) upgrades. Trucked-in waste receiving station improvements were also recommended to increase high-strength waste receiving capability and obtain the benefits of increased digester gas production for operating cost paybacks from digester gas to energy facilities and hauling revenues.

4.2.1.3 Assessment of Advanced Wastewater Treatment Facility Capacity

One component of CRW's strategy for compliance with the Environmental Protection Agency (US-EPA) National CSO Policy is through maximizing use of available capacity at the existing AWTF. This section summarizes an assessment of the AWTF treatment processes to handle the proposed peak wet weather flow.

4.2.1.3.1 Preliminary Treatment

The current AWTF preliminary treatment process consists of grit removal only. Screenings removal is performed at the Front Street pump station. CRW is constructing new screening facilities at the AWTF. Construction is scheduled for completion in 2018. The new screening facilities will mitigate historical problems with rags, wrappers, and other solids clogging and causing equipment failure in the grit removal system, primary clarifiers, and anaerobic digesters. The Screening Facility will consist of two mechanically-cleaned bar screens with ¼-inch bar spacing. Each fine screen has a capacity of 80 mgd which will provide 100-percent redundancy for peak wet weather flow. A washer/compactor unit on each screen will clean and reduce the volume of screenings for landfill disposal. The inlet chambers to the new Screening Facility will have an overflow arrangement in the event of an emergency to bypass the screens and direct flows to the grit removal system, or to bypass both the screens and grit removal systems.

The grit removal process consists of four vortex grit chambers. Each chamber is 16 feet in diameter with a maximum water depth of 7 feet. These have a rated capacity of 20 mgd per unit. The plant Operators normally operate with one or two units in service, and bring a third unit in

service as plant flows reach 40 mgd and the fourth unit at 60 mgd to achieve the total 80 mgd capacity.

It is concluded that the preliminary treatment facilities, upon completion of the new Screening Facility, will have a wet weather screening and grit removal treatment capacity of 80 mgd.

4.2.1.3.2 Primary Treatment:

The AWTF includes a battery of four primary clarifiers that have the design criteria shown in **Table 4-2.** The clarifiers were modified in the mid-1980s to convert the first 51.5 feet of each unit, which was originally a flocculation tank, to remove the flocculation equipment and install a second sludge collector. Both sludge collectors convey settled sludge to a common cross collector that feeds a sludge sump. The sludge sump in each tank is connected to one of two sludge inspection wells by an 8-inch diameter pipe. Primary Clarifiers 1 and 2 share a common sludge inspection well, as do Primary Clarifiers 3 and 4. Primary sludge pumps that feed gravity thickeners draw suction from the sludge inspection wells.

Table 4-2: Primary Clarifier Design Criteria

Parameter	Criteria*
No. of Clarifiers	4
Original Clarifier Unit Dimensions, feet	
Length	220
Width	35
Depth at Average Water Level (AWL) = 315	7.5 – 8.82
Section Surface Area, square feet	7,700
Weir Length	359
Modified Flocculation Tank Unit Dimension, feet	
Length	51.5
Width	30.5
Depth at AWL = 315 Tanks 1 & 4	8.21
Depth at AWL = 315 Tanks 2 & 3	7.71
Section Surface Area, square feet	1,540
Total Unit Surface Area, square feet	9,240

*Design criteria for the primary clarifiers were obtained from City of Harrisburg 1957 Sewage Treatment Plant design drawings and Harrisburg Sewage Authority 1987 record drawings for the Grit Removal and Other Modifications to the Harrisburg Advanced Wastewater Treatment Facilities.

One way to maximize flow to the AWTF is by utilizing additional capacity in the primary treatment process beyond the secondary treatment process capacity. The wet weather flow that bypasses secondary treatment also undergoes disinfection prior to discharge. The current CRW wet weather flow routing practice is that influent flows above the secondary treatment capacity of 45 mgd are diverted after primary treatment to disinfection (up to 35 mgd) for a total of 80 mgd peak weather treatment capacity. CRW performed full-scale stress testing of the primary treatment process to assess treatment capacity.

4.2.1.3.3 Primary Stress Testing

The objectives of primary stress testing were to (1) confirm the peak flow-through hydraulic capacity of the primary clarifiers is 80 mgd, or more, and (2) evaluate the performance of the primary treatment process under proposed wet weather operating conditions. The testing was performed under full-scale operating conditions by isolating plant flow through two of the four primary clarifiers. Plant flow of 40 mgd through two tanks would simulate the flow conditions of operating at 80 mgd through four tanks.

The PA-DEP Domestic Wastewater Facilities Manual guidelines for primary clarifier design recommends a maximum surface overflow rate (SOR) of 1,000 gallons per day per square foot (gpd/ft^2) at maximum monthly average flow and 2,500 gpd/ft^2 at design peak hourly flow, including recirculation flows. **Table 4-3** shows the surface overflow rates under various flow conditions with all four primary clarifiers in service, three clarifiers in service, and under the stress testing conditions with two primary clarifiers in service.

Table 4-3: AWTF Flow and Primary Clarifier Surface Overflow Rates

Parameter	Flow mgd*	Surface Overflow Rates, gpd/ft^2		
		4 Clarifiers	3 Clarifiers	2 Clarifiers
Current annual average flow (AAF)	21.1	570	760	1140
Current maximum monthly flow (MMF)	28.2	760	1020	1525
Current peak daily flow (PDF)	50.6	2030	1825	2740
Design annual average flow	37.7	1020	1360	2040
Design peak hourly flow	45	1220	1620	2435
Peak instantaneous flow	80	2160	2890	2890

* Flow data obtain from Design Engineer's Report for WQM Permit Application. AWTF Headworks Screening Project. February 26, 2016.

The hydraulic stress test demonstrated a capacity to pass up to 94.4 mgd with four primary clarifiers in service. However, some submergence of the top floatables collecting flights was observed and would require the top rails of the collector mechanisms to be raised to prevent the pass-through of floatable materials.

Performance of the primary treatment process under the stress testing conditions was monitored using daily composite samples and laboratory analyses of primary influent and primary effluent. Process performance was measured based on percent removals of total suspended solids (TSS) and biochemical oxygen demand (BOD). A concurrent sampling program obtained grab samples of the primary influent and effluent to monitor process performance in "real-time" during storm events. A total of four storm events were sampled over the stress testing period.

In general, the plant flows encountered during the stress testing program were lower than the targeted flow of 40 mgd. One storm resulted in a peak plant flow of 39 mgd, however, the performance of the primary treatment process during this event was inconsistent with limited TSS and BOD removals. The testing program demonstrated the primary clarifiers will achieve satisfactory removals for SORs up to approximately 1,600 gpd/ft^2 which is equivalent to 59 mgd

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with all four clarifiers in service. Above that SOR, clarifier performance was inconsistent depending upon the nature of the storm event.

CRW will investigate performance enhancements to the existing primary clarifiers including, testing the chemically-enhanced primary treatment (CEPT) facilities during wet weather and evaluating hydraulic improvements such as baffling and inlet modifications. Hydraulic (baffling, etc.) improvements to the primary clarifiers may be included in the upcoming primary clarifiers rehabilitation project currently scheduled for construction in 2019-20. Once rehabilitation is complete, additional stress testing is recommended to determine the effectiveness of these enhancements and to support adaptive management decision making to determine the nature, priority, and timing of further enhancements within CRW affordability limits.

4.2.1.3.4 Secondary Treatment

In 2016, CRW completed construction and startup of improvements to the secondary treatment portion of the facility. The primary objective of this project was to achieve compliance with the PA-DEP Chesapeake Bay Tributary Strategy (CBTS) nutrient removal limits and significantly reduce the need to purchase nutrient credits. PA-DEP established annual nitrogen and phosphorus discharge loading limits for the AWTF that were unachievable with the prior secondary facilities. The 1980's secondary treatment biological process was a high rate pure oxygen activated sludge facility that could only perform limited nitrification during warm weather and could not denitrify. This presented a challenge to CRW due to limited space for expansion of treatment facilities on the plant site. An innovative approach utilizing sidestream treatment and bioaugmentation was selected to limit the additional space necessary to achieve nutrient removal goals.

The process improvements constructed between 2014 and 2016 included the addition of a Return Activated Sludge Reaeration Sidestream Treatment process that receives the high ammonia belt press filtrate; conversion of the first cells of the High Purity Oxygenation Activated Sludge (HPOAS) tanks to anoxic selectors; addition of new post-anoxic, oxic and swing bioreactors after the HPOAS tanks with supplemental carbon addition. Aerobic, anoxic and swing zones were created in the new facilities to enable optimization of the biological nutrient removal processes. Other improvements included replacement of final clarifier mechanisms and addition of energy dissipating internal baffles, and modifications to the Chemically Enhanced Secondary Treatment (CEST) process.

The advanced wastewater treatment improvements design and PA-DEP construction permit were based on a secondary treatment process flow of 45 mgd to achieve the nutrient removal requirements. Thus, it is concluded that additional wet weather advanced treatment capacity is not available at the facility due to the risk of discharge permit violation.

4.2.1.3.5 Disinfection

Prior to discharge to the Susquehanna River, treated wastewater is disinfected in the chlorine contact tanks (CCT). There are four CCTs at the AWTF, which are each 100 feet long and 24 feet wide. The tank width is split into three passes by concrete divider walls. At a total plant flow of 80 mgd, the depth of water in the tanks is 11.3 feet, which provides a total water volume in the CCTs of approximately 761,000 gallons with all four tanks in service. Under these conditions the

resulting detention time in the CCTs is 14 minutes, which is slightly below PA-DEP wastewater treatment guidelines for chlorine disinfection detention time at peak flow of 15 minutes. However, considering the volume in the CCT Effluent Channel and Outfall pipe, there is additional 132,000 gallons of chlorine contact volume prior to discharge in the river. This results in over two minutes additional contact time which totals over 16 minutes contact time at a plant flow of 80 mgd, thereby, exceeding the PA-DEP recommended criteria.

In the recently completed AWTF improvements project the divider walls in CCT Nos. 3 and 4 were raised to the match the top of tank walls. This additional height prevents flow from overtopping the interior walls in each tank under river flood conditions. CCT Nos. 1 and 2 were originally constructed with higher divider walls.

4.2.1.3.6 Solids Handling

CRW recently completed a conditions evaluation of the existing solids handling facilities and is in the process of developing a biosolids facilities improvement plan. The proposed plan will recommend improvements to rehabilitate failing processes and re-establish or increase overall solids handling capacity. The plan will also provide recommendations to enhance digester gas production for additional heat and energy generation. The existing biosolids handling facilities include:

- Gravity thickening of combined primary and waste activated sludges.
- Anaerobic digestion of thickened sludge.
- Mechanical dewatering of digested sludge using belt filter presses.
- Digester gas storage and usage for two engine driven electrical power generators, three heat exchangers, and two hot water boilers.
- Covered dewatered sludge storage area.
- Dewatered sludge is hauled and land applied on agricultural sites.

The draft biosolids facility plan proposes the following solids handling improvements:

- Replacement of equipment that is beyond its service life.
- Digester cover and mixing improvements.
- Improve digester gas production and energy recovery.
- Add capacity for high-strength hauled waste from outside sources.
- Separation of primary and waste activated sludge thickening. Primary sludge will remain gravity thickened with separate mechanical thickening of waste activated sludge.

4.2.1.3.7 Susquehanna River Stage Evaluation

The outfall for the AWTF is a 60-inch diameter pipe that is buried in the river bed. There are three, 24-inch diameter discharge nozzles extending from the outfall pipe in the river. The plant

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discharge is by gravity, so the water elevation in the river has a direct impact on the plant hydraulic profile. The PA-DEP guidelines indicate the treatment facilities should remain fully operational up to the 25-year flood elevation. A hydraulic model was developed for the AWTF to analyze the hydraulic profile through the gravity flow portions of the plant to assess the capacity of the facilities and the impact of river flood elevations.

The Susquehanna River flood elevations shown in **Table 4-4** were obtained from Federal Emergency Management Administration (FEMA) maps.

Table 4-4: Susquehanna River Flood Elevations at AWTF

Flood Recurrence Interval	FEMA River Elevation (NAV29)	River Level (Plant Datum)
10-year	306	305.5
25-year	308.8*	308.3
50-year	311	310.5
100-year	313.5	313.0

* Flood elevation interpolated

The hydraulic model was used to assess the plant hydraulic profile at the 10-year and 25-year flood recurrence intervals at a peak wastewater flow of 80 mgd. It was concluded that the AWTF can pass 80 mgd peak flow during the 10-year river flood elevation without submerging any weirs in the plant. The hydraulic analysis indicates the weirs in the chlorine contact tanks will begin to submerge at a river flood elevation of 305.9 feet (plant datum) which is 0.4 feet above the 10-year flood.

At the 25-year river flood elevation the chlorine contact tanks weirs will be submerged by approximately 2.5 feet, however, the weirs in the primary clarifiers are not submerged. The submergence of the weirs in the chlorine contact tank does not adversely affect the disinfection process. The interior divider walls have been raised to a top elevation of 316.0 feet. This means the flow will remain within the channels and continue to provide chlorine contact time for disinfection. The weirs at the final settling tanks are high enough so that no submergence occurs at the 10-year and 25-year river flood elevations.

4.2.2 Conveyance System

CRW's wastewater conveyance system consists of 59 CSO regulators, 58 outfalls, six interceptor sewers (i.e., Front Street, Paxton Creek, Paxton Creek Relief, Asylum Run, Spring Creek, and Hemlock Street), the Front Street and Spring Creek wastewater pumping stations, the Market Street stormwater pumping station, and associated force mains. Most components of the collection system are original, subject to years of deferred maintenance, and in need of rehabilitation/repair. The following projects have been designed to fully rehabilitate these assets to address years of deferred maintenance, as well as implement hydraulic enhancements intended to increase the hydraulic capacity of the conveyance system to 80 mgd, equivalent to the enhanced hydraulic capacity of the primary treatment processes at the AWTF.

- ***CSO Regulators*** were inspected in 2013[6] and found to be largely equipped with original Brown and Brown regulators, in good structural and mechanical condition, but set at levels that restrict flows to current pumping / treatment capacity. Subsequent evaluation of the CSO outfall pipes and river intrusion potential in 2016[7] found 15 CSO outfall pipes in fair to critical condition in need of repair, as well as the 40 CSOs subject to potential river intrusion during a 2-year flood event or less. Early action repairs for outfalls with extreme structural deficiencies and/or frequent river intrusion are proposed for 2018, with remaining repairs to be scheduled under this Program Plan for consistency with long-term CSO control objectives. The engineer's opinion of probable cost for these rehabilitation and hydraulic/operational enhancement measures is $2,188,000 (2017 dollars).

- ***Interceptor Sewers*** were inspected in 2014[8]. In 2016, CRW cleaned 33,534 linear feet of its interceptor system and re-inspected the reaches to confirm cleaning effectiveness and confirm previous structural condition assessment[9]. Approximately, 1,500 tons of debris were removed from the interceptors in 2016, and a 5-year cycle of interceptor re-inspection and cleaning was recommended to verify maintenance of the structural integrity and hydraulic capacity of the interceptor system. **Table 4-5** lists the current scope and schedule for rehabilitation of CRW's interceptors to address critical structural conditions. The engineer's opinion of probable cost for these rehabilitation measures is $22 million (escalated cost and 2017 dollars).

- ***Front Street Wastewater Pump Station*** appears to be in fair to poor overall physical condition based on the available documents and inspections, with many of the pump station components near the end of their useful life, including the screens, pumps, HVAC system, and electrical and control systems. Planned pump station upgrades include replacement of pumps, bar screens, screenings conveyance equipment, controls and associated improvements to electrical, HVAC and building systems to meet current code requirements[10]. ***Spring Creek Wastewater Pump Station*** appears to be in fair overall physical condition based on the available documents and inspections.[11] Many of the pump station components are near the end of their useful life, including the screens, pumps, HVAC system, and electrical and control systems. The estimated cost for the rehabilitation measures at both pumping stations is $19 million (escalated cost), $17 million (2017 dollars).

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[6] CDM Smith, *Long-Term Control Plan Development: Regulator Infrastructure Inspection*, October 2013.

[7] CDM Smith, Technical Memorandum, *CSO Outfall Repair Early Action Project Schedule*, February 2016.

[8] Capital Region Water, *High Priority Combined Sewer Interceptor Improvements*, Letter to U.S. Department of Justice, February 26, 2015.

[9] CDM Smith, Technical Memorandum, *Capital Region Water Interceptor Cleaning and Rehab Improvements Update*, May 2017.

[10] Johnson, Mirmiran and Thompson, *Draft Preliminary Engineering Report, Front Street Sewage Pump Station.*

[11] Hazen and Sawyer, *Engineering Report*, April 21, 2015.

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Table 4-5: Recommended Rehabilitation of CRW's Interceptor System

Interceptor Name	Pipe Shape and Size (inches)	Rehabilitation Length (linear feet)	Scheduled Implementation
Paxton Creek	48 (H) x 59 (W) Parabolic 60 (H) x 72 (W) Parabolic 42 (H) x 60 (W) Rectangular Dual 30-inch Siphons*	7,556 5,068 387 488*	2017-2018
Asylum Run	24-inch Circular	2,504	2017-2018
Front Street	30-inch, Circular 30 to 40-inch, Non-Circular 36 (H) x 30 (W) Rectangular	1,933 8,248 2,400	2017-2018 2019-2020 2019-2020
Spring Creek	24 to 36-inch, Circular	5,117	2022-2023
Hemlock Street	No Rehabilitation Scheduled		
Paxton Creek Relief	No Rehabilitation Scheduled		

* Extent of siphon rehabilitation and related costs are not yet defined.

4.2.3 Collection System Problems

CRW's collection system includes approximately 33 miles of sanitary sewers, 40 miles of stormwater sewers, and 87 miles of combined sanitary and stormwater sewers. Approximately 80 percent of the collection system was installed prior to 1940.

Rapid Assessment Inspection Results: CRW retained a contractor to perform the collection system Rapid Assessment Inspection Program in 2015 and 2016. The inspection observations were divided between operations and maintenance (O&M) findings and structural findings. O&M findings consist of defects related to the operation of the sewer system. Defects such as root intrusions and debris and grease deposits are examples of O&M defects. Structural defects pertain to any issue that may jeopardize the structural integrity of the pipe or manhole. Cracks, fractures, holes, exposed rebar, and missing bricks are examples of structural defects. The rapid assessment inspections are being followed by comprehensive, prioritized closed circuit television (CCTV) inspections of the entire collection system. This information is being integrated into CRW's asset management program.

CRW analyzed the rapid assessment data, and assigned each manhole a priority level, which reflects the number and severity of defects that were identified. Scores were given on a scale of one through five, with one being the lowest priority level and five being the highest. CRW also analyzed pipe assessments of the zoom camera inspection findings applying a modified NASSCO PACP[12] protocol. The results indicated that 17 percent of the pipes that were inspected were in excellent condition, 19 percent in good condition, 25 percent in fair condition, 21 percent in poor condition, and 17 percent in very poor condition. There were understood limitations to the

[12] National Association of Sewer Service Companies, Pipeline Assessment and Certification Program

information provided, so subsequently, CRW developed and is implementing a prioritized CCTV inspection program to fill in the information gaps at a pace within its financial capabilities.

CCTV Inspection Program: CRW is in the process of conducting a prioritized remedial CCTV inspection of the entire collection system within the next five years to eliminate risk associated with unknown defects, especially for critical sewers which have a high consequence of failure. CRW is utilizing its Cityworks Asset Management System to document completed CCTV inspections, prioritize future CCTV inspections, and manage the pace at which inspections are conducted.

Using this condition information (where CCTV data supersedes Rapid Assessment findings as it becomes available), and using the pipe's age or work order history where rapid assessment / CCTV data is not available, CRW has developed an approach to identify and prioritize asset renewal needs as part of the overall asset management program. This approach combines an asset's probability of failure (POF) and consequence of failure (COF) to determine the core risk, placing each asset in risk management zones, which in turn are used to develop priority levels. Additional details on the methodology to determine priority levels can be found in the technical memorandum, CRW Sewer and Stormwater Prioritization[13].

The current estimated total cost of needed collection system repairs is over $100 million (2017 dollars), based upon the completed rapid inspections and CCTV inspections to date. However, there is remaining uncertainty in the potential risk and costs associated with significant collection system defects until the CCTV inspections are completed system-wide. CRW will reassess the appropriate level of long-term investment when the CCTV inspections and condition analysis are completed.

Catch Basin and Inlet Inspection Findings: The CRW collection system includes approximately 4,300 inlets and catch basins. CRW is conducting a comprehensive program of inspection, cleaning and repair of its inlets and catch basins. Based on the most recent data, 2,007 inlets have been cleaned to date (approximately 47 percent of the system), and 655 inlets have been repaired (approximately 31 percent of structurally deficient inlets, assumed to be half of the system) through the end of December 2017. CRW plans to complete all the inlet cleaning and repair by the end of 2021. CRW plans to clean and, where necessary, repair the remaining catch basins and storm inlets over the next four to five years.

4.3 Wet Weather Discharges at CSOs and MS4 Outfalls

CRW applied its calibrated H&H model (extended into the selected trunk sewers) to evaluate the existing hydraulic performance of its combined sewer system. The response of the current combined sewer collection system to wet weather events is characterized in terms of the average annual volume of wet weather flow captured and treated, and the volume overflowed to receiving waters. Percent capture, defined as the fraction of wet weather combined sewer flow that is captured and treated, is also commonly used to characterize the performance of the combined sewer collection system.

[13] GHD, Technical Memorandum, *CRW Sewer and Stormwater Prioritization*, January 2018.

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4.3.1 Systemwide CSO Discharge Frequency, Duration and Volume

The hydrologic parameters in the calibrated model account for existing land cover conditions as well as the effect on measured/modeled flows of the significant deferred maintenance within CRW's collection and conveyance systems (e.g., over 50 percent of the catch basins clogged with debris, and over 350,000 feet of trunk sewers requiring light to heavy cleaning). In addition, the hydraulics of CRW's regulators are complex, particularly the operation of the Brown and Brown regulators within most regulator chambers, set to divert most wet weather flow away from the interceptor and discharged as CSOs during moderate rainfall events.

Table 4-6 presents the estimated systemwide wet weather performance measures, based on H&H model simulations for a typical year precipitation record, for a range of scenarios typifying system improvements that are currently in process to address these uncertainties. Since the CRW system is in a continual state of being cleaned, critical rehabilitation measures are already designed and scheduled, and operational rules of Brown and Brown regulator structure mechanisms (B&Bs) are uncertain, the following conditions were used to set the operational range presented in **Table 4-6**.

- **Scenario 1:** Existing conditions with an interceptor system and catch basin network partially obstructed by accumulations of debris and solids, prior to the cleaning of the interceptors and the continuing efforts to clean and rebuild catch basins. The existing hydraulic restrictions of the B&B regulator mechanisms and the existing Front Street Pump Station during wet weather are retained.
- **Scenario 2:** Existing conditions with the completed cleaning of the interceptor system, but prior to completing the scheduled and continuing efforts to clean and rebuild catch basins. The existing hydraulic restrictions of the B&B regulators and the existing Front Street Pump Station during wet weather are retained. The H&H model simulations showed that cleaning the interceptors, even though the accumulated sediment depths and volumes were significant in places, provided a virtually undetectable improvement on system performance and systemwide CSO capture without providing other system improvements.

Figures 4-1 and 4-2 further illustrate how these scenarios affect the hydraulic grade line within the Front Street and Paxton Creek interceptors.

Table 4-6: Combined Sewer System Wet Weather Characterization of Current Conditions

Scenario	Captured Volume (MG)	Overflow Volume (MG)	Percent Capture	CSO Regulator Average Annual Number of Hours Overflow	CSO Regulator Average Annual Number of Overflows
1- Previous Existing Conditions prior to Interceptor Cleaning	861	798	53%	175	54
2- Existing Conditions after Cleaning of Interceptor	863	796	53%	175	54

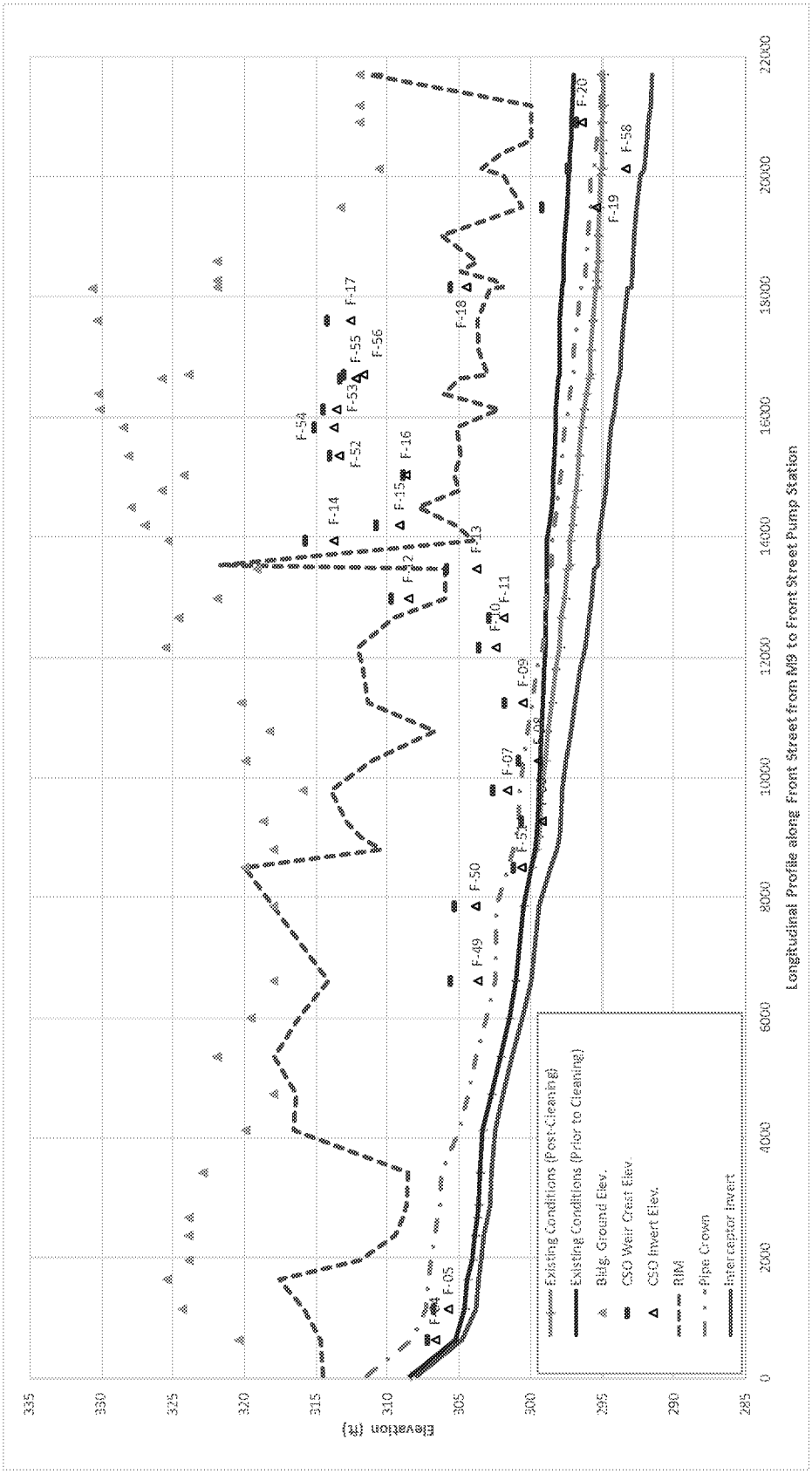

Figure 4-1: Peak HGL along the Front Street Interceptor during Typical Year

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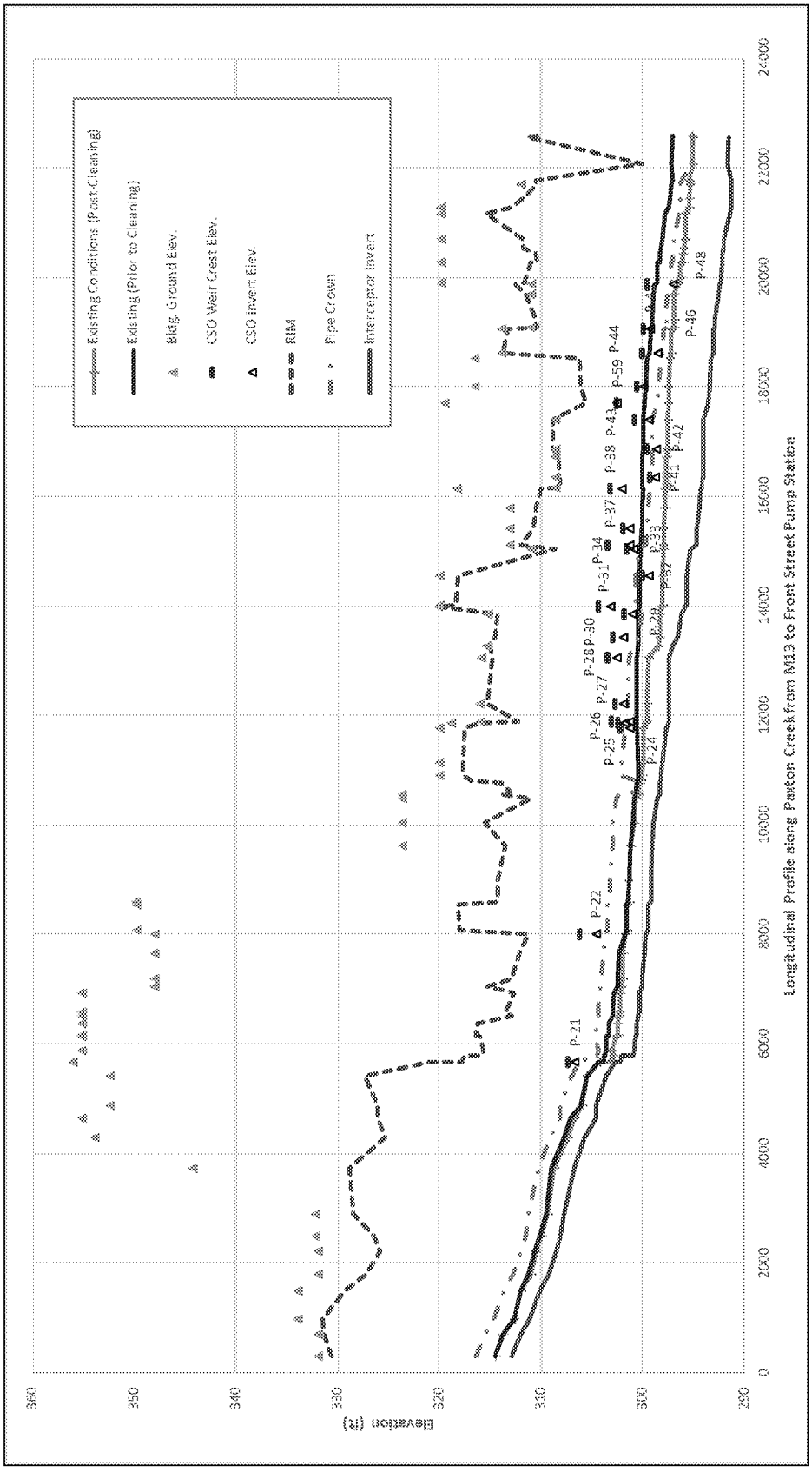

Figure 4-2: Peak HGL along the Paxton Creek Interceptor during Typical Year

4.3.2 Existing Performance Statistics for Individual CSO Regulators

The response of the combined sewer collection system to wet weather events is characterized in terms of the average annual volume of wet weather flow captured and treated, and the volume overflowed to receiving waters. While the previous section provided system-wide CSO statistics, this section provides CSO statistics for each individual regulator structure within the CRW system. Individual regulator statistics are based upon system-wide hydrologic and hydraulic model simulations for the typical year precipitation record. **Table 4-7** presents wet weather performance measures for each CSO regulator structure in the CRW combined system.

The volumes of combined sewer overflows at each CRW regulator structure location are presented in **Figure 4-3**. The outfall circles are color coded to more easily see the distribution of CSO discharge volumes along the Susquehanna River and Paxton Creek. The frequencies of CSOs at each CRW regulator structure location are provided in **Figure 4-4**. Again, the outfall circles are color coded to more easily see the distribution of CSO discharge frequencies along the receiving waters.

The frequency of combined sewer overflows is also a measure of system wet weather performance and is presented in **Figure 4-5** as box and whisker plots depicting the cumulative overflow frequency for each interceptor. The plot shows the range of overflow frequencies for the combined sewer regulators along the Front Street, Paxton Creek and Hemlock Street interceptors. The average annual overflow frequency for each outfall is based on model simulations for the typical year precipitation record. The model results indicate that the annual number of overflows varies greatly between regulators along each interceptor and within the system.

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Table 4-7: Existing Combined Sewer System Wet Weather Characterization by CSO Regulator

Interceptor	CSO	Captured Volume (MG)	Overflow Volume (MG)	Capture %	Annual Overflow Duration (hours)	Annual Number of Overflows	Drainage Area (acres)
Front Street Interceptor	CSO-004	6.05	11.3	35%	284	68	34
	CSO-005	11.9	15.3	44%	227	61	74
	CSO-006	8.15	3.86	68%	74	39	19
	CSO-007	8.16	4.72	63%	103	52	16
	CSO-008	13.0	24.1	37%	300	70	40
	CSO-009	19.3	32.9	37%	252	58	67
	CSO-010	15.9	30.4	34%	696	89	42
	CSO-011	11.5	12.4	48%	107	47	31
	CSO-012	6.96	7.36	49%	139	55	25
	CSO-013	6.91	2.82	71%	36	33	16
	CSO-014	16.8	17.4	49%	392	84	30
	CSO-015	10.1	5.94	63%	111	36	20
	CSO-016	2.10	1.89	53%	49	37	8
	CSO-017	3.29	0.66	83%	12	21	6
	CSO-018	12.5	10.6	54%	186	59	31
	CSO-019	6.54	6.67	50%	194	63	41
	CSO-020	0.13	0.77	14%	159	90	16
	CSO-049	14.4	7.36	66%	125	48	28
	CSO-050	19.2	24.5	44%	353	84	42
	CSO-051	44.4	25.0	64%	407	83	79
	CSO-052	10.2	9.79	51%	232	69	22
	CSO-053	4.47	2.87	61%	94	46	10
	CSO-054	3.07	3.80	45%	176	69	8
	CSO-055	7.92	3.56	69%	45	33	14
	CSO-056	4.20	4.54	48%	164	64	10
	CSO-057	2.71	4.48	38%	95	49	16
	CSO-058	2.84	0.60	82%	21	26	22
	Total	273	276	50%			766
Hemlock Creek Interceptor	CSO-060	5.29	1.46	78%	31	36	16
	CSO-061	12.2	16.5	43%	305	84	56
	CSO-062	8.07	3.46	70%	142	74	10
	CSO-063	10.7	5.78	65%	154	66	40
	CSO-064	3.66	0.70	84%	24	37	11
	Total	39.9	27.9	59%			133

Table 4-7: Existing Combined Sewer System Wet Weather Characterization by CSO Regulator

Interceptor	CSO	Captured Volume (MG)	Overflow Volume (MG)	Capture %	Annual Overflow Duration (hours)	Annual Number of Overflows	Drainage Area (acres)
Paxton Creek Interceptor	CSO-021	65.4	11.3	85%	160	65	149
	CSO-022	6.02	0.69	90%	7	13	20
	CSO-023	3.75	0.69	84%	21	25	16
	CSO-024	28.7	21.3	57%	263	69	158
	CSO-025	5.48	0.27	95%	8	18	10
	CSO-026	11.2	5.89	66%	29	24	51
	CSO-027	7.35	1.59	82%	48	41	8
	CSO-028	23.1	10.5	69%	135	49	54
	CSO-029	8.26	13.21	38%	667	95	43
	CSO-030	16.7	1.23	93%	26	30	40
	CSO-031	95	49.5	66%	503	79	220
	CSO-032	5.14	7.01	42%	289	76	14
	CSO-033	7.14	5.14	58%	80	49	20
	CSO-034	29.7	19.5	60%	190	60	62
	CSO-037	26.4	26.4	50%	265	76	77
	CSO-038	9.46	5.34	64%	78	47	19
	CSO-039	6.2	5.3	54%	88	49	21
	CSO-040	3.07	2.03	60%	44	31	12
	CSO-041	5.2	2.63	66%	164	65	12
	CSO-042	31.4	37.6	31%	752	92	6
	CSO-043	4.02	1.02	80%	25	32	6
	CSO-044	23.5	6.82	78%	60	40	47
	CSO-045	4.69	0.59	89%	2	8	10
	CSO-046	5.95	0.66	90%	4	12	9
	CSO-048	117	225	34%	309	58	766
	CSO-059	see 042	30.9	31%	256	61	154
	Total	550	492	53%			2,001
System Total		**863**	**796**	**53%**			**2,900**

Figure 4-3: Distribution of Existing Condition CSO Discharge Volumes

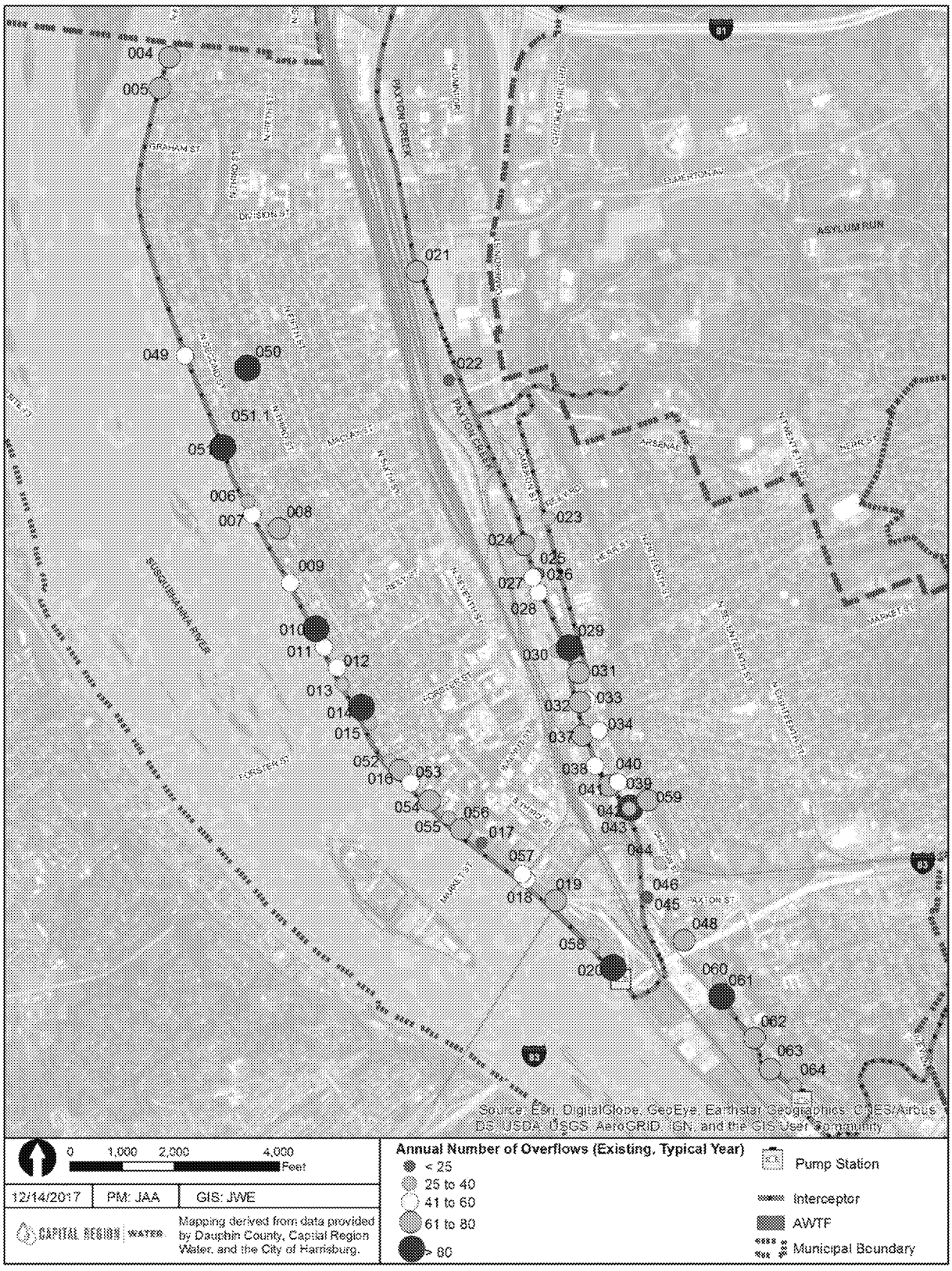


Figure 4-4: Distribution of Existing Condition CSO Discharge Frequencies

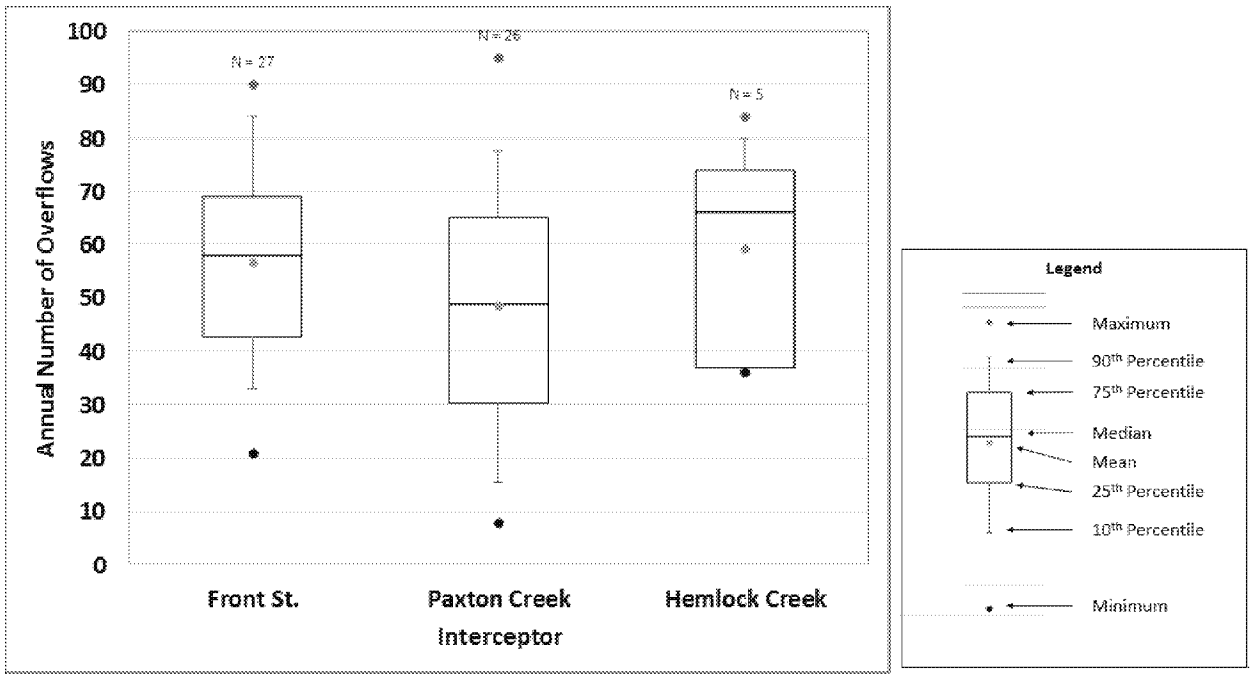
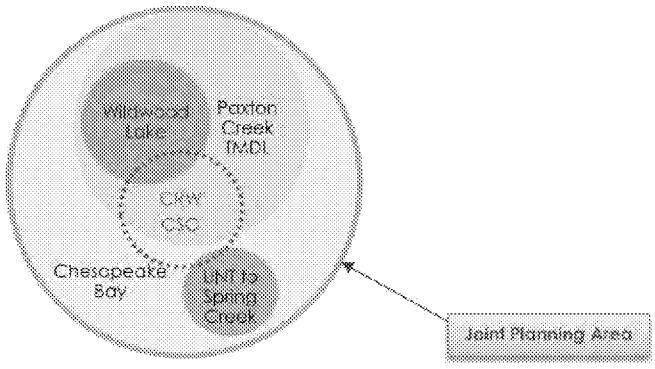


Figure 4-5: Average Annual Regulator Overflow Frequency by Interceptor

4.3.3 Stormwater Discharges at MS4 Outfalls

Paragraph V.D of CRW's partial Consent Decree requires CRW to "*develop and submit for review and approval an MS4 Individual Permit application for operation of the MS4, in accordance with applicable Federal and State regulations*". This was accomplished per PA-DEP regulations on September 15, 2017 through submission of PA-DEP's permit application. Key elements of CRW's MS4 program, many of which were included in the application, are outlined below:

- ***General Information*** describing the MS4 permittee and the location of the MS4.
- ***Stormwater Discharge Information***, including a map/inventory of the MS4 outfalls and identification of the surface waters receiving discharges from these outfalls.
- A ***Stormwater Management Program (SWMP) Plan***, defining how CRW intends to comply with the six minimum control measures (MCMs) identified in DEP regulations. CRW's Nine Minimum Controls (NMC) Plan is intended to also serve as its SWMP.
- A commitment to implement a ***Stormwater Management Ordinance*** compatible with the 2022 DEP Model Ordinance For consistency, CRW intends to also address CSO control requirements in its stormwater management ordinance.



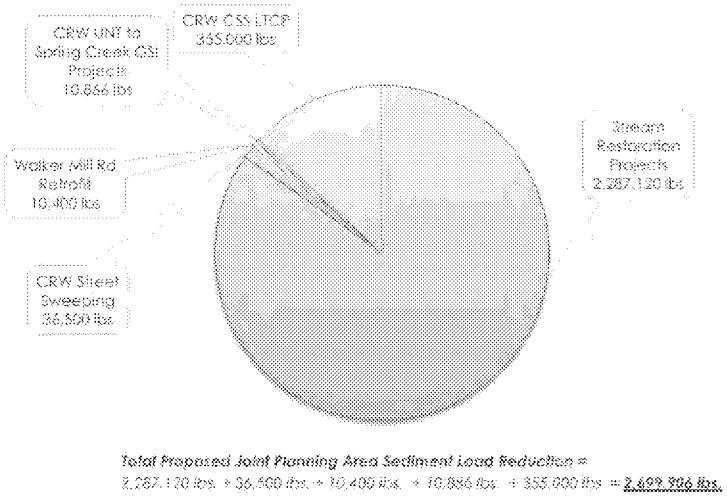
- ***Pollutant Reduction Plans*** for impaired water bodies identified by PA-DEP. Capital Region Water, Lower Paxton Township, and Susquehanna Township prepared a Joint Pollutant Reduction Plan (Joint Plan)[14] to meet the pollutant load reductions requirements of DEP's September 2017 MS4 permit renewal process. The Joint Plan commits the three jurisdictions to implement the following projects over the next five years:

  - Thirteen streambank stabilization projects, addressing approximately 17,890 linear feet of streambank stabilization within the Paxton Creek watershed.

  - A green stormwater infrastructure (GSI) project controlling impervious area contributing to an unnamed tributary (UNT) to Spring Creek.

  - Bi-weekly (25 times/year) street sweeping within the City of Harrisburg.

  - Rehabilitation and optimization of CRW's AWTF, major pumping stations, and CSO regulators.



Successful implementation of the Joint Plan is projected to reduce sediment loads by nearly 2.7 million pounds per year, achieving the following objectives:

- Short-term sediment load reduction of 10 percent for the Paxton Creek TMDL.
- Long-term 35 percent sediment load reduction necessary to meet the prescribed WLAs for Paxton Creek TMDL.
- 10 percent sediment load reduction for the Municipal Entities' combined Chesapeake Bay Planning Areas (Joint Planning Area).
- 10 percent sediment load reduction for Wildwood Lake.
- 10 percent sediment load reduction for the UNT to Spring Creek.

The engineer's opinion of probable cost to implement these improvements is $8 million (2017 dollars), with CRW contributing approximately $2 million (2017 dollars). As of this writing, CRW is awaiting a response from PA-DEP on this application and the draft terms of the individual MS4 permit.

[14] Capital Region Water, Lower Paxton Township and Susquehanna Township, Joint Pollution Reduction Plan, September 2017.

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4.3.4 Summary Conclusions on Wet Weather Control Needs

The National CSO Control Policy considers CSOs to be point sources subject to NPDES permit requirements including both technology-based and water quality based requirements of the Clean Water Act (CWA). NPDES permitting requirements for CRW's MS4 outfalls are also subject to CWA requirements. In addition, numerous hydraulic capacity constraints existing in both the combined collection system and the MS4, increasing risks of flooding and basement backups (see Sections 4.4 and 4.5). CRW must balance its efforts to address these systemwide wet weather control needs and significant system renewal priorities attributed to decades of deferred maintenance:

- The ongoing inspection of CRW's conveyance and collection systems is revealing numerous structurally deficient sewers, catch basins, and inlets requiring cleaning, rehabilitation and renewal;
- The Front Street and Spring Creek Pump Stations are over 50 years old and require major renovations to ensure reliable service, prevent potential system failure, and increase the available hydraulic capacity to convey peak wet weather flow;
- Critical equipment at the AWTF is at or near the end of its expected design life and needs to be replaced or repaired to ensure reliability and where possible expand the hydraulic and treatment capacity for peak wet weather flow.

This Program Plan seeks to allocate CRW's limited financial resources among competing priorities for comprehensive system renewal and systemwide wet weather control. Maintaining a healthy balance between these critical needs will be essential to developing a successful Program Plan.

4.4 Hydraulic Capacity of Combined Trunk Sewers

Paragraph H(34) of CRW's partial Consent Decree states that "*all Unauthorized Releases from the Combined Sewer System are prohibited,*" while Paragraph E(15)(g) requires CRW's H&H model to represent portions of the collection system "*. . . that hydraulically impact known chronic Unauthorized Releases.*" CRW applied its H&H model to evaluate the hydraulic capacity of its collection system trunk sewers to identify and characterize chronic unauthorized release locations and incorporate their control into the Program Plan. This section summarizes the findings of this characterization.

Synthetic design storm rainfall (described previously in Section 3.3.4) was applied to the H&H model to estimate peak wastewater flows and water surface elevations within the existing combined sewer systems during the 1-year, 2-year, 5-year, and 10-year 24-hour design storm events. The modeling results are summarized in **Tables 4-8** and **4-9**.

Table 4-8: Summary of Hydraulic Conditions along Combined Trunk Sewer Pipes

Scenario	Trunk Sewer Length (linear ft.) at Percent of Full Pipe Depth of:				
	0% to 30%	30% to 60%	60% to 90%	>= 90%	Total
1-Year Design Storm	5,675	25,998	45,165	91,404	168,243
2-Year Design Storm	3,583	14,634	37,282	112,743	168,243
5-Year Design Storm	1,852	8,684	25,077	132,631	168,243
10-Year Design Storm	1,308	4,464	20,704	141,767	168,243

Table 4-9: Summary of Hydraulic Conditions at Combined Trunk Sewer Manholes

Scenario	Number of Trunk Sewer Manholes with Peak Depth Below Rim Elevation of:					
	> 8 ft	6 to 8 ft	4 to 6 ft	0 to 4 ft	< 0 ft	Total
1-Year Design Storm	313	78	56	235	96	682
2-Year Design Storm	209	78	55	339	171	682
5-Year Design Storm	139	47	61	435	245	682
10-Year Design Storm	84	46	52	500	290	682

The modeling results for each of the synthetic design storm precipitations are depicted in **Figures 4-6** through **4-9**. Because of the large format size of the maps, they are provided in **Appendix A**. The percent of full pipe depths and the wastewater depths within the manholes are color coded for easy identification. Sewer segments coded as red, are flowing full or surcharged during design storm conditions. The maps also identify specific locations where the design storm flows exceed the capacity of the combined collection system and surface flooding occurs. The approximate volume of surface flooding is indicated by the color coding. Orange dots indicate minor street flooding by surcharged sewers, while red dots indicate more significant street flooding.

4.5 Hydraulic Capacity of Separate Sanitary Sewers

CRW is required to perform a Separate Sanitary Sewer System Capacity Assessment under section V-F Paragraph 30-a of the PCD. Paragraph 30-b requires CRW to address a specific list of assessment activities in the Plan. Paragraph 30-c of the partial Consent Decree defines what the Separate Sanitary Sewer Capacity Assessment Report (SSSCAR) should include. In March of 2017 CRW submitted a SSSCAR to the regulatory agencies that met the PCD requirements. [15].

Monitored wastewater flow data from the suburban community separate sanitary sewer systems and the selected separate sanitary sewer catchment areas within the City of Harrisburg were analyzed to quantify and characterize flow under dry and wet weather conditions and validate the H&H model. Synthetic design storm rainfall was applied to the H&H model to estimate peak wastewater flows and water surface elevations within the existing separate sanitary sewer systems during typical peak dry weather flow conditions, and the 2-year, 5-year, and 10-year 24-hour design storm events. The objective of this evaluation was to define the projected probability and locations of potential SSO discharges, including water in basements, within the CRW separate

[15] *Separate Sanitary Sewer Capacity Assessment Report, Version 1.0*, March 2017, available at **https://capitalregionwater.com/cbh2o/**.

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sanitary sewer system. Detailed descriptions of the analyses and a series of maps depicting the results are found in Sections 3 and 5 and Appendix A of the SSSCAR.

4.5.1 System Performance during Design Storm Flows

The PCD committed CRW to apply the calibrated H&H model of its conveyance and collection systems and the synthetic design storm rainfalls to estimate peak wastewater flows and water surface elevations within the existing separate sanitary sewer system during peak dry weather flow and the 2-year, 5-year and 10-year design storms. The objective of this evaluation was to define the projected probability and locations of potential SSO discharges, including water in basements, within the CRW separate sanitary sewer system. The model simulations produced a series of hydraulic profiles along each of the modeled interceptor sewers and separate sanitary trunk sewers. The water surface elevations from each of the hydraulic profiles were applied to the Geographic Information System (GIS) database of the CRW collection system to produce a series of color-coded maps[16].

The hydraulic capacity evaluation results under each flow scenario are summarized in **Tables 4-10** and **4-11**. Model simulations confirmed that under peak dry weather flow conditions there are no hydraulic limitations anywhere within the CRW separate sanitary trunk sewer system that would cause SSO discharges or basement backups. Under 2-year design storm flow conditions, 37 percent of the pipe lengths were flowing full or under surcharge conditions and 18 structures have basements potentially subject to backwater flooding. Under 5-year design storm flow conditions, 51 percent of the pipe lengths were flowing full or under surcharge conditions and 24 structures have basements potentially subject to backwater flooding. Under 10-year design storm flow conditions, 63 percent of the pipe lengths were flowing full or under surcharge conditions and 49 structures have basements potentially subject to backwater flooding.

Table 4-10: Summary of Hydraulic Conditions along Separate Sanitary Sewer Pipes

Scenario	Sewer Length (linear ft.) at Percent of Full Pipe Depth of:*				Total
	0% to 30%	30% to 60%	60% to 90%	>= 90%	
Peak Dry Weather Flow	38,284	8,035	759	69	47,147
2-Year Design Storm	2,706	15,126	11,888	17,426	47,147
5-Year Design Storm	2,101	10,772	10,432	23,842	47,147
10-Year Design Storm	1,616	7,419	8,594	29,517	47,147

*Includes Asylum Run and Spring Creek Interceptors

[16] *Separate Sanitary Sewer Capacity Assessment Report, Version 1.0, Appendix A,* March 2017, available at **https://capitalregionwater.com/cbh2o/**.

Table 4-11: Summary of Hydraulic Conditions at Separate Sanitary Manholes

Scenario	Number of Manholes with Peak Depth Below Rim Elevation of:*					Potential for Water in Basement
	> 8 ft.	6 to 8 ft.	4 to 6 ft.	0 to 4 ft.	< 0 ft.	
Peak Dry Weather Flow	144	43	15	0	0	0 structures
2-Year Design Storm	119	17	11	47	8	18 structures
5-Year Design Storm	109	24	13	47	9	24 structures
10-Year Design Storm	86	20	19	67	10	49 structures

*Includes Asylum Run and Spring Creek Interceptors

The 2-year design storm has a 50 percent statistical probability of being equaled or exceeded in a given year, the 5-year design storm has a 20 percent probability of being equaled or exceeded in a given year, and the 10-year design storm has a 10 percent probability of being equaled or exceeded in a given year. The assessment also yielded the following findings about the portion of the Spring Creek Interceptor operated by CRW.

- Evaluation of flow and precipitation data with US-EPA's Sanitary Sewer Overflow Analysis Program (SSOAP) found the amounts of non-wastewater flow entering the Spring Creek Interceptor summarized in **Table 4-12**.
- A comparison with similar evaluations of non-wastewater flows from other communities reveals that:
  - RDII rates from separate sanitary areas in the City of Harrisburg are near the median RDII value (considered to be average, not excessive RDII).
  - RDII rates from the suburban communities are less than median RDII value (considered to be low RDII).
  - Other communities have found that it is typically not cost-effective to achieve significant reductions in RDII at such rates of RDII.
- While measured RDII and GWI rates are considered low to average, H&H model simulations reveal significant limitations in the hydraulic capacity of the Spring Creek Interceptor during the 2- to 10-year, 24-hour design storms:
  - Flow monitoring and H&H model projections indicate that over 90 percent of the flow in the Spring Creek interceptor is generated by the suburban communities discharging into CRW's system.
  - Peak flows during the 2-year design storm exceed the existing hydraulic capacity of the Spring Creek Pump Station, and surcharge the entire length of the Spring Creek interceptor owned and operated by CRW. Most of the interceptor manholes have less than four feet of freeboard below the rim elevations.
  - Six manholes exhibit hydraulic grade line profiles above the manhole rims during the 2-year and 5-year design storms, increasing to six manholes during the 10-year design storm.

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- There are no adjacent buildings near these manholes, located along a deep valley, so no basement backup would occur.
- CRW has sealed many of the manholes along its section of the Spring Creek interceptor to withstand pressure flow conditions and reduce the risk of SSOs. In June 2017, CRW Field Operations began inspecting each manhole along the Spring Creek Interceptor every month and following significant storm events. While the hydraulic model suggests the possibility for SSOs, CRW field staff have not observed SSOs along Spring Creek since the "problem lids" were bolted down, believed to be in 2009.

Table 4-12: Ground Water Infiltration along the Spring Creek Interceptor

Service Area	Contributing Area (square miles)	Average Groundwater Infiltration (GWI) as a Percent of Average Daily Flow	Average Rainfall Dependent Infiltration/Inflow (RDII) Volume as a Percent of Precipitation Volume
Suburban Communities	10.5	69	1.4
City of Harrisburg	0.9	64	3.8 to 4.2
Total:	**11.4**	-	-

Section 8 describes alternatives for addressing capacity constraints along the Spring Creek Interceptor.

4.6 Characterization of Receiving Water Conditions

The Partial Consent Decree, in Section V-E, Paragraph 21-c, requires CRW to "*. . . provide a characterization of current water quality conditions in its Receiving Waters, based upon available data, the use of a Water Quality Model*(s) *in Receiving Waters in which the Demonstration Approach is being utilized, and its efforts to identify pollutants of concern . . .*". The following Waters of the Commonwealth directly receive discharges from CRW's separate and combined sewer systems.

- The east shore of the Susquehanna River.
- The main stem of Paxton Creek from its confluence with the Susquehanna River upstream to Wildwood Lake.

CRW's service area also lies within the Chesapeake Bay watershed, and is subject to the objectives of the Pennsylvania Chesapeake Watershed Implementation Plan. As part of its individual MS4 NPDES Permit Application to PA-DEP, CRW participated in preparation of a Joint Pollution Reduction Plan with Lower Paxton Township and Susquehanna Township, recommending specific controls to meet current requirements of the Chesapeake Watershed Implementation Plan, the Paxton Creek TMDL, and an unnamed tributary of Spring Creek.

To characterize receiving water depth, CRW obtained monitored depth data and conducted a flood frequency analysis. To characterize receiving water quality, CRW identified, collected, and analyzed available water quality sampling study data. Pollutants of concern were identified, along with their geographic extent.

4.6.1 Regulatory Context, Water Quality Objectives, and Use Designations

Under the Clean Water Act (CWA), the PA-DEP Bureau of Point and Non-Point Source Management is responsible for establishing designated uses of each receiving water, establishing criteria for measuring if these designated uses are attained, assessing the attainment status of each receiving water, and where necessary, defining requirements for achieving future attainment. The current attainment status of the waters receiving discharges from CRW's combined sewer system, according to the PA-DEP 2016 *Pennsylvania Integrated Water Quality Monitoring and Assessment Report* is summarized in **Table 4-13**. There were no changes in attainment status of the receiving waters from 2014 to 2016, as indicated in Appendix F of the draft 2016 Integrated Report.

Table 4-13: Attainment Status of Waters Receiving CRW Combined Sewer System Discharges

Receiving Water	Designated Use	Cause / Constituent(s)	Source	Related to CSOs?	TMDL Date
Susquehanna	Fish Consumption	PCBs	Unknown	No	2027
	Potable Water	N/A	N/A	N/A	Attained
	Aquatic Life	N/A	N/A	N/A	Unassessed
	Recreation	N/A	N/A	N/A	Unassessed
Paxton Creek	Aquatic Life	DO/BOD	CSOs	Yes	None Required
		Siltation / TSS	Urban/Storm Sewers, Stream Erosion	Potential	2008
		Flow Variability	Urban / Storm Sewers	Potential	None Required
		Habitat Alteration	Urban / Storm Sewers	Potential	None Required
	Recreation	Pathogens	Unknown	Potential	2025

Existing Regulated Industrial Users: In accordance with US-EPA's CSO guidance, a preliminary assessment was performed as part of the development of CRW's *Nine Minimum Control Plan* to ascertain whether industrial discharges are concentrated in certain areas, thereby having the potential to impact specific CSO discharge points. As discussed in Section 3 of the NMC report, only one of the regulated industrial users is located within a CSO catchment area: CSO-043. However, the other eight industrial users discharge wastewater to interceptors that flow to the Front Street and Spring Creek pump stations. There are permitted emergency bypass CSOs at both pump stations (CSOs 002 and 003); therefore, these regulated industrial users are upstream of permitted CSOs. H&H modeling, however, reveals that neither of these two pump station bypasses activate during the typical year. The assessment indicated there is not a concentration of non-domestic discharges within the combined sewer system.

4.6.2 Receiving Water Depth Characterization and Flood Frequency Analysis

A network of four water surface elevation monitors was installed along Paxton Creek. Three of the monitors were installed over the creek along roadway bridge beams, and the ultrasonic sensors focused downward to the water surface. The fourth water surface elevation monitor was installed within a CSO outfall pipe and the pressure transducer sensors measured the depth up to the water surface. A summary of the site locations and data collection are provided in **Table 4-14** and illustrated on **Figure 4-10**. The elevation of the monitoring equipment at each site was surveyed and the sensor elevations were tied to the elevations of the sewer system structures in CRW's GIS database. The data provided the necessary boundary conditions in the H&H model during historical storm events at each CSO along Paxton Creek. A flood frequency analysis was

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also performed for estimating the frequency of potential river intrusion into CSO regulators along Paxton Creek.

Table 4-14: Paxton Creek Water Surface Elevation Monitoring Summary

Site Number	Gauge Location	Installation Date	Data Collection Status	Data Analysis Status
Paxton Creek 1	CSO-021 Outfall Pipe	Nov 3, 2014	Ongoing	Ongoing
Paxton Creek 2	Calder Street Bridge	Nov 3, 2014	Ongoing	Ongoing
Paxton Creek 3	Market Street Bridge	Nov 3, 2014	Ongoing	Ongoing
Paxton Creek 4	Shanois Street Bridge	Nov 4, 2014	Ongoing	Ongoing

For the Susquehanna River, CRW obtained monitoring data from United States Geological Survey (USGS) gauge 01570500. The gauge location on City Island is shown on **Figure 4-10**. The USGS river monitor records river stage elevation data in 30-minute increments. The slope of the river shoreline from the upstream to the downstream limits of the CRW service area was used to extrapolate the monitored river stage elevations to each of the CRW CSO outfall locations along the river. The data provided the necessary boundary conditions in the H&H model during historical storm events at each CSO along the Susquehanna River.

Historical water surface elevation data for the Susquehanna River is available for a 117-year period of record. The historical dataset was obtained and a Log-Pearson flood frequency analysis was conducted to determine river elevations associated with the 2-year, 5-year, 10-year, and 25-year flood frequency events. These flood events have a 50 percent, 20 percent, 10 percent, and 4 percent chance of being equaled or exceeded within a given year, respectively.

The 10-year flood level was obtained from the water surface profiles published in the FEMA Flood Insurance Study for the greater Harrisburg region. For the more frequent flood frequencies, the FEMA and Log-Pearson analyses were supplemented with data obtained from the USACE Silver Jackets program, which provides water surface elevation data for each flood stage in 1-foot increments. River stages during flood frequency events were used for estimating the frequency of potential river intrusion into CSO regulators along the Susquehanna River.

4.6.3 Water Quality Information Sources

Information on historic sampling locations within the Susquehanna River and Paxton Creek, the specific water quality parameters that were sampled, and the results of the completed water quality analyses are provided within the reference documents listed below.

- *Results of the Nationwide Urban Runoff Program*. Volume 1 – Final Report. U.S. Environmental Protection Agency. December 1983.
- *Water Quality Monitoring Data Analysis Report.* 2005 LTCP Attachment H. The Harrisburg Authority. August 2005.
- *2014 Pennsylvania Integrated Water Quality Monitoring and Assessment Report.* DEP.
- *LTCP Approach.* Partial CD Deliverable. Submitted to PA-DEP December 23, 2014.

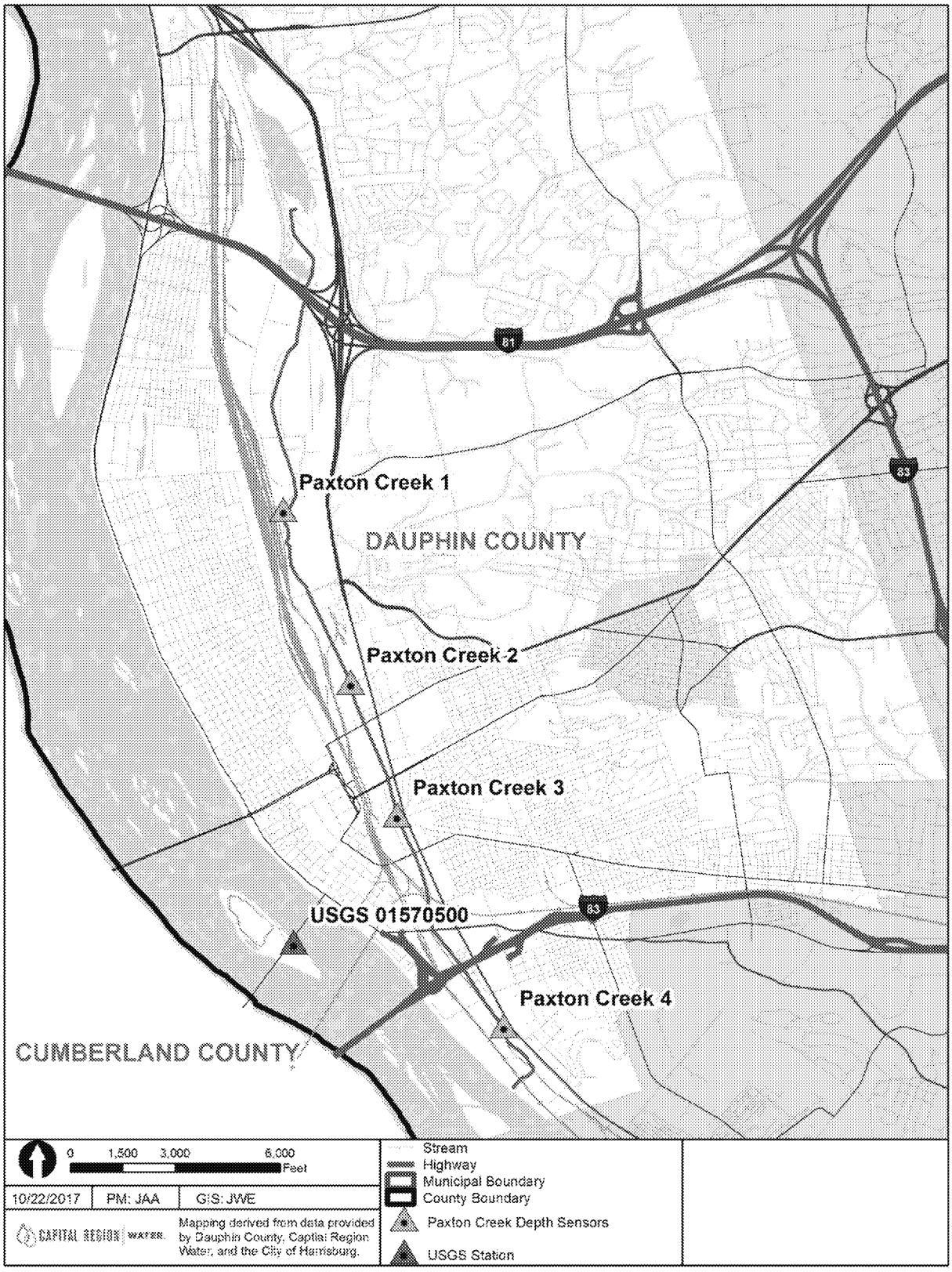

Figure 4-10: Paxton Creek and Susquehanna River Elevation Monitoring

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- *Water Quality Modeling Plan.* Partial Consent Decree Deliverable. Submitted to PA-DEP July 27, 2015.
- *Sensitive Areas/Priority Areas in the Harrisburg Receiving Waters.* Partial Consent Decree Deliverable. Submitted to PA-DEP April 1, 2016.
- *PADEP Susquehanna River Bacteria Sampling Report.* Sent to Capital Region Water August 1, 2016.
- *2016 Draft Pennsylvania Integrated Water Quality Monitoring and Assessment Report.* DEP

4.6.4 Receiving Water Quality Studies and Characteristics

Over the past 10 years, periodic water quality monitoring and analysis has been conducted on the two waterbodies receiving direct discharges from CRW's CSOs, the Susquehanna River and Paxton Creek. This data has been collected by CRW (for preparation of the 2005 LTCP), US-EPA (for preparation of the 2008 Paxton Creek TMDL), and by PA-DEP / Susquehanna River Basin Commission (via the relatively long-term Water Quality Network and over the past three years as part of the Susquehanna River Study).

A review of existing water quality data is documented in the PCD deliverable *LTCP Approach* submitted to PA-DEP on December 23, 2014. The review presents data from monitoring, over the past decade or more, within the reaches of the Susquehanna River and Paxton Creek receiving discharges from CRW's combined sewer system. The document summarizes pertinent available data and published conclusions drawn from these data regarding CSO discharge characteristics, water quality, physical stream assessments, and biomonitoring for the Susquehanna River and Paxton Creek. Further documentation of completed water quality sampling activities, and the data that were obtained, was documented in Section 4 of the March 2017 *Combined Sewer System Characterization Report.* [17]

4.6.4.1 Susquehanna River Sampling and Studies

As part of the development of the 2005 LTCP, CSO discharges were monitored in 2003. Samples of CSO discharges were collected throughout overflow events to determine the combined sewer wastewater characteristics. Three CSO events between June and November 2003 were sampled at eight discharge locations selected based on estimated overflow volume and spatial distribution. The water quality parameters that were measured include total settleable solids, total suspended solids, BOD_5, total nitrogen, total phosphorus, and fecal coliform bacteria. The system-wide average event mean concentrations (EMCs) for all storm events were calculated by determining the arithmetic average EMC for each parameter.

Water quality monitoring was also conducted at sample sites along the east, west, and center tracts of the Susquehanna River during three wet weather events in 2004 to determine the effect of CSO discharges on water quality. The water quality parameters that were measured include fecal coliform, dissolved oxygen, pH, temperature and turbidity.

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[17] Capital Region Water, Combined Sewer System Characterization Report, Version 2.0, March 2017, available at **https://capitalregionwater.com/cbh2o/**.

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Additional sampling data to measure fecal coliform along the Susquehanna River was collected by PA-DEP between July and September 2014. Sampling locations included sites that were upstream and downstream of Harrisburg mostly adjacent to developed suburban neighborhoods, as well as six locations along the reach impacted by CRW's CSO discharges. The system-wide average event mean concentrations for all storm events were calculated by determining the arithmetic average EMC for each sampling parameter.

The results from the receiving water sampling events, and the subsequent water quality analyses, are summarized in a series of tables provided in Section 4.2.3 of the March 2017, *Combined Sewer System Characterization Report.* The results include sampling dates, the number of samples taken, fecal coliform concentrations, and calculated EMCs for selected water quality parameters.

A 2016 PA-DEP assessment of the Susquehanna River concluded that due to the shallow and wide physical characteristics of the river, tributary waters have limited opportunity to mix with the volume of river water that originates upriver. In the vicinity of Harrisburg, the PA-DEP study concluded that the river is divided into five distinct flow streams with water quality differences across the total river transect. **Figure 4-11** shows the five flow streams at Rockville, PA, located approximately one mile above Harrisburg. The 2016 PA-DEP integrated report indicates that CSO discharges from CRW regulators would tend to be shore-hugging plumes.

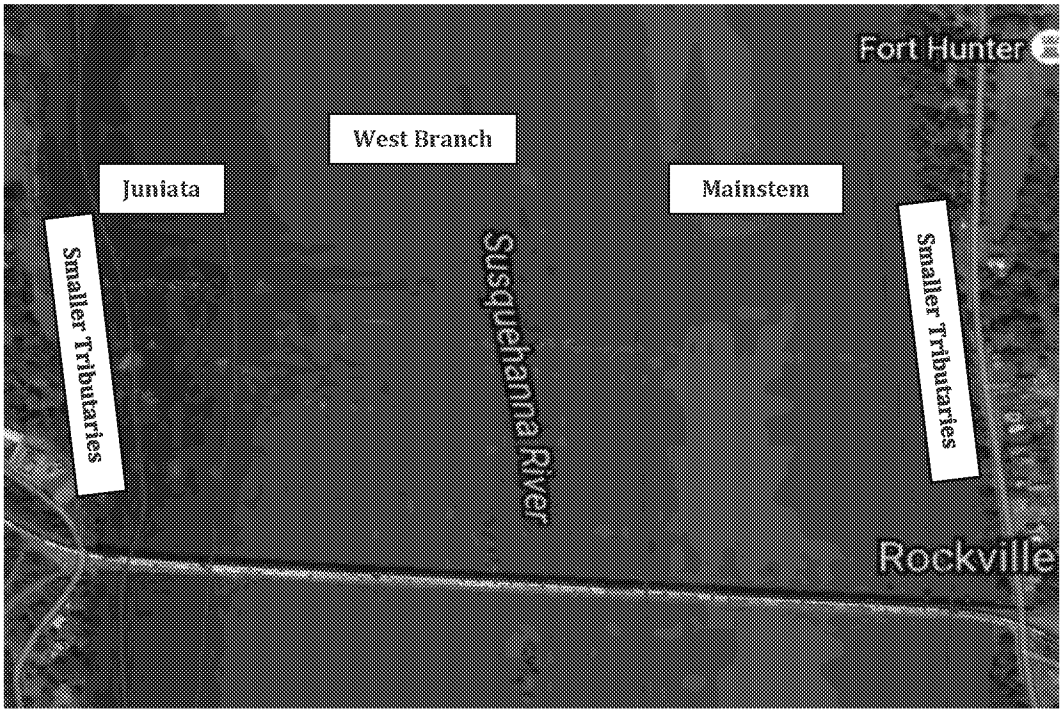

Figure 4-11: Susquehanna River Flow Streams in the Vicinity of Rockville, PA

4.6.4.2 Paxton Creek Sampling and Studies

Similar to CSO monitoring for locations along the Susquehanna River, four CSO outfalls discharging into Paxton Creek were monitored as part of CRW's 2005 Long Term Control Plan

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flow monitoring program. Sampling along Paxton Creek was conducted concurrently with sampling along the Susquehanna River, for CSO discharges during the same wet weather events between June and November 2003. The sampling analysis results were used to determine the combined sewer wastewater characteristics. The parameters measured include total settleable solids, total suspended solids, BOD_5, total nitrogen, total phosphorus, and fecal coliform bacteria. The system-wide average EMCs for each sampling parameter for all storm events were calculated.

4.6.5 Pollutants of Concern

Table 4-15 identifies the pollutants of concern associated with discharges from CRW's sewer systems to the Susquehanna River, Spring Creek, and Paxton Creek. These pollutants were identified based on the various water quality/stream attainability studies by PA-DEP and others, and from prior available water quality monitoring and modeling information. Further information is provided in the December 23, 2014 memorandum *LTCP Approach*.[18]

Sediment is identified as a pollutant of concern in Paxton Creek, Chesapeake Bay, and an unnamed Tributary of Spring Creek, but not the Susquehanna River. The 2008 Paxton Creek TMDL Report indicates that about 86 percent of the sediment concentration is attributed to stream erosion and the rest to wet weather discharges.

Table 4-15: Pollutants of Concern Discharging from CRW's Combined Sewer System

Pollutant of Concern	Susquehanna River	Paxton Creek	Unnamed Trib., Spring Creek	Chesapeake Bay
Sediment		✓	✓	✓
Bacteria	✓	✓		
Dissolved Oxygen / BOD		✓		
Nitrogen / Phosphorus			✓	✓

Bacteria is a pollutant of concern in Paxton Creek and the Susquehanna due to potential human health risks from pathogens during in-stream recreational activities. Elevated levels of bacteria are associated with CSO discharges and present a potential threat in areas of the Susquehanna used for recreation. No recreation occurs in Paxton Creek at this time.

Oxygen-demanding substances (e.g., BOD, COD) that cause dissolved oxygen concentrations to fall below limits necessary to sustain aquatic life are considered a pollutant of concern in Paxton Creek. Per PADEP's 2012 Susquehanna River Study, which included water quality monitoring between June and August 2012, dissolved oxygen concentrations along the east transect of the Susquehanna were less variable. This would indicate lower discharges of oxygen-demanding substances and/or higher aeration rates, and/or greater assimilation capacity of the receiving water, resulting in few observed in-stream DO depletion events. The Paxton Creek TMDL states, however, that DO depletion is an issue in Paxton Creek related to discharge of oxygen demanding substances in CRW's CSOs.

Nitrogen and phosphorus loads must be reduced under the Pennsylvania Chesapeake Watershed Implementation Plan, and to meet PA-DEP's pollution reduction requirements for an unnamed

[18] CDM Smith, Technical Memorandum, *LTCP Approach*, December 2014.

tributary to Spring Creek. As a result, nutrients should be considered pollutants of concern for wet weather discharges to each receiving water body. Existing levels of wet weather treatment achieved by CRW's combined sewer system, coupled with additional treatment achieved under the LTCP, will help achieve the targeted nitrogen load reduction of approximately 50 percent and the targeted phosphorus load reduction of approximately 40 percent. PADEP's May 2016 NDPES General Permit for Stormwater Discharges from small MS4s establishes minimum loading reductions of Chesapeake Bay pollutants of concern–10 percent for sediment, 5 percent for total nitrogen, and 3 percent for total phosphorus.

4.6.6 Priority and Sensitive Areas

Due to the distribution of the 58 CRW outfalls (2 CSO regulators share a common outfall) along the receiving waters and the relatively uniform characteristics of the receiving waters, there are not any Sensitive Areas as defined in the National CSO Policy in the receiving waters that would directly require more attention than others in evaluating LTCP options. Portions of the Susquehanna River are used for recreation, including fishing, boating, and swimming/wading. However, it should be noted that the primary points of direct contact (swimming and wading) within the Susquehanna River are located on City Island at the public beach, which is not susceptible to discharges from CRW's CSO outfalls due to the Susquehanna River's flow regime. Near-shore discharges to the Susquehanna do not migrate or disperse from the shore, as noted in the *2016 Pennsylvania Integrated Water Quality and Assessment Report, "...this results in five distinct water columns from the east to west shores in the Susquehanna River around Harrisburg, PA. These waters do not mix due to the Susquehanna River being relatively low and shallow."* Additional information is documented in the April 1, 2016 memorandum *Sensitive Areas/Priority Areas in the Harrisburg Receiving Waters*.

4.7 Regulatory Compliance Framework

This section summarizes the various regulatory obligations applicable to entities discharging to receiving waters of the Commonwealth, providing a framework for either demonstrating that the Program Plan is able to achieve compliance with these obligations or supporting a re-assessment of water quality objectives.

4.7.1 Framework for Structural/Operational Deficiencies and Debris Buildup

CRW's partial Consent Decree recognizes the significant remedial measures necessary to restore the operational integrity of the existing AWTF, conveyance system, and collection system after years of deferred maintenance. Paragraph 11(a)(iv) requires *"a program to evaluate the structural integrity and maintenance needs of the Conveyance and Collection Systems through internal inspections utilizing state of the industry technology.* Paragraph 11(a)(vii) further requires *"a program to identify and prioritize remedial work determined based on the findings of internal and visual inspections",* while Paragraph 11(a)(viii) requires *"a list that identifies and prioritizes equipment purchases for critical equipment".* This requirement supports CRW recommendations of priority remedial repairs and equipment upgrades for its AWTF and its two major pumping stations. The failure of any of these systems presents a heightened risk of major failures at this critical infrastructure, potentially leading to significant water quality and public health risks. The PCD considered these remedial cleaning and repair needs of such high priority that Paragraph 31 identified certain projects as early action projects:

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- High priority combined sewer interceptor improvements for the Paxton Creek, Asylum Run, and Front Street Interceptors.
- Repair of known sinkholes.
- Priority remedial repairs of CSO Outfalls.

A second major element of the framework for prioritizing structural/operational deficiencies and debris buildup is found in the *Government Accounting Standards Board (GASB) Statement 34.* This requires state and local governments to report the value of their infrastructure assets in annual financial reports, including a reporting of the value of infrastructure assets, the remaining useful value of these assets, and the cost of deferred maintenance (i.e., unmade repairs that result in equipment or facility deterioration). These GASB 34 requirements are based on asset management, which is defined in US-EPA's Reference Guides for Asset Management Tools as "… the practice of managing infrastructure capital assets to minimize the total cost of owning and operating them, while delivering the service level customers desire. Asset management is a framework widely adopted by the water sector as a means to pursue and achieve sustainable infrastructure." Failure to routinely address remedial repair and operational needs created by deferred maintenance affects the value of infrastructure assets and, consequently the financial position of their owner. As a result, re-investment in existing infrastructure has become a priority element of CRW's capital improvement and maintenance programs, resulting in an improved financial position.

4.7.2 Framework for Addressing Water Quality Degradation

Paragraph E(14) of CRW's partial Consent Decree requires CRW to "*complete and submit a revised and updated Long Term Control Plan ("LTCP") . . .* that . . . *shall conform to the requirements of the EPA's CSO Policy and EPA's "Guidance for Long-Term Control Plan, EPA 832-B-95-002, September 1995, and consider EPA's Greening CSO Plans: Planning and Modeling Green Infrastructure for Combined Sewer Overflow (CSO) Control, EPA 832-R-14-001, March 2014, and EPA's Integrated Municipal Stormwater and Wastewater Planning Approach Framework Memorandum, dated June 5, 2012*". This paragraph goes on to state that *"The updated LTCP shall include schedules, deadlines and timetables for remedial measures designed to meet the following goals:*

- *Bring all CSO discharge points into full compliance with the technology-based and water quality-based requirements of the CWA; and*
- *Minimize the impacts of CSOs on water quality, aquatic biota, and human health".*

4.7.2.1 Technology-Based Requirements of the CWA

Paragraph II(B) of US-EPA's CSO Control Policy[19] states *"Because the CWA requires immediate compliance with technology-based controls (section 301(b)), which on a Best Professional Judgment basis should include the nine minimum controls, a compliance schedule for implementing the nine minimum controls, if necessary, should be included in an appropriate enforceable mechanism".* Paragraph C of CRW's PCD provides the compliance schedule for implementing the nine

[19] Federal Register, *Environmental Protection Agency, Combined Sewer Overflow (CSO) Control Policy,* Vol. 59, No. 75, Tuesday April 19, 1994, Pages 18688 through 18698.

minimum controls, stating that CRW is to prepare and annually update a Nine Minimum Control (NMC) Plan which *"... shall evaluate and document the current level of implementation of the NMCs within the Combined Sewer System, and shall identify and include an implementation schedule for actions necessary for achieving compliance with the CSO Policy for all NMCs ..."*. CRW's latest NMC Plan was submitted to US-EPA on August 10, 2017[20]., documenting CRW's current level of compliance with the NMCs accompanied by an implementation schedule for remaining actions necessary to achieve compliance with remaining NMCs. Certain actions required to achieve compliance with the NMCs are to be reported in this Program Plan.

4.7.2.2 Water Quality-Based Requirements of the CWA

US-EPA's Combined Sewer Overflows, Guidance for Long-Term Control Plan[21] states that Permittees should develop LTCPs using one of two approaches:

1. *Demonstrate that its plan is adequate to meet the water quality-based requirements of the CWA ("demonstration approach"), or*
2. *Implement a minimum level of treatment (e.g., primary clarification of at least 85 percent of the collected combined sewage flows) that is presumed to meet the water quality-based requirements of the CWA, unless data indicate otherwise ("presumption approach").*

The guidance also defines two additional considerations for establishing water quality-based requirements for CSO control:

- *WQS authorities should review and revise, as appropriate, State WQS during the CSO long-term planning process.*
- *NPDES permitting authorities should consider the financial capability of permittees when reviewing CSO control plans.*

Further, the principles articulated by US-EPA's Integrated Municipal Stormwater and Wastewater Planning Approach Framework[22] will be applied, namely:

- *Reflect State requirements and planning efforts and incorporate State input on priority setting and other key implementation issues.*
- *Provide for meeting water quality standards and other CWA obligations by utilizing existing flexibilities in the CWA and its implementing regulations, policies and guidance.*
- *Maximize the effectiveness of funds through analysis of alternatives and the selection and sequencing of actions needed to address human health and water quality related challenges and non-compliance.*

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[20] Capital Region Water, *Nine Minimum Control Plan, Version 3.0*, August 2017, available at **https://capitalregionwater.com/cbh2o/**.

[21] US-EPA, Office of Water, *Combined Sewer Overflows, Guidance for Long-Term Control Plan*, EPA 832-B-95-002, September 1995.

[22] US-EPA, Memorandum, "*Integrated Municipal Stormwater and Wastewater Planning Approach Framework*", June 5, 2012.

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- *Evaluate and incorporate, where appropriate, effective sustainable technologies, approaches and practices, particularly including green infrastructure measures, in integrated plans where they provide more sustainable solutions for municipal wet weather control.*
- *Evaluate and address community impacts and consider disproportionate burdens resulting from current approaches as well as proposed options.*
- *Ensure that existing requirements to comply with technology-based and core requirements are not delayed.*
- *Ensure that a financial strategy is in place, including appropriate fee structures.*
- *Provide appropriate opportunity for meaningful stakeholder input throughout the development of the plan.*

This Program Plan is intended to serve as CRW's Integrated Municipal Stormwater and Wastewater Plan, and as such is designed to evaluate and establish priorities among a range of water quality and public health issues, including CSOs, SSOs, MS4 discharges, AWTF discharges, unauthorized releases from combined sewers, and non-point sources within CRW's service area.

Chapter 93 of the Pennsylvania Code defines designated uses of the Waters of the Commonwealth and the Water Quality Standards (WQS) for each use. Both the segments of the Susquehanna River and Paxton Creek receiving discharges from CRW's combined sewer system have been assigned the same designated uses:

- ***Aquatic Life***: Warm Water Fishery (WWF), Migratory Fishes (MF)
- ***Water Supply***: Potable (PWS), Industrial (IWS), Livestock, Wildlife, Irrigation
- ***Recreation***: Boating, Fishing, Water Contact Sports (WC), Aesthetics

The following water quality criteria apply to these designated uses:

- ***General Criteria***: Control floating materials, oil, grease, scum and substances that produce color, tastes, odors, turbidity or settle to form deposits.
- ***Specific Criteria***: The constituent concentration listed in Chapter 93 should not be exceeded. **Table 4-16** provides a partial list of constituents most applicable to CSO control.

In applying these water quality criteria, Pennsylvania Code Chapter 96 states that water quality criteria "*. . . shall be achieved in all surface waters at least 99% of the time, unless otherwise specified in this title*", and that general water quality criteria "*. . . shall be achieved in surface waters at all times at design conditions*". This criterion applies to the development of Total Maximum Daily Loads (TMDLs) and Water Quality-Based Effluent Limitations (WQBEL), along with the following criteria:

- Consider relevant design factors, including, but not limited to: water quality criteria duration, flow duration and frequency, natural seasonal variability in water temperature,

the natural variability of pH and hardness, the physical characteristics of a watershed, reserve factors, factors of safety, and pollutant contributions from other sources.

- Treat all pollutants as conservative unless it finds based on scientifically valid information that the substance is not conservative and adequate information is available to characterize the substance's fate or transformation, or both.

Pennsylvania Code Section 96 is relevant to episodic wet weather discharges, which occur at varying magnitudes, durations, and frequencies. Under this criterion, excursions from water quality criteria up to 1 percent of the time are allowed. In other words, excursions of water quality criteria are allowed up to a total of 3.65 days (87.6 hours) over a typical year. Compliance with water quality criteria for fecal coliform is evaluated based upon a geometric mean of five consecutive samples during a 30-day period.

Table 4-16: Numeric Water Quality Criteria for Designated Uses of Pennsylvania Waters

Constituent	Ambient Water Quality Standard	Use
Alkalinity	20 mg/l as CaCO3 (or natural alkalinity, if less)	WWF, MF
Ammonia Nitrogen	Varies, per pH of water	WWF, MF
Fecal Coliform	5/1 to 9/30: 200 per 100 ml (30-day geometric mean) 400 per 100 ml (<10% of monthly samples) 10/1 to 4/30: 2,000 per 100 ml (30-day geometric mean) Year Round: 5,000 per 100 ml (max monthly average) 20,000 per 100 ml (<5% of samples)	WC WC WC PWS
Chloride	250 mg/l	PWS
Color	75 units (platinum-cobalt scale)	PWS
Dissolved Oxygen	7-day average: 5.5 mg/l Minimum: 5.0 mg/l	WWF WWF
Fluoride	Daily Average: 2.0 mg/l	PWS
Iron	30-day average: 2.0 mg/l	WWF, MF
Manganese	1.0 mg/l	PWS
Nitrite plus Nitrate	10 mg/l as nitrogen	PWS
Osmotic Pressure	50 milliosmoles/kg	WWF, MF
pH	Between 6.0 and 9.0	WWF, MF
Phenolics	0.005 mg/l	PWS
Sulfate	250 mg/l	PWS
Temperature	Varies throughout year	WWF
Total Dissolved Solids	Monthly Average: 500 mg/l Maximum: 750 mg/l	PWS PWS
Total Residual Chlorine	4-day average: 0.011 mg/l 1-hour average: 0.019 mg/l	WWF, MF
Toxic Substances	Develop per Chapter 16	WWF, MF
Metals	Chronic, Acute Values	WWF, MF

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Based on the preceding discussion, CRW's Program Plan will evaluate four distinct levels of control:

- ***Baseline Level of Control***, involves multi-objective projects that provide priority remedial repairs to CRW's AWTF and conveyance system, coupled with other low cost, high performance projects that can improve the capacity, efficiency, and performance of the existing sewer system in the near term.
- ***Affordable Level of Control*** that represents the highest level of water quality control that can be achieved based on the financial capabilities of CRW's rate payers, balanced appropriately between the expenditures needed to address system rehabilitation needs and SSOs / unauthorized releases caused by hydraulic capacity limits.
- ***Cost-effective level of Control,*** defined as the wet weather controls at the "knee of the curve" of the cost-effectiveness analysis, where the inflection point in each cost curve indicates an optimal level of CSO control from a cost-to-benefit perspective.
- ***Presumptive Level of Control***, defined as the controls necessary to capture and treat 85 percent of the systemwide combined sewage during typical year precipitation.

4.7.2.3 Water Quality Requirements for Bacteria

The State of Pennsylvania water quality criteria for bacteria are based on fecal coliform and state:

> *(Fecal coliforms/100 ml) – During the swimming season (May 1 through September 30), the maximum fecal coliform level shall be a geometric mean of 200 per 100 milliliters (ml) based on a minimum of five consecutive samples each sample collected on different days during a 30-day period. No more than 10% of the total samples taken during a 30-day period may exceed 400 per 100 ml. For the remainder of the year, the maximum fecal coliform level shall be a geometric mean of 2,000 per 100 milliliters (ml) based on a minimum of five consecutive samples collected on different days during a 30-day period.*

These criteria are based on the use of in-stream water quality sampling data for assessing water quality attainment. Generally, the cost of sample collection and analysis limits water quality sampling programs in terms of the frequency of sample collection, the duration of the sampling program, and the number of sampling locations that can be cost effectively assessed.

4.7.3 Framework for Addressing SSOs and Unauthorized Releases

CRW's PCD is clear on the priority that should be given to sanitary sewer overflows (SSOs) and unauthorized releases from the combined sewer system. PCD Paragraph 27 is clear: *"All SSOs are prohibited".* Since the PCD defines SSOs to include *"(i) discharges to waters of the Commonwealth or United States from the Separate Sanitary Sewer System and (ii) any release of wastewater from the Separate Sanitary Sewer System to public or private property that does not reach waters of the United States or the Commonwealth of Pennsylvania, including but not limited to Building/Private Property Backups",* it is clear that this Program Plan must prioritize mitigation of hydraulic capacity constraints within the separate sanitary collection system, and their heightened risk to public health and safety equivalent to the water quality impacts caused by discharges to receiving waters.

Similarly, PCD Paragraph 34 states that "*All Unauthorized Releases from the Combined Sewer System are prohibited*" and defines an unauthorized release as "*any release of wastewater from the Combined Sewer System to public or private property that does not reach waters of the Commonwealth or United States, including Building/Private Property Backups*". As such, this Program Plan must prioritize mitigation of hydraulic capacity constraints within the combined collection system, and their heightened risk to public health and safety equivalent to the water quality impacts caused by CSOs. Clearly, traditional, end-of-pipe CSO controls focused on improvements to the conveyance system and AWTF do not address unauthorized releases, while more decentralized controls placed within the collection system could provide multiple benefits.

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Section 5

City Beautiful H_2O Program Planning Process

This section summarizes the governing principals, objectives, approach, and planning process for developing CRW's *City Beautiful H_2O Program Plan* (Program Plan). The Program Plan, is a long-term, integrated strategy to address the hydraulic and structural deficiencies of CRW's wastewater / stormwater assets, improve in-stream water quality, and protect public health. The planning process is outlined in **Figure 5-1**, illustrating how previous data collection and analyses have been incorporated to develop CSO control strategies for further evaluation. This process is consistent with both the US-EPA CSO Policy[1], and the US-EPA Integrated Municipal Stormwater and Wastewater Planning Approach Framework[2].

5.1 Overview of the Planning Process

CRW utilized three governing principals and objectives to guide the City Beautiful H_2O Program planning process:

- Be affordable and cost-effective
- Balance control of CSOs, SSOs, "unauthorized discharges", and MS4 discharges
- Optimize multi-objective opportunities to control stormwater, rehabilitate CRW assets, and enhance service area communities

The four-step planning process illustrated in **Figure 5-1** is summarized here and described in more detail in the subsequent subsections of this section.

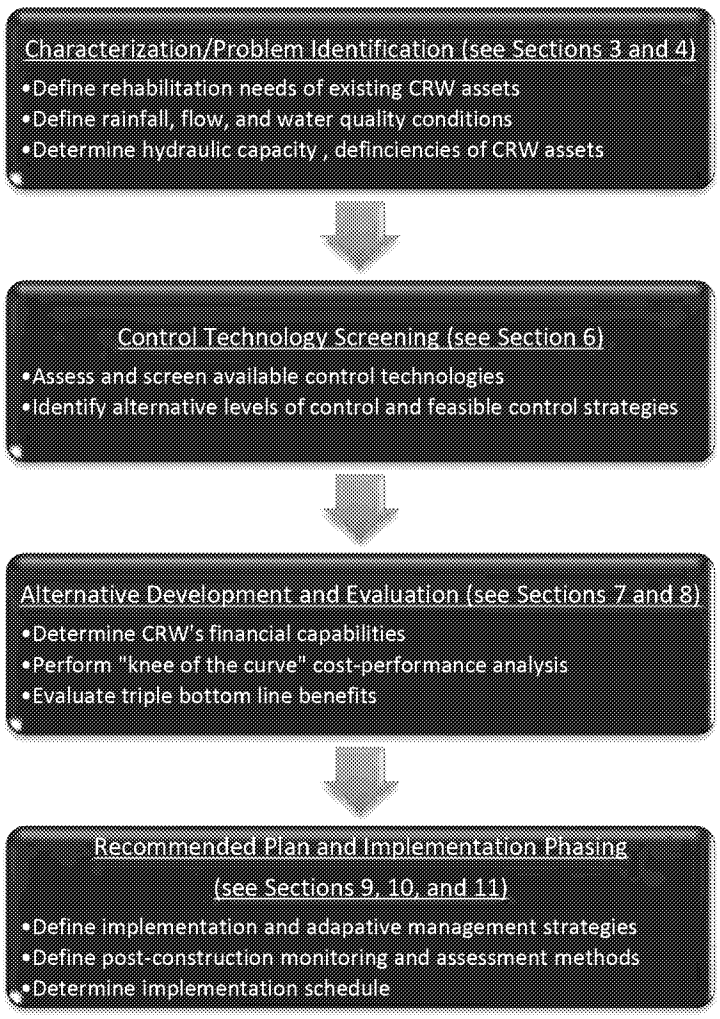

Figure 5-1: Summary of Integrated Wet Weather Control Plan Process

[1] Federal Register, *Combined Sewer Overflow (CSO) Control Policy: Notice; Part VII Environmental Protection Agency,* Vol. 59, No. 75, April 19, 1994, pp 18688 through 18698, Washington, DC.

[2] Stoner, Nancy, Memorandum: *Integrated Municipal Stormwater and Wastewater Planning Approach Framework,* June 5, 2012, U.S. Environmental Protection Agency, Washington, DC.

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Characterization/Problem Identification involves the activities and processes used to characterize the CRW service area, including:

- The configuration and rehabilitation needs of CRW's treatment, conveyance, and collection assets,
- The characteristics of rainfall over CRW's service area, the wastewater/stormwater flows within CRW's sewer systems, and quality and condition of surface waters that receive discharges for CSW's systems, and
- The hydraulic performance of CRW's combined sewer system and separate sanitary sewer system, including the quantity and quality of discharges from this system.

Sections 3 and 4 of this Program Plan summarize the findings of CRW's characterization and problem identification process. Planning procedures for performing these tasks are included in these sections. CRW's characterization and problem identification process revealed substantial asset rehabilitation needs attributable to years of deferred maintenance throughout the treatment, conveyance, and collection systems. Hydraulic evaluation revealed frequent, short-duration overflows at each of CRW's regulated CSO outfalls, coupled with localized collection system flooding and potential basement backups. Evaluation of water quality data indicated that CRW's CSO and municipal separate stormwater sewer system (MS4) discharges, coupled with significant hydromodification of Paxton Creek, contribute to water quality degradation.

Control Technology Screening involves the initial planning processes by which decentralized and multi-objective control opportunities were identified for CRW's treatment and conveyance systems, along with designated planning areas within CRW's collection system. It explains how the planning areas were selected and delineated. It goes on to describe the screening analyses used to evaluate and pare down the alternative control opportunities, and defines baseline alternatives. Section 5.3 summarizes the screening processes used to define feasible technologies and develop alternative control strategies for CRW's assets. Complete findings of the technology screening process are found in Section 6.

Alternative Development and Evaluation, defines appropriate control technologies for each control strategy, determines the "knee-of-the-curve" cost performance, and evaluates the benefits of each strategy using triple bottom line (TBL) evaluation criteria. The process is explained in Section 5.4.

- Formulating baseline, systemwide, and local control strategies, composed of specific feasible control technologies that meet the identified planning objectives and the opportunities to further enhance wet weather control,
- Using a "knee-of the curve" cost evaluation process to size alternative control technologies to achieve each alternative level of control being evaluated, i.e., an affordable, cost-effective, and water quality compliant level of control.
- Employing a "triple bottom line" decision making process to select a preferred control strategy (or combination of strategies) for CRW's treatment, conveyance, and collection assets.

- Performing a financial capabilities analysis according to US-EPA protocol and using it to establish realistic investment strategies and phasing of priority system rehabilitation and wet weather controls.

The CRW Program Plan has adopted a triple bottom line (TBL) accounting framework that incorporates three dimensions of performance: social, environmental and financial. TBL is a concept which seeks to broaden the focus on the financial bottom line by including social and environmental responsibilities and Program benefits. The CRW planning process included preparing and considering three different (and quite separate) bottom lines. One was the traditional measure of cost versus benefit, the bottom line. The second was the bottom line of the Plan's "people account", a measure in some shape or form of how socially responsible the Plan is in improving the quality of life for CRW's customers. The third was the bottom line of the Plan's "planet" account, a measure of how environmentally responsible it is.

Recommended Plan and Implementation Phasing employs a financial capability assessment (FCA) to determine an affordable, balanced level of investment in CRW's assets, and uses this evaluation to establish appropriate program phasing and limits on program financing. In addition, an adaptive management process is defined that sets program milestones, establishes a long-term monitoring and implementation tracking system to measure progress, and establishes decision-making metrics for future adjustments to the implementation schedule under an evolving adaptive management process. This process is explained in Section 5.5.

5.2 Characterization and Problem Identification

The first major phase of the Program Plan development process was to implement the activities and processes required to fully understand the existing system; how it is configured, its current condition and defects, and how it performs hydraulically. Characterization and problem identification were addressed in Sections 3 and 4 of this Program Plan. This section summarizes the key elements of the planning process used to develop this portion of the Program Plan.

5.2.1 Evaluation of Collected System Data and Monitoring Results

A brief summary of the data collection process is provided in Section 3.2. In addition, flow/precipitation/stream depth monitoring data and system condition data were processed and analyzed to understand the existing system and characterize existing hydraulic conditions.

5.2.2 Hydrologic and Hydraulic Model Development

After collecting the required data, a hydrologic and hydraulic (H&H) model was developed and used as a tool to simulate existing conditions and evaluate alternative control strategies and levels of control. The H&H model was developed from the collected data, and was calibrated and subsequently used to quantify and characterize sewer system flows and the frequency, duration and volume of CSO discharges into receiving water bodies. Refer to Section 3.4. The calibrated model was then used to characterize the changes in hydraulic flow through the conveyance system and the changes to CSO discharges to receiving waters under a range of selected alternative improvements/ controls.

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5.2.3 Characterization of Existing Combined Sewer Systems

The next step in planning process is to utilize the calibrated H&H model to quantify and characterize the hydraulic performance of the combined sewer system and identify specific areas of surface flooding or potential basement flooding or backups. Refer to Section 4.4. Concurrently, the system inspection data and subsequent condition assessment analyses were used to characterize the condition of the existing conveyance and collection systems, and to identify critical defects that need to be corrected as part of the Plan. Many system rehabilitation projects, to be included and scheduled in the Plan, have already been identified from the inspection information gathered.

As continuing CCTV inspections are completed, the list of rehabilitation projects will be updated and re-prioritized as needed. The reality is that there will likely be more identified significant problem areas than there is available budget to repair, as demonstrated in Section 7. Rehabilitation projects may be deferred until budget becomes available. Imminent defects requiring immediate rehabilitation may require reallocating budget from green infrastructure or CSO control budgets, and may ultimately result in a worst-case scenario, reducing the level of CSO/SSO/MS4/unauthorized release control provided by the Program Plan.

5.2.4 Characterization of Existing Separate Sanitary Sewer Systems

A thorough understanding of CRW's separate sanitary sewer systems was developed. The Program Plan must address both CSO and SSO discharges as well as MS4 stormwater discharges and unauthorized releases (sewage surface flooding, dry weather overflows, and basement backups) from the combined system. The calibrated H&H model was used to quantify and characterize the hydraulic performance of the separate sewer system and identify locations for potential SSO discharges and basement flooding. Refer to Section 4.5. Concurrently, the system inspection data and subsequent analyses were used to characterize the condition of the existing conveyance and collection systems, and to identify critical defects and hydraulic bottlenecks that need to be corrected as part of the Program Plan.

5.3 Control Technology Screening

The second major phase of the Program Plan development process consists of evaluating available stormwater/wet weather control technologies, categorizing them to fit the baseline, systemwide, and local control strategies, and eliminating from consideration technologies that are not feasible or relevant to implement within CRW's system. Section 6 presents the full evaluation and screening of available control technologies.

5.3.1 Describe, Evaluate Feasibility of Available Control Technologies

CRW established a list of technologies that are commonly used for stormwater/wet weather control, sewer rehabilitation, and hydraulic enhancements. Refer to Section 6 for these technologies. Each of these control technologies is further assessed and categorized to fit into the various control strategies under this Program Plan (identified in Section 5.3.2 below) to identify feasible and cost-effective technologies to be further refined, and those that will not be considered. The identified technologies were screened based upon construction feasibility, siting feasibility, cost effectiveness, and other criteria. Technologies that were clearly not constructible, would not fit within the available space, are not cost-effective, or are not applicable to the CRW

service area were ruled out. Technologies that were feasible, cost-effective and applicable were retained for further evaluation in Section 8.

5.3.2 Define Alternative Levels of Control

CRW's partial Consent Decree requires performance of a "knee-of-the-curve" cost performance evaluation. The findings of this evaluation are presented throughout Section 8. This "knee-of-the-curve" evaluation, in turn, is used to define four distinct levels of control:

- ***Level 1: Baseline Level of Control.*** The level of control provided by the multi-objective projects that optimize the existing sewer system, which include relatively low-cost operating changes, repairs, and small-scale capital projects.
- ***Level 2: Affordable Level of Control.*** The level of control that would lie within the maximum financial capabilities of CRW's ratepayers without severe economic hardship, as defined in Section 7.
- ***Level 3: Cost-Effective Level of Control.*** The level of control provided at the inflection point of the "knee of the curve", where the ratio of the control benefits to the associated control cost is maximized, based on analyses described in Section 8.
- ***Level 4: Presumptive Level of Control.*** The level of control provided by implementing sufficient wet weather controls to capture and treat 85 percent of the systemwide combined sewage during the typical year.

5.3.3 Define a Baseline Level of Control

A baseline level of control involves multi-objective projects to first rehabilitate, then provide routine renewal of CRW's assets, including its AWTF, its major pumping stations, its interceptors, and its various CSO regulator structures. Included are asset rehabilitation projects that include hydraulic/treatment enhancements feasible to incorporate into the existing AWTF, pump station, and/or CSO regulator structures. Defining the baseline level of control involves:

- Define "baseline" technologies that are low-cost, simple changes, including minimum control measures, operational changes, and simple structural refinements that optimize or enhance the existing system.
- Provide an ongoing program of rehabilitation and renewal of CRW assets to recognize and address critical risks, enhance system resiliency, and restore/enhance the hydraulic capacity of existing assets where cost-effective (i.e., no new or replacement assets).
- Determine the associated level of control. This will provide a starting point for establishing feasible systemwide and local control strategies.
- Phase the implementation of baseline controls using risk-based prioritization criteria and cost-effectiveness considerations, defined based on financial capabilities analysis presented in Section 7.

Program Plan Section 4.2 provides descriptions of the high risk/high priority projects at the AWTF and along the conveyance system that are included in the baseline level of control.

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5.3.4 Delineate Program Planning Areas

CRW's service area was divided into program planning areas, a standard procedure for the development of all LTCPs. Fifteen planning areas were delineated, some largely separate and some largely combined. This delineation was based on receiving water, interceptor sewershed, recognized neighborhoods, and logical groupings of catchments to support satellite control strategies. A map of the delineated planning areas is found in **Figure 5-2**.

5.3.5 Establish Feasible Systemwide and Local Control Strategies

The next step in the planning process is to formulate feasible control strategies. First, the following two *systemwide control strategies* start with the baseline strategy and progressively integrate appropriate control technologies into CRW's AWTF and conveyance system:

- ***Systemwide Strategy 1***: achieve the full hydraulic conveyance capacity of CRW's interceptors (approximately 120 MGD) by increasing the AWTF hydraulic/primary treatment capacity, adding additional pumping capacity, and replacing restrictive connector pipes at CRW regulators.
- ***Systemwide Strategy 2***: install deep tunnels parallel to CRW's conveyance system, including consolidation sewers from CSO regulators to tunnel drop shafts and new dewatering pump stations, increasing overall conveyance and storage within CRW's conveyance system.

Next, the following three *local control strategies* start with the baseline strategy within each of the program planning areas, and progressively integrate appropriate control technologies into CRW's collection system:

- ***Local Strategy 1:*** A *decentralized control strategy* that focuses controls (a) within catchments where the baseline strategy does not achieve the desired CRW level of control and (b) to achieve multi-objective benefits (e.g., reduce CSOs/SSOs/unauthorized discharges, and MS4 discharges; maximize triple bottom line benefits, leverage non-traditional funding sources).
- ***Local Strategy 2:*** A *satellite control strategy* that employs storage/treatment/conveyance facilities focused on CSO control within catchments where the baseline strategy does not achieve the desired CRW level of control.
- ***Local Strategy 3:*** A *sewer separation strategy* within catchment areas where the baseline strategy does not achieve the desired CRW level of control, defining various percentages and areas of the collection system to separate to achieve desired control levels.

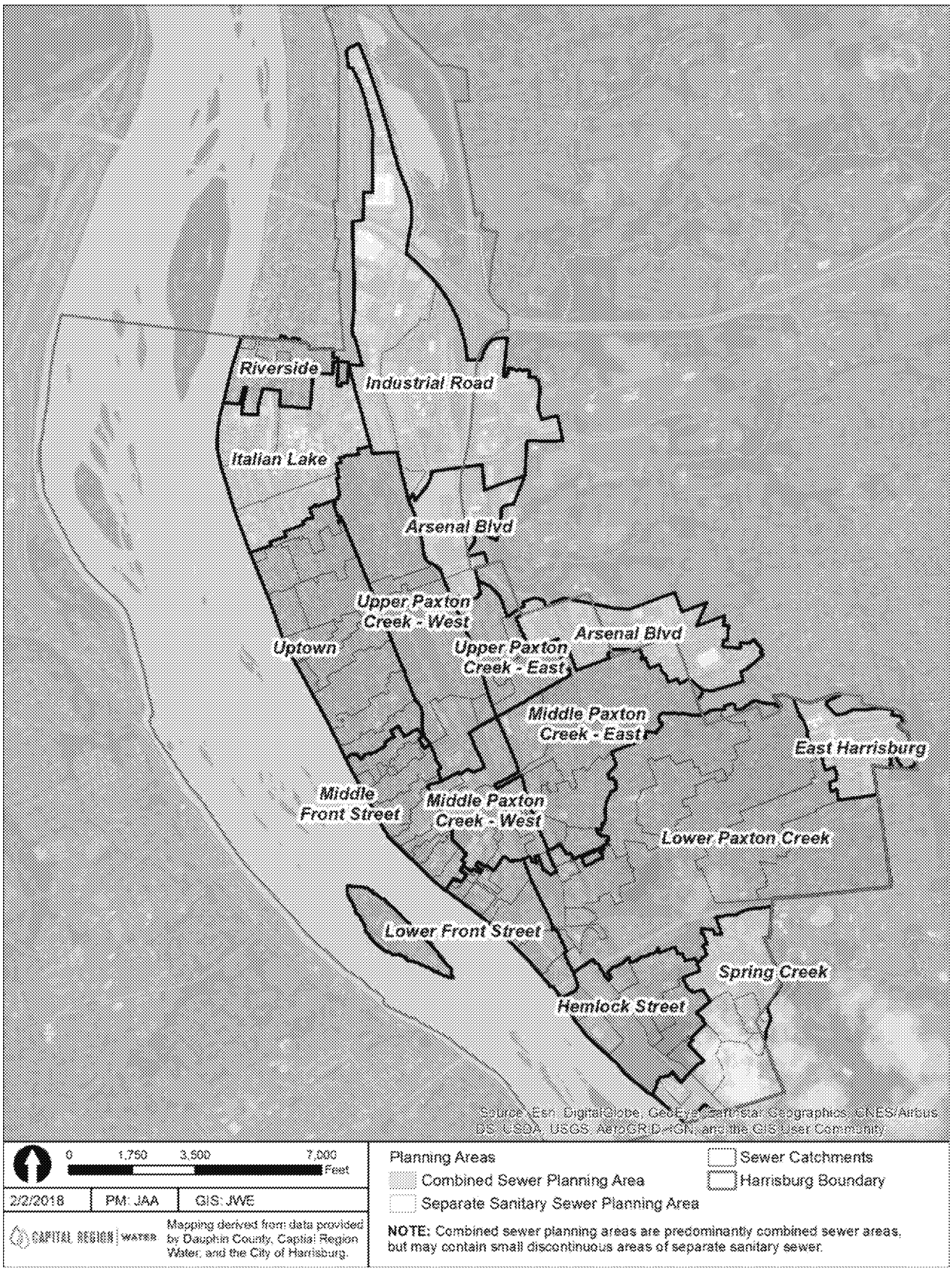

Figure 5-2: Designated Planning Areas within the CRW Service Area

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Within each of the program planning areas, control strategies are developed to best balance the following three priorities.

- Reduce CSO discharge volumes and frequencies to mitigate water quality impairment.
- Mitigate hydraulic pinch-points and their associated risks of unauthorized releases and SSOs.
- Improve the structural integrity and resilience of priority sewer assets.

Alternative controls to consider may include a combination of further modifications to CSO regulator structures and connector pipes, required rehabilitation for grade 4 (poor condition) and 5 (very poor condition) pipe defects, solutions for localized flooding and basement backup areas, and green stormwater infrastructure opportunities. As required sewer rehabilitation projects come up on the series of 5-year schedules, opportunities for additional levels of stormwater/CSO control will be identified and assessed for potential project elements such as oversizing the damaged pipe reach to provide additional storage, adding supplemental green stormwater infrastructure to the project for stormwater runoff control, etc.

5.4 Alternative Development and Evaluation

The third major phase of the Program Plan development process is to evaluate and select appropriate control technologies for each control strategy, conduct the "knee-of-the-curve" cost performance analyses (including limitations on the level of control achievable within each strategy), and evaluate the benefits of each strategy using triple bottom line evaluation criteria.

5.4.1 Define Alternatives to Enhance Wet Weather Control

Specific control technologies were selected for each control strategy, as well as feasible levels of implementation based upon an evaluation of the opportunities and barriers to implementing these controls within CRW's system across the range of sizes necessary to define the "knee-of-the-curve" as defined in the Partial Consent Decree (PCD). The PCD requires CRW to evaluate system-wide sewer separation and system-wide tunnel storage alternatives regardless of financial/implementation feasibility or cost effectiveness.

CRW has developed and assessed a series of decentralized approaches that implement various combinations of the grey control technologies and the green control technologies that were selected through the previously completed control technology screening process. Specific decentralized strategies have been developed for each of the designated planning areas within the CRW service area. The series of evaluated strategies provided a range of levels of CSO discharge control. Each level of control has an associated cost and resulting benefits.

5.4.2 Perform Knee-of-the-Curve Cost Performance Analyses

A knee-of-the curve cost performance evaluation was performed for the entire control range for each selected decentralized alternative within each of the designated planning basin areas. A knee-of-the curve cost performance evaluation was also performed for the entire range of PCD-required system-wide sewer separation and system-wide tunnel storage alternatives. The process, illustrated in **Figure 5-3**, is intended to identify whether a systemwide or

decentralized/local control strategy is best for the CRW service area under each level of control, as well as identify potential implementation and feasibility issues, including economic feasibility constraints.

5.4.3 Determine Benefits and Costs of each Control Strategy

The CRW Program Plan has adopted a triple bottom line (TBL) framework for evaluating the alternative control strategies that incorporates three dimensions of performance: social, environmental and financial. TBL is a concept which seeks to broaden the focus on the financial bottom line by including social and environmental responsibilities and Program Plan benefits. CRW prepared a strategic plan for the entire organization, setting strategic goals and objectives for measuring performance. Those strategic objectives associated with CRW's stormwater / wastewater system were incorporated into the TBL framework for alternatives evaluation, as illustrated in **Table 5-1**. In addition, specific criteria are noted for each TBL objective, which were taken into consideration during the evaluation.

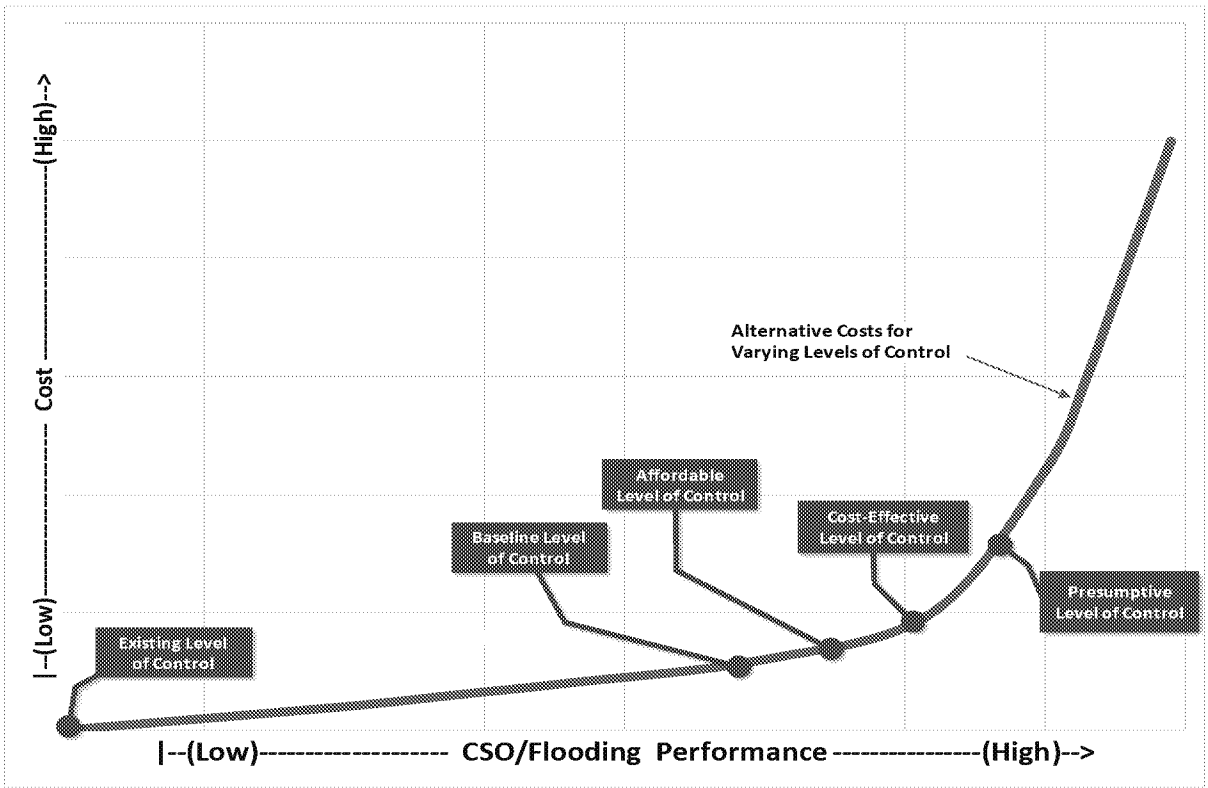

Figure 5-3: Example Cost Performance Curve with Differing Endpoints

The CRW planning process included preparing and considering three different (and quite separate) bottom lines. One is ***financial***, the traditional measure of profit, the bottom line of the cost and benefit analysis. The second is ***social/community***, the bottom line of the Plan's "people account", a measure in some shape or form of how socially responsible the Plan is in improving the quality of life for CRW's customers. The third is ***environmental,*** the bottom line of the Plan's "planet" account, a measure of how environmentally responsible it is.

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Table 5-1: Triple Bottom Line Evaluation Criteria and Relationship to CRW Strategic Goals and Objectives

Triple Bottom Line Category	CRW Strategic Planning Goals	CRW Strategic Planning Objectives	Evaluation Criteria to Consider
Financial	Efficient Use of Resources	Use Financial Resources Efficiently	▪ Capital cost-effectiveness ▪ O&M cost-effectiveness ▪ Potential operational/resource impacts
		Use Energy Efficiently	▪ Anticipated energy use
		Integrate Infrastructure/Operations to Achieve Multiple Objectives	▪ Strategy addresses multiple objectives ▪ Strategy achieves operational efficiencies ▪ Strategy integrates programs/facilities
	Infrastructure Stability	Ensure Reliable Operations	▪ Technologies are feasible and reliable ▪ Strategy is acceptable to regulators
		Minimize Construction Difficulty/Risk	▪ Anticipated construction difficulty, risk
		Ensure Flexibility, Adaptability, and Expandability of New Infrastructure	▪ Flexibility to address multiple risks ▪ Public-private partnership opportunities ▪ Adaptive management opportunities
Social/ community	Customers and Stakeholders	Increase Customer and Stakeholder Satisfaction	▪ Is affordable to ratepayers ▪ Has stakeholder support ▪ Integrates with community objectives ▪ Environmental justice population impacts
	Workforce	Create Employment Opportunities at CRW and in the Community	▪ Employment opportunities at CRW ▪ Employment opportunities in City
Environmental	Public Health and the Environment	Improve Water Quality	▪ CSO volume/frequency reduction ▪ Pollutant load reduction ▪ Addresses pollutants of concern ▪ Addresses sensitive/priority areas ▪ Regulatory compliance considerations
		Support Long-term Community Health	▪ Reduced risk of SSOs ▪ Reduced risk of unauthorized releases ▪ Increases green space/vegetation/trees

5.5 Recommended Control Plan and Implementation Phasing

The final phase of the Program Plan development process is to use the findings of the screening activities and the selected control strategy/technology combinations to consider a range of facility sizes and associated control ranges, and to conduct cost-effectiveness analyses to identify the optimal control range and implementation duration. A control plan is selected that minimizes CSO discharges, improves water receiving quality, addresses stormwater management and local flooding, and meets affordable guideline constraints for rate payers.

5.5.1 Determine Affordability of Alternative Control Levels

From a triple bottom line perspective, based upon the knee-of-the curve cost performance results, the affordability limits, and the identified optimal solutions for each of the program planning areas, select the preferred control strategy (or combination of control strategies) for the affordable level of control.

5.5.2 Prioritize and Phase Implementation of Controls

The selected plan, as identified and defined in the Program Plan, will evolve over time under an adaptive management implementation approach. To facilitate an adaptive management approach, required sewer rehabilitation projects (for pipe reaches with grade 4 or 5 defects) will be

identified on the series of 5-year schedules. These 5-year schedules and the associated selected projects and costs, will evolve as new CCTV information becomes available and implementation priorities adjust accordingly. It must be understood that strongly desired projects and/or control facility elements may need to be ruled out because their costs are obviously outside the range of affordability, even though the component may be "needed" or provide significant desired benefits. Unless an unmet/unaffordable need is critical with significant and unacceptable consequences, many desirable projects or project elements will not be included in the Program Plan because of affordability constraints. Under the adaptive management approach, opportunities for additional levels of stormwater/CSO control will be identified and assessed as each individual prioritized rehabilitation project is scheduled for implementation. The design process will include identifying potential grey/green project elements that would provide additional stormwater runoff control and reduce demands on sewer infrastructure.

5.5.3 Prepare Integrated Wet Weather Control Plan

The *City Beautiful H_2O Program Plan* was prepared to address all required elements of the PCD, the CSO Control Policy, the CSO LTCP Guidance, and US-EPA's integrated stormwater/wastewater planning strategy. PCD requirements and other PCD compliance documents were summarized and/or incorporated into the Program Plan by reference.

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Section 6

Control Technologies and Screening

6.1 Overview of Control Technologies and Screening

This section describes the potential Combined Sewer Overflow (CSO) control technologies to be considered by Capital Region Water (CRW). The technologies included are generally grouped into the following categories:

- Source Controls: Technologies, operating strategies, and policies that affect the quantity and quality of runoff that enters CRW's combined sewer system.
- Conveyance/Collection System Control: Modifications within the collection system that affect CSO flows and loads after the introduction of runoff.
- Storage Technologies: In-line and off-line storage for wet weather flows that are detained and released once treatment and conveyance capacity have been restored.
- Treatment Technologies: Technologies to reduce pollutant load to the receiving waters.
- Receiving Water Technologies: Methods for removing pollutants after they have been discharged to the receiving waters.

6.2 Identification of Feasible CSO Controls

6.2.1 Source Controls

Green Stormwater Infrastructure (GSI): Specific sets of source controls that use natural processes such as infiltration, evapotranspiration, and filtration, storage, and controlled release to reduce the volume of stormwater entering the sewer system. Green stormwater infrastructure includes bioretention, subsurface infiltration, green roofs, porous pavement, rain gardens, and street trees, and is capable of providing significant levels of control over the course of a year through their performance in small- to moderate-sized storms.

Inflow Reduction: A variety of control measures can be utilized to reduce the inflow of stormwater and/or pollutants to the combined sewer. These include roof leader disconnections, sump pump disconnections, catch basin modifications and maintenance, street storage (catch basin inlet control), etc.

Construction-Phase Controls: The Dauphin County Conservation District (District) enforces construction-phase erosion and sediment (E&S) control within the CRW service area in accordance with PA-DEP requirements. These measures reduce the load of solids to the combined sewer and receiving waters. District staff review and approve E&S plans submitted by developers and conduct site inspections during construction, levying fines if necessary to ensure compliance.

Post-Construction Controls: CRW enforces stormwater management rules and regulations for new development and redevelopment. Post-construction controls are most effective for CSO

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control where they focus on restoring a more natural balance between stormwater runoff and infiltration, reducing pollutant loads, and controlling runoff rates at levels that minimize stream bank erosion. CRW has initiated a pilot green infrastructure program to better define design criteria and potential enhanced regulations that address impairment of a surface water body in Harrisburg. Site designers can provide the level of performance required using a variety of controls such as disconnection of impervious cover, bioretention, subsurface storage and infiltration, green roofs, swales, and tree canopy.

Pollution Prevention/Good Housekeeping: Several good housekeeping practices can reduce pollution in local waterways, such as proper handling of hazardous materials, spill prevention, and street sweeping. Additional means of preventing pollution include requirements for industrial pretreatment and stormwater management, septic system management, household hazardous waste collection, and litter and illegal dumping enforcement.

6.2.2 Conveyance/Collection System Controls

Sewer Separation: An inflow removal/source control method whereby a combined sewer system is divided into separate sewers/pipes for sanitary and stormwater flows. The scope of work could be limited to sewers within the public right-of-way or it could extend to private property. Sewer separation can be accomplished by providing new sanitary sewers, including private connections to existing structures and constructing a new separate sanitary collection system. The existing combined sewers will then serve as the new separate storm sewers. Sewer separation can also be accomplished by leaving the previously combined sewers as sanitary sewers and new storm sewers would be constructed. This is more commonly referred to "stormwater redirection." Complete separation involves both public and private inflow removal whereas partial separation involves only the public inflow sources, such as a catch basin in the public right-of-way.

Optimization of Existing System: Use of the collection system for storage has long been recognized as a potentially cost-effective means to mitigate the occurrence and impacts of CSOs. An approach that can be implemented to gain additional in-system storage is to raise the overflow elevation by physically modifying the overflow structure (e.g. raising an overflow weir). However, this approach must be implemented cautiously, since raising the overflow elevation also raises the hydraulic grade line in the combined trunk sewer during storm flows, and therefore increases the risk of basement and other structural flooding within the upstream sewer system due to backup or surcharge problems.

Real-Time Control: Real-time controls are controlled CSO outfall/regulator gate facilities that use level monitors to control the position of the connector pipe gate and tide gate at each location for maximizing the utilization of in-system storage in the combined sewer system. These computer controlled outfall facilities apply real-time control (RTC) mechanisms to maximize in-system storage. The use of RTC allows the capture and delivery to the treatment works of flow at the maximum rate at which it can be treated. This approach is attractive in terms of optimizing the use of the existing sewer system to capture combined wastewater and minimize CSOs.

Regulator/Pump Station Inspection/Maintenance/Repairs: In order to keep the regulators and pumping stations optimized it is necessary to have routine site inspections and maintenance performed. It is not uncommon for debris and grit to interfere with regulator and pump

operations and therefore, expansion and continuation of the current regulator and pumping station inspection and maintenance programs will allow for efficient detection of malfunctioning regulator and/or pumping stations. Presently, the maintenance and repair program relies on site inspections to identify faulty mechanisms, grit or debris build-up and/or damage to the regulator or pumping structure itself. The observations are documented and updated in a database to track repairs.

Outfall and Regulator Consolidation: Where several outfalls are near each other, CRW can investigate whether to consolidate them to a single location for storage and/or treatment. Consolidation can provide more cost-effective control of CSOs, minimizing the number of sites necessary for abatement facilities, and reducing the number of permitted outfalls. In waterfront areas where redevelopment is taking place and new public amenities are being created, elimination of outfalls can remove an impediment to public use and enjoyment of the waterfront.

Outfall Maintenance Program: Because of the debris normally present in combined sewage, regulators are particularly susceptible to the accumulation of materials that cause clogging and blockages. Trash blockages at the entrance to the orifice of the interceptor increase head loss through the orifice and cause the majority of unnecessary overflows in passive regulators. Other causes of unnecessary diversions at regulators include weir plates or dams that are improperly set, damaged, or broken off. Similarly, tide gate failure can often be attributed to trash or debris becoming lodged in the gate, or corrosion of the gate or deterioration of the gate gaskets. Tide gate failure allows the receiving water to enter the combined sewer system (CSS), reducing the storage and flow capacity.

Sewer System Inspection and Cleaning: Maintenance of sewers includes activities required to keep the system functioning as it was originally designed and constructed. Any reinvestment in the system, including routine maintenance, capital improvements for repair or rehabilitation, inspection activities, and monitoring activities are generally classified as maintenance.

An inspection program is vital to proper maintenance of a wastewater collection system. Without inspections, a maintenance program is difficult to design, since problems cannot be solved if they are not identified. Sewer inspections identify problems such as blocked, broken, or cracked pipes; tree roots growing into the sewer; sections of pipe that settle or shift so that pipe joints no longer match; and sediment and other material building up and causing pipes to break or collapse. The elements of an inspection program include flow monitoring, manhole inspections, smoke/dye testing, closed circuit television inspection, and private sector inspections. Private sector building inspection activities include inspection of area drains, downspouts, cleanouts, sump discharges, and other private sector inflow sources into the system.

In addition to inspection, routine maintenance must also include sewer cleaning, root removal/treatment, cleaning of mainline stoppages, cleaning of house service stoppages, and inspections and servicing of pump stations.

Parallel Interceptors: Parallel interceptors provide increased transmission capacity to bring flows to the Advanced Wastewater Treatment Facility (AWTF).

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Remove Flow Bottlenecks: CRW's collection system includes some localized instances where infrastructure does not have the capacity to convey the full flow from upstream. Examples include siphons and pipes of smaller diameter than upstream pipes. In these cases, localized replacement may be a cost-effective way to increase transmission capacity to the AWTF.

Combined Sewer Rehabilitation: An inspection program may identify sections of sewer that are in poor condition and in need of major repair or replacement. Under the traditional method of sewer relief, a replacement or additional parallel sewer line is constructed by digging along the entire length of the existing pipeline. While these traditional methods of sewer rehabilitation require unearthing and replacing the deficient pipe (the dig-and-replace method), trenchless methods of rehabilitation use the existing pipe as a host for a new pipe or liner. Trenchless sewer rehabilitation techniques offer a method of correcting pipe deficiencies that requires less restoration and causes less disturbance and environmental degradation than the traditional dig and-replace method.

Diversion of Trunk Flow Directly to AWTF: For a limited number of small catchment areas close to the AWTF, it may be possible to divert all trunk flow to the AWTF without regulation.

6.2.3 Storage Technologies

In-Line Storage in Interceptor or Trunk Sewer: In-line storage can be developed in two ways: (1) construction of new tanks or oversized conduits to provide storage capacity or (2) construction of a flow regulator to optimize storage capacity in existing conduits. The new tanks or oversized conduits are designed to allow dry weather flow to pass through, while flows above design peaks are restricted, causing the tank or oversized conduit to fill. A flow regulator on an existing conduit functions under the same principle, with the existing conduit providing the storage volume. Developing in-line storage in existing conduits is typically less costly than other, more capital-intensive technologies, such as offline storage/sedimentation, and is attractive because it provides the most effective utilization of existing facilities. The applicability of in-line storage, particularly the use of existing conduits for storage, is very site-specific, depending on existing conduit sizes and the risk of flooding due to an elevated hydraulic grade line.

Earthen Basins: Generally, there are three types of earthen basins used in stormwater management design: Detention, Wet Weather Retention, and Infiltration. All basins are supplemented with some form of underdrain and emergency overflow structure to manage flow into the combined system. Detention basins are large areas of depression within a pervious location that remains dry except during wet weather events. The detention basins capture wet weather runoff during storm events and detain the runoff to attenuate peak flows into the combined system. Wet weather retention basins always have a small pond of water and generally are vegetated. The retention pond allows for greater nutrient and solids removal than that of the detention basin. Infiltration basins are constructed with a more intricate underdrain system to facilitate nutrient and solids removal as well as infiltration and groundwater recharge of captured stormwater.

Earthen basins, as described above, may be implemented in a variety of sizes and locations to help meet stormwater management needs for large or small drainage areas. The flexibility of

earthen basins allow for them to be used in conjunction with other stormwater management practices to reduce CSOs into receiving waters.

Offline Above or Below Grade Closed Storage Tanks: Off-line or tank storage control technologies are designed to capture a prescribed volume of overflow, with no provisions for flow-through operation. Volumes exceeding the design capacity bypass the tank storage. The volume stored is sufficient to allow capture of all smaller storms and some fraction of larger storms. The tanks have influent screening and automatic flushing systems to assist in the post-event tank cleaning. Dewatering pumps are provided to transport the contents of the tank and the collected solids to the interceptor system following the overflow event.

Tunnel Storage: A system used to capture, store, and convey large volumes of CSO or SSO discharge. The pumped effluent is transported and treated either at the AWTF or through another technology before being discharged to the receiving waters. Tunnels can accommodate large overflow volumes with little or no disruption to the surrounding land surface area and capture all smaller storms and some fraction of larger storms.

Instream Storage: The instream storage method involves using floating pontoons and flexible curtains to create a storage facility within the receiving water. CSO flows fill the facility by displacing the receiving water that normally occupies the storage facility. The CSO flows are then pumped to the collection system following a storm. The technology has been used for CSO control in Brooklyn, New York. This alternative involves permanently installing the floating pontoons in the receiving water near the CSO outlets. The feasibility of this technology, therefore, depends in part on whether the structure would be a hindrance to navigation.

6.2.4 Treatment Technologies

Screening: Screens and trash racks consist of a series of vertical and horizontal bars or wires that trap floatables while allowing water to pass through the openings between the bars or wires. Screens can be installed at select points within a CSS to capture floatables and prevent their discharge in CSOs. Screens used for CSO control include mechanically cleaned permanent screens, static screens, traveling screens, or drum screens. Screens can also be divided into three categories according to the size of floatable material they are designed to capture. These are:

- Bar screens (> 2.5 centimeter [1 inch] openings)
- Coarse screens (0.5 to 2.5 centimeter [0.19 to 1 inch] openings)
- Fine screens (0.01 to 0.5 centimeter [0.004 to 0.19 inch] openings)

The screens most commonly used to control CSOs are trash racks (a type of bar screen primarily used as an end-of-pipe control) and coarse screens.

Netting: Two types of netting systems can be used to collect floatables in a CSS: in-line netting and floating units. In-line netting can be installed at strategic locations throughout the CSS. The nets would be installed in underground concrete vaults containing one or more nylon mesh bags and a metal frame and guide system to support the nets. The mesh netting is sized according to the volume and types of floatables targeted for capture. The CSO flow carries the floatables into the nets for capture. Bags are replaced after every storm event. Floating units consist of an in-

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water containment area that funnels CSO flow through a series of large nylon mesh nets. Mesh size depends on the volume and type of floatables expected at the site. This system is passive and relies on the energy of the overflow to carry the floatables to the nets. However, nets must be located some distance from the outfall (often 15 meters [50 feet] or more) to allow floatables entrained in the turbulent CSO flow to rise to the flow surface and be captured. The nets are single use, and after an overflow, the nets are typically removed and taken to a disposal area.

Swirl Concentrator: Swirl concentrators provide flow regulation and solids separation by inducing a swirling motion within a vessel. Solids are concentrated and removed through an underdrain, while clarified effluent passes over a weir at the top of the vessel. Types of swirl devices include the US-EPA swirl concentrator. Conceptually, the US-EPA swirl concentrator is designed to act as an in-line regulator device. In addition to flow routing or diversion, it removes heavy solids and floatables from the overflow. Each type of swirl unit has a different configuration of depth/diameter ratio, baffles, pipe arrangements, and other details designed to maximize performance.

Vortex Separation: The commercial vortex separators are based on the same general concept as the US-EPA swirl concentrator, but include a number of design modifications intended to improve solids separation. The commercial designs have been applied as offline treatment units. Vortex separators placed at discharge points are intended for inorganic solids separation and removal prior to discharging. Separation is facilitated by a swirling motion similar to a centrifuge and the solids are settled out at the bottom of the unit. Vortex Separators are available for both in-line and offline treatment, are available in varying sizes and designs, which are based on the peak flow design event and on-site configuration requirements.

High Rate Clarification: High rate clarification (HRC) processes have surface overflow rates greater than 20 gallons per minute per square foot (gpm/ft^2). Several proprietary technologies exist.

- *DensaDeg® Ballasted Flocculation* recirculates settled sludge as the ballast to achieve total suspended solids (TSS) removal at a standard design surface overflow rate of 40 gpm/ft^2 for wet weather flow. The process consists of a rapid mix zone, reactor zone, and a clarifier/thickening zone. Polymer is added as a flocculating agent as the wastewater flows to the reactor zone, which is equipped with an axial flow impeller/ draft tube arrangement. The water and flocculated sludge enter the clarification zone where most of the solids settle. Suspended solids removal in excess of 90 percent of influent concentrations can be achieved consistently by Actiflo® Ballasted Flocculation

- *Actiflo® Ballasted Flocculation* utilizes microsand as the ballast to achieve TSS removal at a standard design surface overflow rate of 60 gpm/ft^2 for wet weather flow. The process consists of a coagulation zone, injection zone, maturation zone, and clarification zone. Wastewater enters the coagulation chamber along with a coagulant for flash mixing. Microsand interacts with the destabilized particles and the polymer. The polymer promotes the formation of strong flocs around the microsand. The Actiflo® process provides high removal efficiencies and is stable at variable influent flows and loads.

- *Biologically and chemically enhanced clarification (Bio CEC)* is a relatively new process that incorporates a short duration biological contact tank upstream of chemically enhanced clarification (CEC) to achieve rapid uptake of soluble organic matter that would not be removed by only CEC. In this process, activated sludge from a plant's secondary process (RAS or WAS) is routed to a short-duration (5-10 minutes) contact basin where it blends with excess wet weather flows to achieve rapid uptake of soluble organic matter into the biomass. This mixture of biomass and influent wastewater is then treated through chemically enhanced primary treatment (CEPT) or HRC. The nonproprietary technology is Bio CEPT, and the current proprietary technology is BioActiflo®.

High Rate Filtration: High rate filtration systems utilize proprietary filter media for CSO treatment with high filtration rates of around 20 to 40 gpm/ft^2. These systems occupy less space than standard filtration systems or sedimentation tanks. Examples of high rate filtration technologies include the Metawater® pinwheel filter medium and Schreiber LLC® Fuzzy Filter compressible synthetic medium.

Disinfection: This process destroys or inactivates microorganisms in overflows, most commonly through contact with forms of chlorine. Various disinfection technologies are available both with and without chlorine compounds. Some of the more common technologies include gaseous chlorine, liquid sodium hypochlorite, chlorine dioxide, ultraviolet radiation, and ozone. For disinfection of CSOs, liquid sodium hypochlorite is the most common of the above technologies.

Dechlorination: A major disadvantage of chlorine-based disinfection systems is that the residual chlorine concentration can have a toxic effect on the receiving waters, due either to the free chlorine residual itself or to the reaction of the chlorine with organic compounds present in the effluent. With the relatively short contact times available at many CSO control facilities, disinfection residuals can be of particular concern and can require consideration of dechlorination alternatives. Two of the more common means for dechlorinating treated effluent are application of gaseous sulfur dioxide or liquid sodium bisulfite solution.

Retention Treatment Basins: Retention treatment basins (RTBs) are satellite high rate treatment facilities designed to provide screening, settling, skimming (with a fixed baffle), and disinfection of combined sewer flows before discharge to a receiving water. Since RTBs are empty between wet weather events, they also provide storage, which can completely capture combined sewer flows from small wet weather events for later dewatering and conveyance to the AWTF for treatment. RTBs can be designed with a variety of screen types, disinfection methods and basin geometries. The surface loading rates can also vary but are typically higher than rates used for design of primary clarifiers. RTBs can be constructed above or below grade but typically require at least an above grade process/control building. If pumping of the combined sewer flow is required, the pump station may be integral to the RTB facility or constructed as a separate structure. An advantage of RTBs is that they are relatively simple to operate and maintain. A disadvantage is that the large footprint of the structure occupies waterfront land that could otherwise provide public amenities.

Satellite Sewage Treatment (SST): A method whereby satellite facilities provide biological treatment for excess wet weather flows, in separate sanitary sewer portions of the system. Examples of satellite sewage treatment include conventional activated sludge process,

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sequencing batch reactor process, and trickling filter process. SST facilities can be considered where sufficient average daily flow is available to sustain a biological treatment facility. Therefore, intermittent operation of an SST facility only during wet weather is not feasible. When evaluating a potential SST site, it is necessary to identify the existing base flow that can be diverted on a continuous basis to the SST.

Satellite Advanced Treatment: A higher level of satellite sewage treatment for use on smaller tributary streams where treatment beyond the secondary level is required due to a TMDL or other water quality factors.

Expansion of Primary Treatment Capacity: Expansion of the primary treatment capacity of the AWTF must take into account the average daily flow, the peak instantaneous flow and the maximum daily average flow that could potentially be delivered to each plant. Using this information, the feasibility of expanding the plant to apply primary treatment to all flow being delivered must be evaluated with regard to spatial limitations of the plant expansion footprint, costing, and a list of design options.

6.2.5 Receiving Water Technologies

Side Stream Aeration: This option consists of adding air directly to a receiving waterway in order to increase dissolved oxygen concentration. Side stream aeration is when flow is diverted to an offline aeration facility and re-diverted back to the stream or river.

Instream Aeration: Instream aeration is a technology developed to add oxygen to the water column in areas where slow, stagnant conditions occur in streams. Air can be added directly to stream or river flow using a diffusion system to increase dissolved oxygen levels for the improvement of fish habitat and water quality.

Stream Cleanup and Maintenance: Keeping streams free of trash is a continuous activity. Cleanup and maintenance crew can be deployed to periodically remove trash and large debris from the receiving waters.

Plunge Pool Removal: When stormwater and combined sewer outfalls discharge directly to the stream channel, they may create deep, poorly mixed pools. Because these pools are typically near the bank and not in the main flow, they can become poorly mixed during low flow. These pools often have increased odors and reduce the aesthetic quality of the stream. Biological activity in the sediment and water column can reduce dissolved oxygen (DO) to low levels, and this low-DO water can be flushed out and affect downstream areas during wet weather. The depression of DO is a function of both pollutant loads from the outfalls and in stream baseflow, and the physical condition of the channel. When DO is in an acceptable range in the well-mixed portion of the channel but not in nearby plunge pools, elimination of the plunge pools can be expected to eliminate the water quality condition that might affect the aquatic ecosystem.

Constructed Wetlands Along Stream Corridors: Because stream relocation and realignment typically involve extensive grading and replanting, new runoff patterns and hydrology can be created that are more similar to original riparian conditions, whereby the riparian corridor receives storm runoff sheet flow from the adjacent landscape. In addition, wetland habitats can be created that allow more diverse habitat. Wetlands are rich habitats that rely on saturated soils

and vegetation adapted to these conditions. They could be recreated concurrently with channel realignment, bank restoration, and planting of more diverse native vegetation, including hydrophytic species adapted to saturated soil conditions.

Invasive Species Management: A plan to control invasive plant species is necessary when restoring or enhancing wetlands and riparian forests. Invasive species provide little value to native animals that depend on native species for habitat and food. Maintaining a healthy riparian plant community will retain biodiversity and support a healthy stream ecosystem.

Reforestation: Reforestation that occurs adjacent to the channel will provide wetland habitat and other associated benefits. Although priority reforestation areas consist of floodplains, steep slopes, and wetlands, smaller areas such as public rights-of-way, parks, schools, and neighborhoods also provide reforestation opportunities. Benefits of reforestation are numerous: cooler temperatures, rainfall interception, reduced runoff, reduced sediment load, reduced discharge velocities, increased groundwater recharge, increased species diversity and habitat, and improved air quality and aesthetics.

6.3 Alternative Control Strategies

CRW has developed a range of alternative control strategies that will be further defined and evaluated in Section 8 of this Program Plan. This section provides the basic framework of these strategies, and indicates the control technologies best aligned with each strategy.

6.3.1 Minimum Control Requirements

The minimum control strategy (MC) represents those controls that must be implemented to meet the technology requirements of the Clean Water Act (CWA). The minimal control strategy is defined by CRW's Nine Minimum Control (NMC) Plan[1], which defines CRW's approach to meeting the technology-based minimum controls of the CSO Control Policy, as well as the six minimum control measures (MCMs) required for municipal separate storm sewer system (MS4) permits.

6.3.2 Baseline Level of Control

A baseline level of control is developed in Section 8 from the control technologies described in this section. The baseline level of control involves multi-objective projects to first rehabilitate, then provide routine renewal of CRW's assets, including its AWTF, its major pumping stations, its interceptors, and its various CSO regulator structures. Included are asset rehabilitation projects that include hydraulic/treatment enhancements feasible to incorporate into the existing AWTF, pump station, and/or CSO regulator structures. Defining the baseline level of control involves:

- Define "baseline" controls that are low-cost, simple changes, including operational changes, that optimize or enhance the existing system.
- Determine the associated level of CSO control. This will provide a starting point for establishing feasible control strategies.

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[1] CRW *Nine Minimum Control Plan, Version 3.0*, August 2017, available at **https://capitalregionwater.com/cbh2o/**

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Table 6-1 lists alternative technologies, which are screened for application within the baseline, systemwide, and local control strategies. Some technologies are minimum controls satisfying the technology-based requirements of the CWA, and satisfying the requirements of CRW's Nine Minimum Control (NMC) Plan and the minimum control measures (MCMs) under PA-DEP MS4 permitting regulations.

6.3.3 Establish Feasible Control Strategies

The next step in the planning process is to formulate feasible control strategies. First, the following two ***systemwide control strategies*** (SW) start with the baseline level of control and add enhanced levels of control for CRW's AWTF and conveyance system.

- ***Systemwide Strategy 1***: achieve the full hydraulic conveyance capacity of CRW's interceptors (approximately 120 MGD) by increasing the AWTF hydraulic/primary treatment capacity, adding additional pumping capacity, and replacing restrictive connector pipes at CRW regulators.
- ***Systemwide Strategy 2***: install a deep tunnel parallel to CRW's conveyance system, including consolidation sewers from CSO regulators to tunnel drop shafts and a new dewatering pump station, increasing overall conveyance and storage within CRW's conveyance system.

Next, the following three ***local control strategies*** start with the baseline level of control within each of the designated program planning areas, and add enhanced levels of control within CRW's collection system:

- ***Local Strategy 1:*** A *decentralized control strategy* (DC) involving green/grey infrastructure that focuses controls (a) within catchments where the baseline strategy does not achieve the desired CRW level of control and (b) to achieve multi-objective benefits (e.g., reduce CSOs/SSOs/unauthorized discharges, and MS4 discharges; maximize triple bottom line benefits, leverage non-traditional funding sources).
- ***Local Strategy 2:*** A *satellite control strategy* (SC) that employs storage/treatment/conveyance facilities focused on CSO control within catchments where the baseline strategy does not achieve the desired CRW level of control.
- ***Local Strategy 3:*** A *sewer separation strategy* (SP) within catchments where the baseline strategy does not achieve the desired CRW level of control, defining various percentages of the collection system to separate to achieve desired control levels.

Within each of the program planning areas, these alternative controls may solve existing problems regarding CSOs, SSOs, unauthorized releases, MS4 discharges, and significant structural deterioration. Alternative controls to consider may include a combination of further modifications to CSO regulator structures and connector pipes, required rehabilitation for grade 4 and 5 pipe defects, solutions for localized flooding and basement backup areas, and green stormwater infrastructure opportunities. As required sewer rehabilitation projects come up on the series of 5-year schedules, opportunities for additional levels of stormwater/CSO control will be identified and assessed for potential project elements such as oversizing the damaged pipe

Table 6-1: Feasible Wet Weather Control Alternatives for CRW's Service Area

Source Controls	Type
Green Stormwater Infrastructure	
▪ Bioretention / rain gardens	DC
▪ Dry wells	DC
▪ Grassed swales	DC
▪ Rain barrels	NA
▪ Infiltration trenches	DC
▪ Green roofs	DC
▪ Permeable pavement	DC
Inflow Reduction	
▪ Catch basin modifications	DC
▪ Sump pump disconnect	DC
▪ Catch basin and storm inlet maintenance	MC
▪ Illicit connection control	MC
▪ Roof leader disconnect program	DC
▪ Street storage (catch basin inlet control)	DC
▪ Offload groundwater pumpage	DC
▪ Stream diversion	NA
▪ Groundwater infiltration reduction	DC
▪ Reduction of contractual flow	DC
Construction-Phase Controls	
▪ Construction-phase E&S controls	MC
Post-Construction Controls	
▪ Post-construction stormwater control	DC
▪ Post-construction inspection/enforcement	MC
Pollution Prevention/Good Housekeeping	
▪ Loading, unloading, and storage of materials	MC
▪ Spill prevention and response	MC
▪ Street sweeping programs	MC
▪ Vehicle and equipment management	MC
▪ Private scrapyard inspection/enforcement	MC
▪ Employee training	MC
▪ Record keeping and reporting	MC
▪ Flow diversion/exposure minimization	MC
▪ Responsible landscaping practices	MC
▪ Responsible bridge/roadway maintenance	MC
▪ Require industrial pretreatment	MC
▪ On-lot disposal (septic system) management	MC
▪ Household hazardous waste collection	MC
▪ Oil/water separator/water quality inlets	MC
▪ Industrial stormwater pollution prevention	MC
▪ Litter and illegal dumping enforcement	MC

Conveyance/Collection System Controls	Type
▪ Sewer separation	SP
▪ Optimization of existing system	BL
▪ Real-time control	SW
▪ Regulator/pump station inspection/maintenance/repairs	MC
▪ Outfall and regulator consolidation	SC
▪ Outfall maintenance program	MC
▪ Sewer system inspection and cleaning	MC
▪ Parallel interceptors	SW
▪ Remove flow bottlenecks	SW DC
▪ Combined sewer rehabilitation	BL
▪ Diversion of trunk flow directly to AWTF	SW

Storage Technologies	Type
▪ In-line storage	SC
▪ Earthen basins	SC
▪ Offline above/below grade storage tanks	SC
▪ Tunnel storage	SW
▪ Instream storage	SC

Treatment Technologies	Type
▪ Screening	SC
▪ Netting	SC
▪ Swirl concentrator	SC
▪ Vortex separation	SC
▪ High rate clarification	SC
▪ High rate filtration	SC
▪ Disinfection	SC
▪ Dechlorination	SC
▪ Retention treatment basins	SC
▪ Satellite sewage treatment	SC
▪ Satellite advanced treatment	SC
▪ Expansion of primary treatment capacity	SC

Receiving Water Technologies	Type
▪ Side stream aeration	SC
▪ Instream aeration	SC
▪ Stream cleanup and maintenance	MC
▪ Plunge pool removal	SC
▪ Constructed wetlands along stream corridors	SC
▪ Invasive species management	MC
▪ Reforestation	MC

Alternative Control Strategies

MC - Minimum Control (e.g., CSO NMC, MS4 MCM)
BL - Baseline
SW - Systemwide
DC – Decentralized Control (i.e., implement within collection system)
SC – Satellite Control
SP – Separation
NA - Not Applicable / Not Feasible

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reach to provide additional storage, adding supplemental green stormwater infrastructure to the project for stormwater runoff control, etc.

6.4 Screening Results

The available control technologies described in Section 6.2 were categorized according to their alignment with the alternative control strategies in Section 6.3. Control technologies deemed infeasible or not applicable to the control strategies suitable for CRW's system are marked "NA". Previously presented, **Table 6-1** indicates the specific control strategies considered suitable for one or more of the defined control strategies, A rationale for this selection follows.

6.4.1 Source Controls

The Partial Consent Decree (PCD) defines Source Controls as "*measures that reduce the volume, peak flow, or pollutant load of runoff, either before it enters the combined Collection System or is re-directed to an MS4, including measures that mimic natural hydrologic processes. Source Controls shall include, inter alia, Green Infrastructure, as defined in this Consent Decree*". They typically consist of minimum controls per NMCs, MCMs and decentralized controls. Source controls are fundamental elements of the minimum level of control (MC) baseline control strategy and the decentralized control strategy.

6.4.2 Collection System Controls

The PCD defines Collection System Controls as "*measures that reduce the volume, peak flow, or pollutant load of flows within the combined Collection System.*" Some Collection System Controls are aligned with the minimum level of control (MC), while others are best aligned with the baseline level of control (BL), the systemwide control strategy (SW), the decentralized control strategy (DC), or the satellite control strategy (SC) conveyance enhancements. In general, they are supporting elements of each control strategy.

6.4.3 Storage Technologies

The PCD defines Storage Technologies as "*structural measures that detain flows within the Conveyance System and reduce peak flows prior to treatment at the AWTF*". They are typically implemented as part of a satellite control strategy (SC), but also include deep tunnels and other technologies that align with the systemwide control strategy (SW).

6.4.4 Treatment Technologies

The PCD defines Treatment Technologies as "*structural measures that reduce the pollutant load in a CSO to its Receiving Water.*" Treatment Technologies are commonly incorporated into satellite control strategies (SC). Some may also enhance the wet weather treatment capacity of the AWTF.

6.4.5 Receiving Water Technologies

Receiving Water Technologies are not defined in the PCD. They may align with the satellite control strategy (SC), or represent a minimum level of control (MC) that enhances the physical, biological, or chemical conditions within a receiving water.

Section 7

Financial Capability and Affordability Assessment

This report section summarizes the financial capability assessment (FCA) and affordability assessment that was completed for Capital Region Water (CRW) related to the development of the *City Beautiful H_2O Program Plan* (Program Plan), other water quality enhancement programs, and system rehabilitation programs required under Section V-E of the Consent Decree between CRW, the City of Harrisburg, United States Environmental Protection Agency (US-EPA) and Pennsylvania Department of Environmental Protection (PA-DEP)[1]. The goal was to assess the current and projected future financial capability and customer affordability to implement the proposed Program Plan. The FCA and affordability assessment is intended to identify the upper limits of what could constitute an affordable future investment strategy as defined by the policy and related guidance documents under an assumed implementation schedule, thereby informing the development of alternatives to address CSO, SSO, MS4, TMDL, system renewal, and other regulatory requirements.

As described in this section of the Program Plan, the assessment evaluated financial capability and affordability from a broad perspective, including the assessment outlined in the 1997 US-EPA guidance document Combined Sewer Overflows – Guidance for Financial Capability Assessment and Schedule Development.[2] The US-EPA Financial Capability Assessment methodology aims to assess the overall financial capability of the utility and its customers to pay for a Long-Term Control Plan (LTCP). This report section also documents other information to provide a more complete assessment of financial capability and affordability, including providing current socioeconomic conditions within the service area and a year-by-year wastewater rate impact analysis.

7.1 Overview of the Financial Capability and Affordability Assessment

The FCA and affordability assessment is presented in this section of the Program Plan in the following order:

1. Current Socioeconomic Conditions – Summarizes important economic and social characteristics of CRW's service area, such as population, labor force, unemployment, median household income (MHI), and income distributions that provide an indication of the current socioeconomic conditions.

2. Financial Capability Assessment – Provides the results of the FCA, which was completed in accordance with the US-EPA FCA guidance document.

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[1] U.S. District Court for the Middle District of Pennsylvania, Civil Action No. 1:15-cv-00921-WWC.

[2] EPA 832-B-97-004.

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3. Year-By-Year Wastewater Financial and Rate Impact Analysis – Provides the results of a wastewater financial and rate impact analysis. This analysis included forecasts of various financial metrics, including year-by-year costs for wastewater services, debt burden, and cash flows, comparisons of customer costs to income levels, and an assessment of how a customer's annual wastewater utility service bill will change over time.

Overall, the FCA and Affordability Assessment demonstrates that the City of Harrisburg has experienced significant financial distress for several years, and there is a significant prevalence of economic hardship among the customers within the City. The City poverty rate was nearly 34 percent in 2016 and the MHI was $33,289 (in 2015), which was more than $20,000 lower than national, state, and local (Dauphin County) MHI's in the same year. While the MHIs of some of the suburban municipalities served by CRW are significantly higher than that of the City, CRW provides only treatment, and in some cases conveyance, services to several suburban municipalities. Since the suburban municipalities own, operate, and manage their own wastewater collection systems, CRW is unable to pass on a large portion of its Program Plan-related costs to these municipalities.

The FCA analysis using the EPA approach indicated that a capital program of approximately $185 million in 2017 dollars was the maximum amount capital spend that could be incurred by CRW while keeping the Residential Indicator at the threshold of "High" financial impact. CRW has identified approximately $120 million in capital costs (in 2017 dollars) needed to be spent to address aging infrastructure issues over the next 10 years. This leaves a capacity of only approximately $65 million for Program Plan-related costs until the Residential Indicator reaches 2.0 corresponding to "High" financial impact.

Affordability was further evaluated by developing a comprehensive year-by-year, long-term financial plan and affordability model. This model was developed to assess the impact of capital program alternatives on customer bills and CRW's financial position. This model indicated that CRW can only include a total of $315 million (escalated), or $253 million (in 2017 dollars) in capital expenditures over a long-term 20-year period, while keeping the annual combined residential wastewater and stormwater cost as a percentage of MHI for City customers at or below the 2.0 percent threshold, while also satisfying its cash and debt service coverage requirements, and in keeping its debt burden at manageable levels. Of the $315 million, approximately $214 million is anticipated to be needed to address aging infrastructure issues over the 20-year period.

While the capital plan included in the long-term financial plan and affordability model was designed to keep total annual City residential customer cost for wastewater and stormwater service at or below 2.0 percent of MHI, it is anticipated that there will be significant and severe affordability issues for some customers within the City, with some customers experiencing wastewater and stormwater costs as a percentage of income exceeding 3.0 percent.

Given these considerations, it was concluded that CRW should receive the maximum schedule relief possible for implementing its City Beautiful H_2O program. The implementation schedule of 20-years or more, which is presented in this report, is a reasonable timeline to consider

affordability considerations, concerns in the more vulnerable areas of the CRW's service area, and for CRW to maintain a secure financial position over the term of the program.

7.2 Jurisdictional Scope of the Analysis

CRW provides wastewater service, consisting of collection, conveyance, and treatment service to the City of Harrisburg (City), and bills the City customers directly for this service. It also provides wholesale wastewater service, consisting of conveyance (through CRW interceptor sewers) and treatment service (at the CRW treatment plant), but not wastewater collection service (through municipal sewer systems), to several suburban wholesale customers comprised of Penbrook Borough, Paxtang Borough, Swatara Township, Lower Paxton Township, Susquehanna Township, and Steelton Borough. CRW only provides wholesale wastewater treatment service to a portion of Swatara Township and Steelton Borough as these municipalities convey wastewater to CRW through their own collection and conveyance infrastructure. A map of the jurisdictional boundary of the CRW service area, showing each of these customer municipalities, is provided on Figure 3-1.

The FCA and affordability assessment was prepared pursuant to paragraph V-E (18) of the Consent Decree, which requires the FCA to address the Harrisburg Sewer System as defined in paragraph IV-8(w). Therefore, this assessment was focused on the customers located within the City of Harrisburg. This is a reasonable approach because the City is the only jurisdiction within CRW's service area that receives wastewater collection, conveyance, and treatment service from CRW. Furthermore, the majority of the water quality related capital expenditures, and related future operation and maintenance (O&M) costs, pertain to infrastructure serving the City of Harrisburg.

7.3 Methodology

7.3.1 US-EPA Financial Capability Assessment

The FCA was completed in accordance with the method outlined in the US-EPA guidance document that specifies a two-phase process for assessing financial capability. Phase I of the analysis focuses on customer financial capability as measured by the Residential Indicator. The Residential Indicator is calculated by dividing the total projected residential cost by the MHI. If the costs are at or above 1.0 percent of the MHI, a Phase II analysis is completed. The Phase II analysis assesses community financial capacity (i.e., financial strength and financing capacity), including an assessment of the permittee's debt burden, socioeconomic conditions, and financial operations. These two phases are combined into a financial capability matrix to determine the financial burden placed on residential customers and the permittee by the existing and projected future costs of the wastewater system.

Phase I of the US-EPA FCA method calls for the use of a simplistic "snap shot" model, which aggregates future capital expenditures and current and incremental future operating expenses, and compares these costs to current income levels. This method can overstate the financial capability of long-term programs since income growth has generally not kept pace with increases in water and wastewater utility costs. For example, the national cost of typical household wastewater services increased at an annualized rate of approximately 4.8 percent from 1999

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through 2013[3], and the national Consumer Price Index increased at an annualized rate of approximately 2.4 percent[4], whereas the national MHI only increased at an annualized rate of 1.6 percent over the same period.[5] A financial capability assessment that does not account for the continuing divergence between wastewater utility costs and income growth over a long-term implementation schedule will overstate the financial capability of customers of the system. Therefore, due to the limitations of this method, additional financial capability and affordability information was provided in this Section of the Program Plan, including a year-by-year residential customer bill impact analysis.

Phase II of the US-EPA FCA method includes analyzing community financial capacity measures. However, three of the six community financial capability measures (overall net debt as a percentage of full market property value, property tax revenues as a percentage of full market property values, and the property tax collection rate) focus on General Fund government bond rating criteria and have little relevance to wastewater utilities, such as CRW, that are authorities and separate from the general city government. As a special purpose governmental enterprise, established pursuant to the Pennsylvania Municipal Authorities Act, CRW has no legal authority to establish or levy property tax assessments, and as such, cannot issue General Obligation bonds. Therefore, while presented, less emphasis has been placed on these factors in the Phase 2 FCA.

7.3.2 Enhancements to the US-EPA Process

The US-EPA encourages inclusion of any additional information related to the unique financial conditions of the permittee.[6] Thus, this report section includes a summary of important socioeconomic trends and indicators, such as employment rates, poverty rates, income distribution, and other economic factors that can help to provide a more complete picture of a community's financial capability. Also provided in this section of the Program Plan is a year-by-year financial projection and rate impact analysis, and a discussion of the current economic conditions within the service area and associated challenges, all of which are relevant to the financial capability and the recommended compliance schedule.

7.4 Overview of the Wastewater Utility

7.4.1 System Description

CRW is a municipal authority that owns and operates a wastewater system that includes an Advanced Wastewater Treatment Facility (AWTF), a conveyance system, and wastewater and stormwater collection systems within the limits of the City of Harrisburg. Overall, the wastewater system includes approximately 36 miles of sanitary sewers, 40 miles of stormwater sewers, and 101 miles of combined sanitary and stormwater sewers. Customers located within the City utilize CRW's treatment, conveyance, and collection systems, while customers located within the

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[3] NACWA 2013 Cost of Clean Water Index.

[4] U.S. Bureau of Labor Statistics

[5] U.S. Census Bureau

[6] E.G. Combined Sewer Overflows – Guidance for Financial Capability Assessment and Schedule Development (EPA 832-B-97-04) page 7 and the November 24, 2014 memorandum to Regional Administrators: *Financial Capability Assessment Framework for Municipal Clean Water Act Requirements.*

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suburban communities outside the City operate their own collection systems and primarily utilize CRW's treatment and conveyance facilities. However, the Borough of Steelton operates its own collection system and maintains its own conveyance system, and discharges wastewater directly to CRW's AWTF. Therefore, its wholesale rate is different than the other suburban communities, as it reflects only its proportionate share of the costs associated with the use of CRW's treatment facilities. Currently, CRW recovers the cost of managing the wastewater and stormwater system with wastewater user charges, since there is not currently a separate funding source to recover stormwater-related costs. However, CRW plans to implement a separate stormwater fee, possibly as early as 2019.

The wastewater system was originally managed, owned, and operated by the City. In 1990, the Harrisburg Authority (which has since been renamed Capital Region Water) was created to purchase the wastewater system from the City and at the same time enter into a 1990 Management Agreement with the City for continued management and operation of the wastewater system. In 2011, the City was placed under Commonwealth of Pennsylvania Receivership due to severe financial distress. As a result, the Commonwealth's Office of the Receiver, the City, and CRW agreed to terminate the 1990 Management Agreement with the City on November 4, 2013. With the termination of this Agreement, CRW has taken back operational and management control of the wastewater system.

In addition to providing wastewater collection and treatment services, CRW also provides drinking water services. CRW operates as one entity; however, CRW separately tracks and records the provision of services associated with each of the utilities it manages and operates.

7.4.2 Customer Base

CRW maintains approximately 17,000 active connections within the City of Harrisburg. Over 15,000, or approximately 88 percent, of the active connections are comprised of residential customers. Suburban communities are billed on a wholesale basis; therefore, individual account data for customers located in these communities is not available. Some suburban customers are billed for wastewater treatment and conveyance services based on metered water consumption, while others are billed based on the estimated number of equivalent dwelling units within their customer base. During fiscal year (FY) 2016, City and Suburban customers were billed for approximately 3.8 billion gallons of flow, as detailed in **Table 7-1**.

The population of CRW's service area has remained relatively flat since 2010 as described later in this section, and future customer growth is anticipated to be minimal in both the City and several of the suburban areas that are served by CRW.[7]

[7]Tri-County Regional Planning Commission, 2010-2040 projections, tcrpc-pa.org.

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Table 7-1: Wastewater Billed Flow by Municipality

Municipality	Billed Flow (1,000 gal.)
City of Harrisburg	1,650,641
Lower Paxton Township	766,398
Susquehanna Township	681,088
Swatara Township	468,118
Steelton Borough	130,264
Penbrook Borough	71,482
Paxtang Borough	36,136
Total	3,804,127

7.4.3 Historical and Current Costs

7.4.3.1 Operating Expenses

CRW's wastewater O&M expenses have increased significantly from FY 2013 to FY 2014 in response to acquiring the City's collection system. Increases in other years were the result of significant reinvestment into the system and efforts to meet wastewater regulatory requirements. Historical actual annual O&M expenses for FY 2013 through FY 2016, and budgeted O&M expenses for FY 2017 and FY 2018 are shown in **Table 7-2**. CRW's fiscal year begins on January 1st and ends on December 31th of each year.

Table 7-2: Historical and Budgeted O&M Expenses

Fiscal Year	O&M Expenses	Percent Change from Prior Year
2013	$2,011,025	
2014	$8,641,477	330%
2015	$9,019,697	4.4%
2016	$11,249,506	24.7%
2017 Budget	$12,023,653	6.9%
2018 Budget	$12,311,253	2.4%

Note: O&M expenses exclude depreciation are shown on an accrual basis, except 2017 and 2018 budget figures, which are shown on a budget basis.

7.4.3.2 Capital Improvement Program

CRW's wastewater capital improvement program (CIP) takes into consideration projects required as part of the utility's Program Plan and ongoing repair and replacement of existing

infrastructure. Annual capital project expenditures projected for FY 2018 through FY 2022, consisting largely of projects related to asset repair and rehabilitation, are shown in **Table 7-3**, with expenditures shown in 2017 dollars. The projected CIP over a 20-year planning period is provided later in this section of the Program Plan.

Table 7-3: Wastewater Capital Project Expenditures

Fiscal Year	Amount
2018	$30,120,000
2019	$31,175,000
2020	$19,143,000
2021	$15,964,000
2022	$17,869,000

7.4.3.3 Debt Service Obligations

As of December 31, 2017, CRW had approximately $69.5 million in outstanding long-term debt, and in FY 2018, CRW will be obligated to pay a total of $4.9 million in annual principal and interest payments on the outstanding debt, which will comprise approximately 23.2 percent of CRW's expenses for that year. A listing of CRW's currently outstanding debt by issue is provided in **Table 7-4**.

Table 7-4: Outstanding Debt of the Wastewater System (As of December 31, 2017)

Debt	Final Maturity (Year)	Remaining Principal
2009 PENNVEST Loan	2029	$1,167,000
2014 PENNVEST Loan	2025	$19,538,000
2017 PENNVEST Loan	2037	$4,895,000
Series 2017 Revenue Bonds	2047	$43,915,000
Total		$69,515,000

7.4.3.4 Historical Financial Results

CRW's historical annual financial results from FY 2013 through FY 2016 are summarized in **Table 7-5**.

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Table 7-5: Historical Wastewater Utility Operating Results

Description	FY 2013	FY 2014	FY 2015	FY 2016
Total Operating Revenues	$2,588,677	$18,252,196	$16,605,674	$17,127,865
Total Operating Expenses	$1,949,230	$11,143,343	$11,057,270	$13,269,589
Revenues Over Expenses	$639,447	$7,108,853	$5,548,404	$3,858,276

Note: The amounts shown for Total Operating Expenses do not include annual principal payments on outstanding debt or the cash-funded portion of capital project expenditures. While not typically not recognized as Operating Expenses, including these amounts would result in annual Revenues Over Expenditures that would be less than those shown in the table.

7.4.4 Wastewater Rates and Customer Bill Comparison

CRW's wastewater rates charged to retail City customers and suburban wholesale customers consist of uniform volumetric rates. A summary of the existing retail and wholesale wastewater rates for FY 2018 is provided in **Table 7-6**.

Table 7-6: Existing Wastewater Rates (FY 2018)

Municipality	Wastewater Rate ($/1,000 gal.)
City of Harrisburg	$6.99
Suburban Wholesale (Except Steelton)	$4.33
Suburban Wholesale (Steelton)	$2.89

As shown in the table, the wastewater rates for suburban customers are lower than the rates charged to City customers. This is because the rates for suburban customers (except Steelton) exclude CRW's collection system costs, while the rate for Steelton excludes CRW's collection and conveyance system costs. The existing inter-municipal agreement with the suburban municipalities, does not allow CRW to pass on collection-related costs to suburban wholesale customers, and does not allow CRW to pass on collection or conveyance-related costs to Steelton Borough.

7.5 Socioeconomic Conditions

7.5.1 Local Economy

CRW's entire service area is in Dauphin County, which is in the south-central portion of Pennsylvania. Dauphin County has a total area of 525 square miles and is bordered on the north by Northumberland County, on the east by Schuylkill and Lebanon Counties, on the south by Lancaster County, and on the west by the Susquehanna River and York, Cumberland, and Perry Counties. Most of the development in the County is in the southern portion of the County in the Harrisburg/Hershey area that is traversed by Interstates 81 and 83, which connect to the Pennsylvania Turnpike (Interstate 76). The Harrisburg/Hershey area contains a significant presence of companies from the food, hotel, insurance, casino, entertainment, and museum

sectors. However, the City of Harrisburg has struggled to find sound financial footing, which has preventing it from delivering a full range of high quality city services.

The City of Harrisburg has experienced significant financial distress for several years, entering state-mandated receivership in 2011. In 2012, the City's debt per capita was among the highest of any city in the United States (U.S.). Although the City has since left formal receivership, it continues to be under state oversight through the State of Pennsylvania's Municipalities Financial Recovery Act (No. 47) and concerns remain regarding future economic growth within the area. Further complicating the City's financial picture, the City cannot collect taxes on nearly half of its assessed property value because many properties are tax-exempt. State properties, including the State Capitol Complex, comprise approximately 42 percent of the City's land area.[8]

7.5.2 Populations and Households

According to the American Community Survey (ACS) five-year estimates for the municipalities within the service area, the population of the City of Harrisburg has declined since 2011, whereas the population within CRW's entire service area (including the suburban communities) has shown only an overall slight upward trend. As shown in **Table 7-7**, the City of Harrisburg, Penbrook Borough, Paxtang Borough, and Steelton Borough have each experienced population declines since 2011, whereas other municipalities, such as Swatara, Lower Paxton, and Susquehanna Townships have shown very modest growth. It should be noted that, of the four areas with population declines, three have at least 25 percent of residents living below the poverty level.

Table 7-7: Historic Population Trends

Area	2011	2012	2013	2014	2015	2016	CAGR
City of Harrisburg	49,499	49,401	49,395	49,297	49,232	49,160	-0.11%
Penbrook Borough	3,020	3,001	3,002	2,997	2,983	2,982	-0.21%
Paxtang Borough	1,546	1,505	1,462	1,450	1,519	1,493	-0.58%
Swatara Township	23,279	23,459	23,703	23,934	24,199	24,411	0.79%
Lower Paxton Township	47,092	47,312	47,532	47,705	47,950	48,175	0.38%
Susquehanna Township	23,804	24,062	24,227	24,332	24,478	24,591	0.54%
Steelton Borough	5,992	5,982	5,976	5,959	5,956	5,938	-0.15%

CAGR = Compound annual growth rate

The various types of households within CRW's service area are shown in **Figure 7-1**. As shown in the figure, families made up 60.5 percent of the households, which consisted of 38.3 percent Married-Couple Families and 22.2 percent Other Families. Of the Other Families, 11.7 percent are female householder families with no husband and with children under the age of 18 years. Non-Family households make up the remaining 39.5 percent of households in the service area, most of

[8] Pennlive. Finding Revenue: Can Cities like Harrisburg Survive? March 10th, 2017. Pennlive.com

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which are comprised of people living alone, but some are comprised of people living in households in which no one was related to the householder.

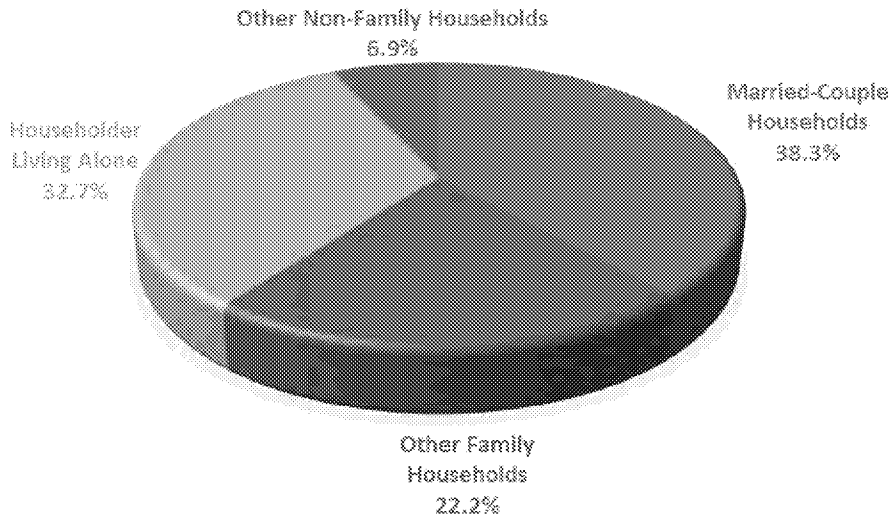

Figure 7-1: Types of Households

The proportion of married-couple households within CRW's service area (38.3 percent) was approximately 10 percent lower than the level of these households nationally and at the state level. For example, across the county and within the Commonwealth of Pennsylvania, married-couple households each comprised approximately 48 percent of all households. This is of note because poverty rates are known to be higher for families without a full-time, year-around worker, which is often the case in single-parent households, especially those with a female head of household.[9]

7.5.3 Labor Force and Unemployment

The historical unemployment rates from 2009 to 2016 for the City of Harrisburg, Dauphin County, the Commonwealth of Pennsylvania, and the U.S. are shown in **Figure 7-2**. As shown in the figure, the unemployment rate in the City of Harrisburg has consistently been significantly higher than national, state and local rates. The unemployment rate within the City of Harrisburg was 14.3 percent in 2016, and had exceeded 15 percent in each of the three years prior, which was more than twice the national, state, and local levels.

[9] Income and poverty in the United States, P60-259, September 12, 2017.

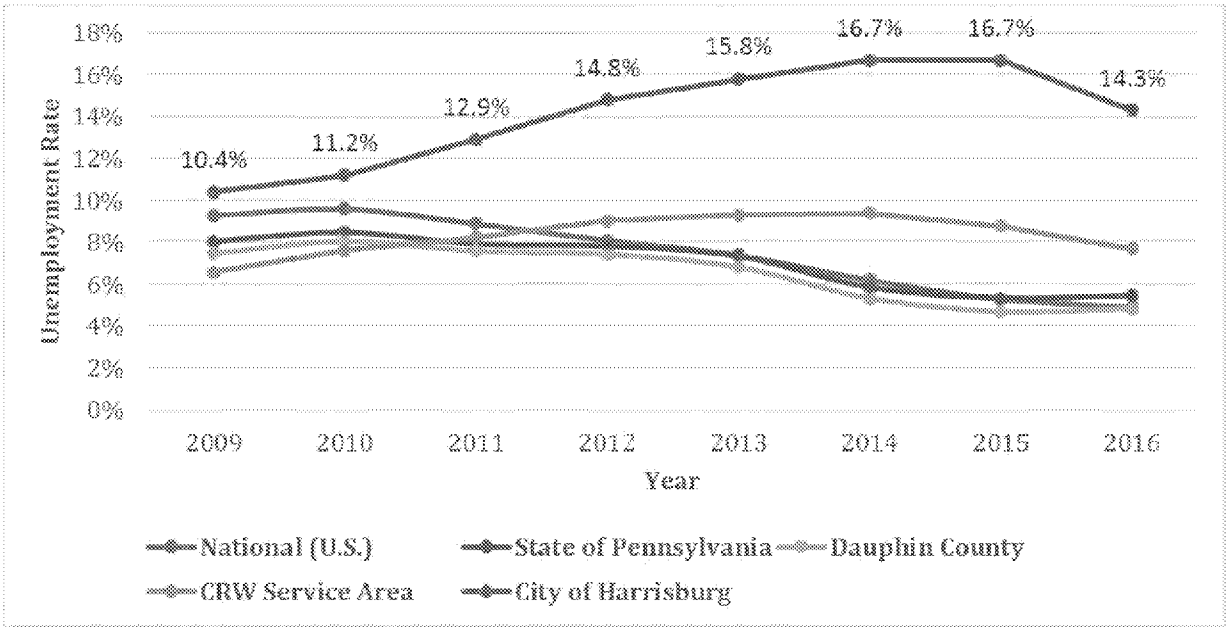

Figure 7-2: Trends in Unemployment Rates

7.5.4 Poverty Rates

The poverty rate measures the number of households reporting earnings lower than the national poverty thresholds, which vary by size of household. The national poverty thresholds for 2016 are shown in **Table 7-8**.

If the disposable income for households is reduced due to higher wastewater bills, this will place an additional financial burden on all households, but especially those that are below the poverty level, and as a result, could impact public health because reducing disposable income for these households would further reduce their ability to pay for necessities such as food, heat, and medical care. As shown in **Table 7-9**, from 2012 to 2016, the poverty rate for the City of Harrisburg has remained between 31 percent and 34 percent.

The historical poverty rates, from 2012 to 2016, for the City of Harrisburg, Dauphin County, the State of Pennsylvania, and the U.S. are shown in **Figure 7-3**. As shown in the figure, the City of Harrisburg has experienced a poverty level that is more than double the national, state, and local levels over this same period, indicating that there is significant economic hardship within the City.

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Table 7-8: National Poverty Thresholds (2016)[10] Trend[11]

Household Size	Poverty Threshold
1	$12,486
2	$16,072
3	$18,774
4	$25,160
5	$29,854
6	$34,337
7	$39,509
8	$44,188

Table 7-9: City of Harrisburg Poverty Rate

Year	Poverty Rate
2012	31.2%
2013	32.0%
2014	33.9%
2015	31.8%
2016	31.7%

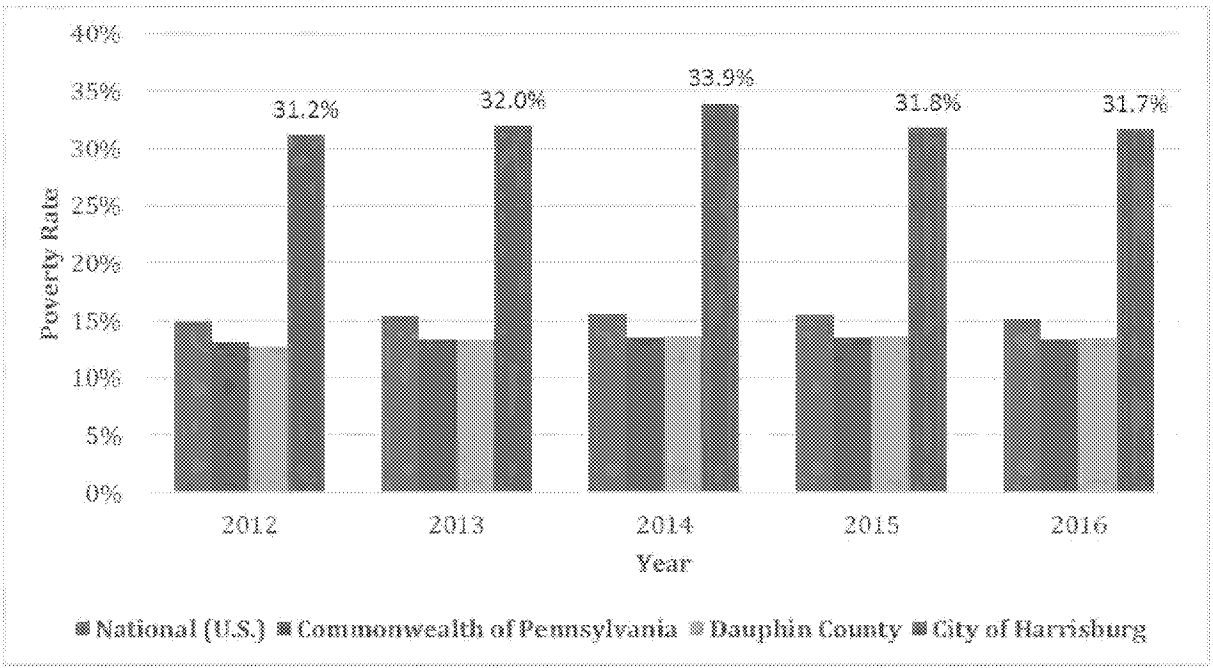

Figure 7-3: Trends in Poverty Rates

In 2016, the percentage of people with a Bachelor's degree or higher in the City of Harrisburg was 40 percent less than the percentage in Dauphin County, the Commonwealth of Pennsylvania and the U.S. This may be one factor contributing to the City of Harrisburg's high poverty rate, as in general, areas with higher educational attainment have lower levels of poverty. The percentage of

[10] US Census Bureau. https://www.census.gov/data/tables/time-series/demo/income-poverty/historical-poverty-thresholds.html
[11] US Census Bureau. https://www.census.gov/library/visualizations/time-series/demo/census-poverty-tool.html

people with a Bachelor's degree or higher at the national, state, and local levels, as compared to the City of Harrisburg, is shown in **Table 7-10**.

Table 7-10: Percentage of Population with a Bachelor's Degree or Higher

Area	Population % with Bachelor's Degree or Higher
National (U.S.)	31.3%
Commonwealth of Pennsylvania	30.8%
Dauphin County	32.5%
City of Harrisburg	18.2%

7.5.5 Income Distribution

Median household income is one measure of a community's financial capability. However, relying solely on the MHI as an indicator of a community's ability to pay for higher wastewater utility bills may be misleading. Some of the limitations of using MHI in this manner are as follows:

- MHI can mask poverty or other measures of economic need within a community, as MHI is only able to represent the "middle" income within a given area. Therefore, there are many households whose annual incomes are substantially lower than this amount.
- MHI does not capture impacts across diverse populations, as there are sub-regions in each area with MHI's that are substantially lower than the overall area's MHI.
- MHI escalation generally lags increases in water and wastewater costs, as well as consumer price increases; therefore, water and wastewater bills can be expected to become a larger burden on customers over time.
- MHI does not reflect the income needed to adequately support larger household sizes. For example, a certain level of income may adequately support a two or three-person household, but this same income level may not adequately support a household of five or six persons. This was illustrated in Table 7-8, which showed different income thresholds for poverty based on household size.
- MHI provides a "snapshot" that does not account for the historical and future trends of a community's economic, demographic, and/or social conditions. This is particularly relevant in areas that may be experiencing economic declines or population losses.

Furthermore, in many communities served by CRW, incomes are less centered on the median compared to incomes included in the national average. Therefore, in addition to the MHI, an analysis of alternative income metrics should be considered to adequately measure a community's financial capability.

7.5.5.1 Median Household Income

The MHI for the City of Harrisburg is provided in **Table 7-11** for 2011, 2013 and 2015 with a comparison to the national, state, and local MHI's in these years. In addition, the MHI of CRW's

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service area is also shown. The MHI of each municipality within the CRW service area was weighted based on its population relative to the total population within CRW's service area. As noted in Section 7.2, the jurisdictional scope of this analysis is limited to the City of Harrisburg pursuant to paragraph V-E (18) of the Consent Decree.

Table 7-11: Median Household Income (adjusted to 2015 dollars)

Area	2011 MHI	2013 MHI	2015 MHI	% Change
National (U.S.)	$52,931	$53,029	$55,775	5.4%
State of Pennsylvania	$54,135	$53,332	$53,599	-1.0%
Dauphin County	$56,357	$54,872	$53,754	-4.6%
CRW Service Area	$55,117	$53,972	$52,732	-4.3%
City of Harrisburg	$34,260	$34,726	$33,289	-2.8%

As shown in the table, the inflation-adjusted MHI for the City of Harrisburg has declined since 2011, while the inflation-adjusted national income level increased. Also, the inflation-adjusted MHI for the City has consistently been more than $20,000 lower than MHI levels for the U.S., Commonwealth of Pennsylvania, and Dauphin County.

The historical MHI trend (adjusted to 2015 dollars) from 2011 to 2015 is shown in **Figure 7-4**. As shown in the figure, the inflation adjusted MHI for the City of Harrisburg has been much lower than the inflation adjusted MHI for CRW's service area. For example, in 2015 the City of Harrisburg's MHI was $33,289; however, the MHI of CRW's service area was $52,732, which is approximately 58.4 percent higher than in the City. This demonstrates that there is a significant disparity in income levels within CRW's service area, with several suburban communities having significantly higher MHI's than the City of Harrisburg. However, since CRW provides only treatment, and in some cases conveyance, services to the suburban communities, and since the suburban municipalities own, operate, and manage their own wastewater collection systems, CRW is unable to pass on a large portion of its Program Plan-related costs to these communities with higher income levels than the City. Moreover, CRW is required to allocate costs between the municipalities proportionately to the causes of cost pursuant to its inter-municipal service agreements, the Pennsylvania Municipality Authorities Act and federal regulations. In addition, the MHI for the City of Harrisburg is only slightly (approximately $8,000) higher than the poverty threshold for a family of four, further demonstrating that income levels are depressed within the City.

7.5.5.2 Income Quintiles

The income distribution within the City of Harrisburg and the other municipalities served by CRW provides additional information on the disparity of income levels within CRW's service area. The upper limits of household income quintiles for the City were compared to those of the U.S., the Commonwealth of Pennsylvania, Dauphin County, and CRW's service area in **Table 7-12**.

As shown in the table, the City has much lower income levels than Dauphin County, the Commonwealth of Pennsylvania, and the U.S.

- The lowest quintile (20 percent) of households in the City of Harrisburg earn less than $12,989 per year, which is 41 percent lower than the lowest quintile of households in the Commonwealth of Pennsylvania and in the U.S.

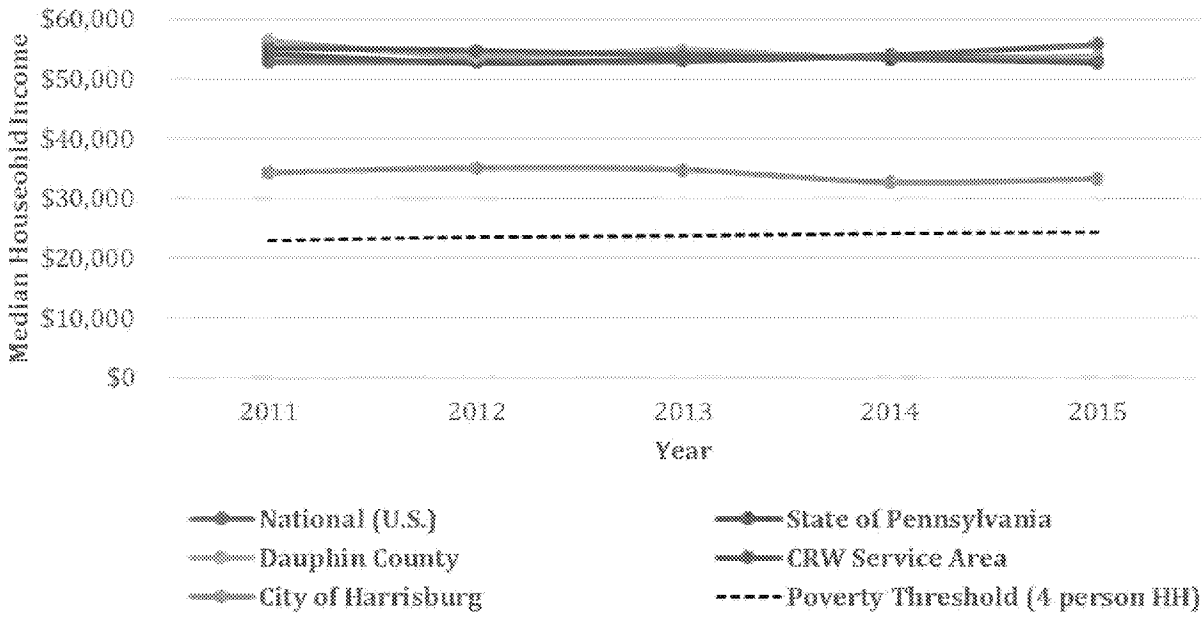

Figure 7-4: Trends in Median Household Income (Adjusted to 2015 Dollars)

Table 7-12: Income Quintiles of the U.S., Pennsylvania, Dauphin County, CRW's Service Area, and the City of Harrisburg

	Lowest Quintile	Second Quintile	Third Quintile	Fourth Quintile
National (U.S.)	$22,001	$42,125	$67,814	$108,994
Commonwealth of PA	$22,116	$42,084	$66,977	$105,848
Dauphin County	$24,986	$44,695	$67,823	$103,207
CRW Service Area	$24,906	$42,759	$63,900	$95,707
City of Harrisburg	$12,989	$25,811	$40,957	$66,422
% Below US Quintile	-41.0%	-38.7%	-39.6%	-39.1%
% Below PA Quintile	-41.3%	-38.7%	-38.8%	-37.2%
% Below County Quintile	-48.0%	-42.3%	-39.6%	-35.6%
% Below Service Area Quintile	-47.8%	-39.6%	-35.9%	-30.6%

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- The second lowest quintile (40 percent) of households in the City earn less than $25,811 per year, which is 39 percent lower than the second lowest quintile of households in the Commonwealth of Pennsylvania and in the U.S.
- The upper incomes of residents in the City on average earn less than those in Dauphin County, the Commonwealth of Pennsylvania, and the U.S. The City's top income quintile earned 37 percent less than the top quintiles in the Commonwealth and the U.S.

This shows that in general, the City of Harrisburg has fewer high earners, as compared to the Commonwealth of Pennsylvania and the U.S.

7.5.5.3 Household Income Distribution

The household income distribution within the City of Harrisburg and the entire CRW service area was compared to the household income distribution within the Commonwealth of Pennsylvania and the U.S. in **Figure 7-5**. As shown in the figure, there is a much larger proportion of households within the City of Harrisburg at low income levels and a much smaller proportion of households at higher income levels as compared to the state and national level.

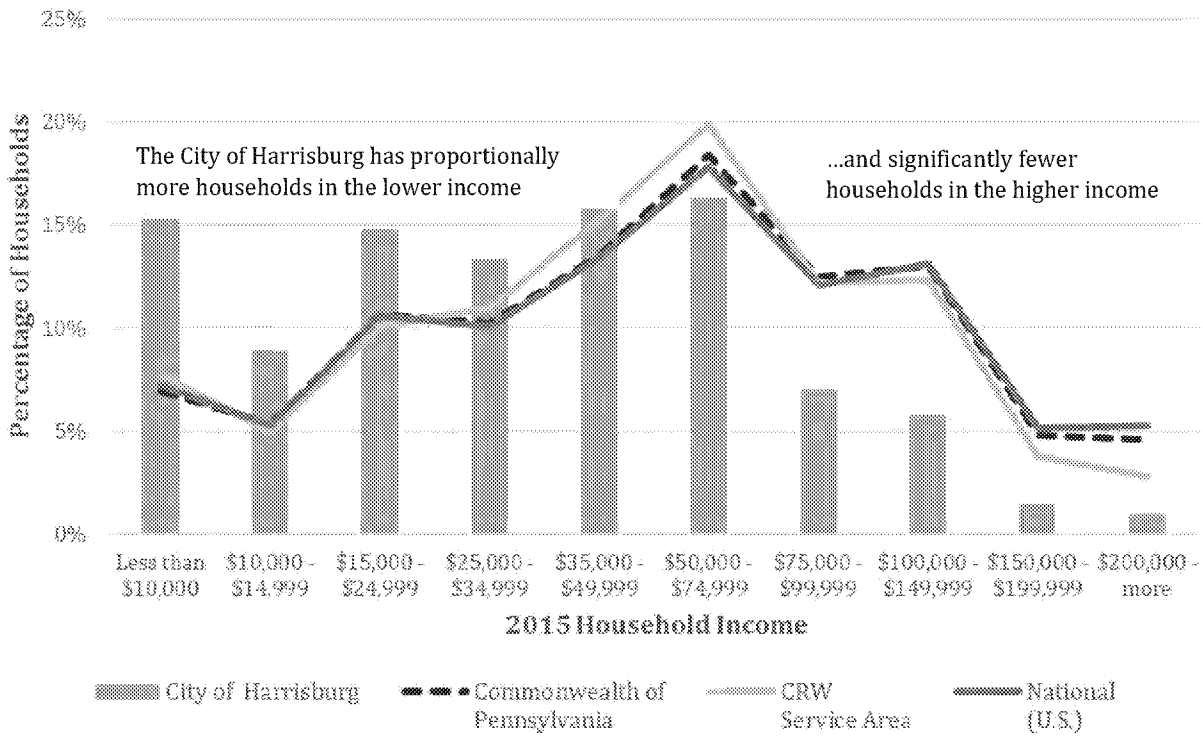

Figure 7-5: Income Distribution for the City of Harrisburg, CRW's Service Area, Pennsylvania, and the U.S.

Furthermore, a map of the MHI levels by census block group for the City of Harrisburg is provided in **Figure 7-6**. The map provides a detailed geographical representation of the income disparity within the City.

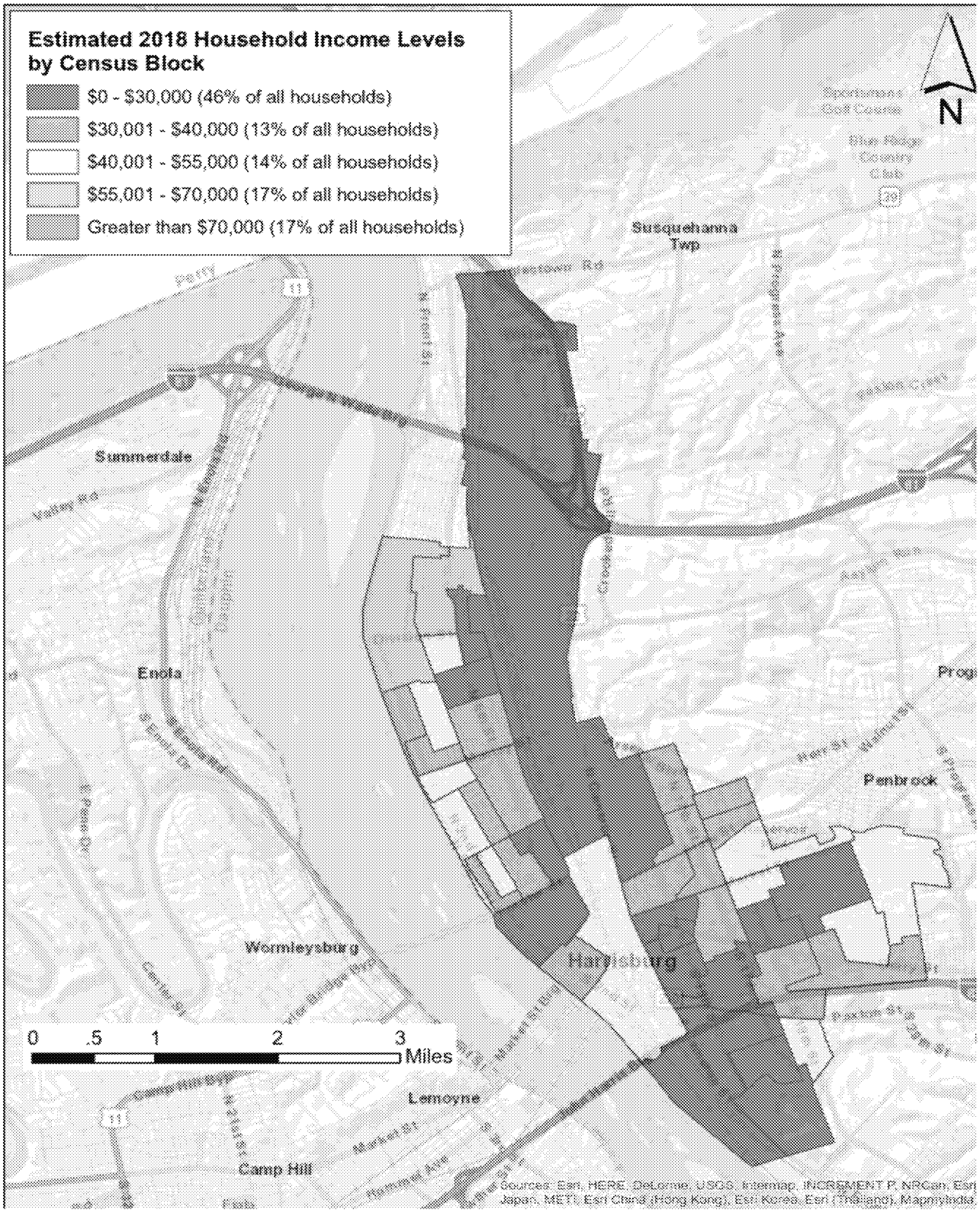

Figure 7-6: Estimated 2018 Income Levels by Census Block for the City of Harrisburg

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7.5.5.4 Renter and Owner-Occupied Household

The proportion of renter and owner-occupied housing units for the City of Harrisburg and the Commonwealth of Pennsylvania are shown in **Figure 7-7**. As shown in the figure, there are significantly more renter-occupied households within the City on a percentage basis (62%), as compared to the Commonwealth of Pennsylvania (31%). The evaluation of income distributions across renter- and owner-occupied households show that renter-occupied households tend to have lower incomes. The weighted MHI in 2015 was estimated to be $33,202 for renter-occupied households within the City of Harrisburg and $58,626, or approximately 76.6 percent higher, for owner-occupied households.

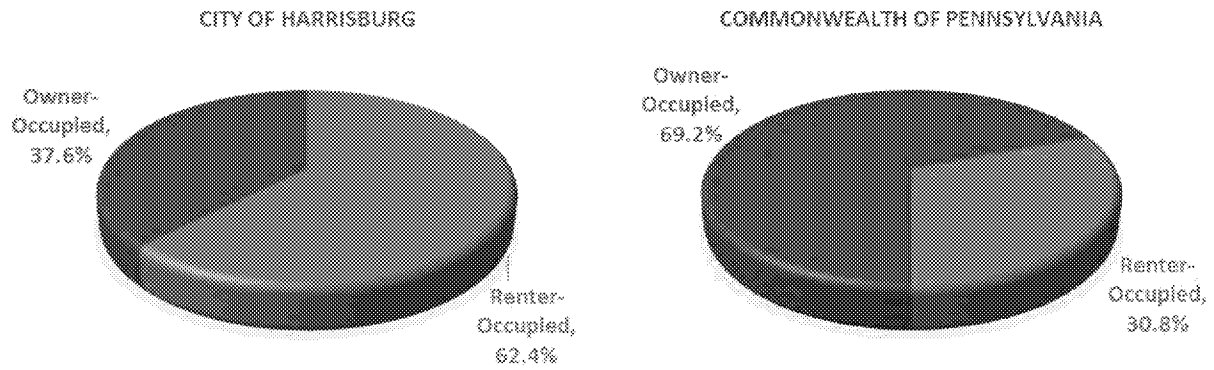

Figure 7-7: Proportion of Renter and Owner-Occupied Housing in the City of Harrisburg and Commonwealth of Pennsylvania

7.5.6 Housing Burden

The housing burden is defined as housing cost as a percentage of household income, and is another factor to consider when assessing financial capability and affordability because it reflects non-discretionary household spending. In order words, households with high housing costs as a percentage of income have fewer funds to spend on other necessary expenses. Typically, households with lower incomes are more likely to be burdened with high housing costs relative to their income level.

The housing burden for the City of Harrisburg for owner- and renter-occupied households with incomes less than $35,000 per year is shown in **Figures 7-8** and **7-9**, respectively. As shown in Figure 7-8, approximately 69 percent of owner-occupied housing units earning less than $35,000 per year have a housing burden at or above 30 percent of their annual household income. These housing units comprise approximately one-third of all owner-occupied housing units within the City. As shown in Figure 7-9, 78 percent of all renter-occupied housing units with household incomes less than $35,000 per year have a housing burden at or above 30 percent of their annual household income. These housing units represent approximately 62 percent of all renter-occupied housing units within the City. The results further demonstrate that low income customers within the City have very limited resources to pay for essential services, such as water and wastewater services.

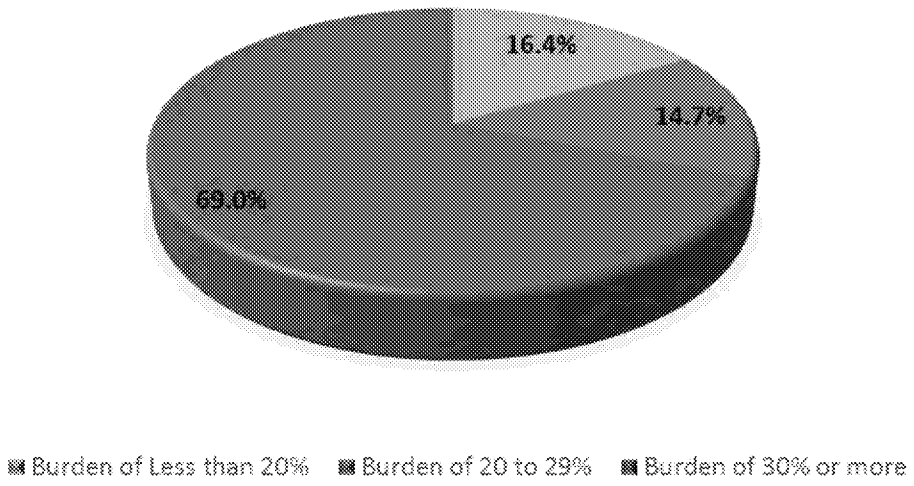

Figure 7-8: Housing Burden for Owner-Occupied Households in the City of Harrisburg (Incomes Less than $35,000 per Year)

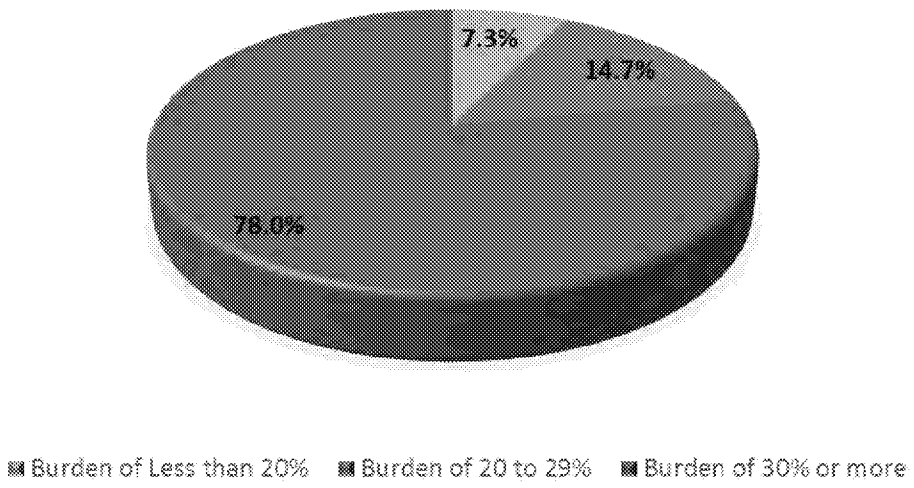

Figure 7-9: Housing Burden for Renter-Occupied Households in the City of Harrisburg (Incomes Less than $35,000 per Year)

7.5.7 Other Economic Indicators

The combined cost of utility services, including both water and wastewater service, is important to consider when assessing financial capability and affordability because both represent non-discretionary household expenses. Therefore, the annual water and wastewater bills for a typical residential customer within the City were compared to the City's MHI. This comparison was also made for various income categories and federal poverty level income thresholds. The current estimated annual water and wastewater bill (FY 2018) assuming 4,000 gallons of billed consumption per month, and a 5/8-inch residential meter is $544 per year for water and $336 per year for wastewater.

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7.5.7.1 Typical Bill as a Percentage of Federal Poverty Threshold Incomes

Reviewing the typical utility bills as a percentage of poverty level income also provides insight into the number of people currently facing unaffordable water and wastewater bills. As discussed earlier in this chapter, poverty thresholds vary by size of the household. Therefore, to complete this analysis, water consumption per person was assumed to be approximately 80 gallons per day, which corresponds to an average consumption of 22,727 gallons per year for the average customer with a one-person household, and up to 181,818 gallons per year for the average customer with 8 people per household.

As shown in **Table 7-13**, the wastewater bill as a percentage of poverty level income for various household sizes ranges from 0.8 percent to 2.7 percent. Similarly, the combined bill for water and wastewater as a percentage of poverty level income for various household sizes ranges from 2.0 percent to 7.0 percent. These results indicate that for those customers that are at or below the poverty threshold, a significant portion of household income is required to pay for water and wastewater service.

Table 7-13: Water and Wastewater Bill as a Percentage of Federal Poverty Threshold Incomes

Household Size	Poverty Threshold	Assumed Annual Usage	Wastewater Bill as a Percentage of Income	Combined Bill as a Percentage of Income
1	$12,486	22,727	2.7%	7.0%
2	$16,072	45,455	2.1%	5.5%
3	$18,774	68,182	1.8%	4.7%
4	$25,160	90,909	1.3%	3.5%
5	$29,854	113,636	1.1%	2.9%
6	$34,337	136,364	1.0%	2.6%
7	$39,509	159,091	0.9%	2.2%
8	$44,188	181,818	0.8%	2.0%

7.6 US-EPA Financial Capability Assessment

A financial capability assessment was completed in accordance with the February 1997 US-EPA guidance document – "CSO Guidance for Financial Capability Assessment and Schedule Development". In this section, the methodology and results of the financial capability assessment for CRW's wastewater CIP and Program Plan are presented for customers located within the City of Harrisburg. The analysis was completed to assess the residential cost as a percentage of income when capital costs that are needed to address known aging infrastructure issues are implemented, and to assess the remaining amount of capital expenditures that could be included in the Program Plan that would allow the Residential Indicator to remain at or just below 2.0 percent, or the US-EPA's defined criteria for its "High" financial impact range.

7.6.1 Financial Capability Assessment

7.6.1.1 Residential Indicator (City)

The Residential Indicator (residential cost as a percentage of MHI) was calculated by first determining the total cost of wastewater treatment (WWT) for customers located within the City of Harrisburg. The portion of wastewater treatment and conveyance costs recoverable from CRW's suburban wholesale customers was deducted from the total WWT cost to arrive at the City's portion. A portion of the total City cost was then allocated to residential customers based on the percentage of total flow generated from these customers. Finally, the total residential cost was allocated among the total number of households in the community to determine the wastewater treatment cost per household (CPH), including Program Plan costs. Once the CPH was estimated, the Residential Indicator was calculated by dividing the CPH by the MHI of the City. The calculated Residential Indicator was then compared to the US-EPA defined criteria for classifying the financial impacts as "Low," "Mid-range" or "High" as shown in **Table 7-14**.

Table 7-14: US-EPA Residential Indicator Financial Impacts

Financial Impact	Residential Indicator (Cost as a Percent of MHI)
Low	Less than 1.0 percent
Mid-Range	1.0 percent to 2.0 percent
High	Greater than 2.0 percent

7.6.1.1.1 Worksheet 1: Cost Per Household

Worksheet 1 develops the cost per residential household served by the City. The US-EPA defines current wastewater treatment costs as the current annual O&M expenses (excluding depreciation) plus current annual debt service payments (principal and interest). These costs are intended to represent the cash expenditures of current wastewater treatment, conveyance, and collection system operations. Lines 100 and 101 show the current FY 2018 O&M and debt service cost for CRW. These amounts were then prorated to subtract the portion of the costs that are currently allocated to suburban wholesale customers.

Line 103 shows the amount of total future capital costs that could be incurred by CRW to address aging infrastructure and for implementation of the City Beautiful H_2O plan while keeping the Residential Indicator from exceeding 2.0 percent. The projected costs include the portion of the costs that are anticipated to be allocated to suburban wholesale customers. However, as noted above, due to limited nature of the wholesale wastewater service provided to the suburban customers, CRW is not able to pass on a large portion of its Program Plan-related costs to these communities. The City's residential share of the total current and projected costs was then estimated based on an analysis of billed volume and CRW's cost of service and rate-setting policies. The cost per household was then calculated by dividing the City customer's residential share of the costs by the number households within the City. A summary of this calculation is provided in **Table 7-15**.

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Table 7-15: Worksheet 1: Cost Per Household

Description		Amount	EPA Line No.
Current WWT Costs:			
Annual Operations and Maintenance Expenses		$12,311,253	100
Annual Debt Service (Principal and Interest)		$4,819,817	101
Total Current WWT Costs		$17,131,069	102
Total Current WWTP Costs (City Share)	58.3%	$9,989,082	
Projected WWT and CSO Costs:			
Estimated Annual Operating and Maintenance Expenses		$1,998,704	103
Projected Capital Cost (Amount needed to reach high burden)	$184,800,000		
Annual Debt Service (Principal and Interest)		$13,983,371	104
Total Projected WWT and CSO Costs		$15,982,075	105
Total Projected WWT and CSO Costs (City Share)	74.5%	$11,903,819	
Total Current and Projected WWT and CSO Costs (City Share)		$21,892,901	106
Residential Share of WWT and CSO Costs	48.1%	$10,533,412	107
Total Number of City Households		15,218	108
Cost per Household		$692	109

7.6.1.1.2 Worksheet 2: Residential Indicator (City)

The Residential Indicator for the City was calculated by dividing the cost per household by the MHI. Multiple statistical sources were evaluated for MHI data for the City. The MHI was adjusted to 2018 dollars and the Residential Indicator was then calculated by dividing the Cost Per Household by the adjusted MHI for the City. A summary of these calculations is provided in **Table 7-16**.

Table 7-16: Worksheet 2: Residential Indicator

Description	Amount	EPA Line No.
MHI Census Year	2015	201
MHI Adjustment Factor	1.040	202
Adjusted MHI	$34,604	203
Annual WWT and CSO Control Cost per Household	$692	204
Residential Indicator:		
Cost per Household as a Percentage of Household Income	2.0%	205

The Residential Indicator was compared to the US-EPA financial impact ranges shown in Table 7-14 provided in the US-EPA guidance document to assess the financial impact that wastewater treatment and Program Plan costs may have on the community's residential customers. Based on the results of the analysis, a capital program of approximately $185 million in 2017 dollars was determined to be the maximum amount capital spend that could be incorporated into the analysis, while keeping the Residential Indicator at or below the "High" financial impact threshold of 2.0 percent.

The projected capital costs included in Worksheet 1 (Table 7-15) totaling approximately $185 million includes both direct Program Plan costs, and other capital needs of the wastewater system to address aging infrastructure and asset replacement needs. These other non-Program Plan related capital costs to address aging infrastructure total approximately $120 million (in 2017 dollars) and are planned to be implemented over the next 10 years. Additional capital expenditures to address aging infrastructure are anticipated to be needed beyond the 10-year period. Therefore, even without the Program Plan-related costs, the Residential Indicator is expected to increase to 1.67 due to implementing capital projects to address aging infrastructure, leaving a capacity of only approximately $65 million (in 2017 dollars) for Program Plan-related costs until the Residential Indicator reaches 2.0 corresponding to "High" financial impact.

7.6.1.2 Community Financial Capability Indicators (City)

The second phase of the US-EPA FCA is intended to assess the financial capability of the community. There are three general categories of measures used to assess the community financial capability: (1) debt indicators, (2) socioeconomic indicators, and (3) financial management indicators. However, three of the six community financial capability measures (overall net debt as a percentage of full market property value, property tax revenues as a percentage of full market property values, and the property tax collection rate) focus on General Fund government bond rating criteria and have little relevance to CRW, as it is a Municipal Authority separate from the City government and has no legal authority to establish or levy property tax assessments, and also cannot issue General Obligation bonds. While presented below for the City of Harrisburg, these factors, which all reflect weak scores, have less relevance to CRW.

The US-EPA has established guidelines for interpreting these indicators and their associated impact on the overall financial capability, and these guidelines are provided below.

7.6.1.2.1 Debt Indicators

Debt indicators assess the current debt burden of the community and its ability to issue additional debt to finance the planned future wastewater treatment and Program Plan projects. The indicators include bond rating and the overall net debt as a percentage of full market property value.

<u>Worksheet 3: Bond Rating</u>

Bond credit ratings measure a community's credit worthiness, and are assessed by one or more of the three major rating agencies. CRW received a rating on its Series 2017 Sewer System Revenue Bonds, dated May 18, 2017 from Standard & Poor's of "A+". CRW's credit rating of A+ from Standard & Poor's places it in the "Strong" category of US-EPA's indicator ranges.

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Worksheet 4: Net Debt as a Percentage of Full Market Value of Taxable Property

Net debt as a percentage of the full market value of taxable property compares the level of debt with the full market value of the real property used to support that debt. The US-EPA defines overall net debt as debt repaid by property taxes. It includes the debt issued directly by the municipality as well as debt of overlapping entities, such as school districts. It excludes debt that is repaid by special user fees (e.g., revenue debt). This measure considers the debt burden on residents within the service area and the ability of the municipality to issue additional debt. Financial information for the City was used for this section of the analysis, since CRW does not have taxing authority. A summary of this measure is provided in **Table 7-17**.

Table 7-17: Worksheet 4: Overall Net Debt as a Percentage of Full Market Property Value

Description	Amount
Overall Net Debt	$294,905,302
Market Value of Property	$1,586,229,000
Ratio	18.6%

As shown in the table, the City's overall net debt as a percentage of the full market value of property is extremely high at 18.6 percent. This results in the City being in the "Weak" category, based on US-EPA indictor ranges shown in **Table 7-18**.

Table 7-18: US-EPA Indicator Ranges for Overall Net Debt as a Percentage of Full Market Property Value

Rating	Ratio
Weak	Above 5 percent
Mid-Range	2 percent to 5 percent
Strong	Below 2 percent

7.6.1.2.2 Socioeconomic Indicators

Socioeconomic indicators are indicators of the economic well-being of residential customers. They offer additional insight into the economic conditions within the City. According to the US-EPA guidance document, two socioeconomic indicators to be considered are the (1) unemployment rate and (2) MHI. A more extensive discussion of the socioeconomic conditions of CRW's service area and its customers was provided previously.

Worksheet 5: Unemployment Rates

Unemployment rate (percent of service area residents who are on the unemployment rolls) for the City was compared to the national average unemployment rate, as shown in **Table 7-19**. The unemployment rate statistics show that the City's unemployment rate is high and currently well above the national average. A comparison of the City's unemployment rate with the national average places the City in the "Weak" range for this measure based on the US-EPA indicator ranges shown in **Table 7-20**.

Table 7-19: Worksheet 5: Unemployment Rates (2016)

Description	Percentage
City	14.3%
National (U.S.)	4.9%
Difference	9.4%

Table 7-20: US-EPA Indicator Ranges for the Unemployment Rate

Rating	Ratio
Weak	More than 1 percent above National Average
Mid-Range	+/- 1 percent of National Average
Strong	More than 1 percent below National Average

Worksheet 6: Median Household Income

The MHI for the City as compared to the national average MHI is shown in **Table 7-21**.

Table 7-21: Worksheet 6: Median Household Income

Description	MHI (2015)	Adjusted MHI (2018)
City of Harrisburg	$33,289	$34,604
National MHI (2015)	$55,775	$57,979
Percentage Below Adjusted National Average		-40.3%

The US-EPA has established indicator ranges for variation between national and permittee MHI in the financial capability assessment. Based on these ranges, which are shown in **Table 7-22**, the City of Harrisburg's adjusted 2018 MHI of $34,604, as compared to the adjusted 2018 national MHI of $57,979, places the City in the "Weak" range, well below the threshold for this rating category.

Table 7-22: US-EPA Indicator Ranges for MHI

Rating	Ratio
Weak	More than 25 percent below National Average
Mid-Range	Within 25 percent of National Average
Strong	More than 25 percent above National Average

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7.6.1.2.3 Financial Management Indicators (City)

The financial management indicators included in the US-EPA FCA are: (1) property tax revenues as a percent of full market property value and (2) property tax revenue collection rate. These financial management indicators are presented for the City of Harrisburg since CRW does not collect property taxes.

Worksheet 7: Property Tax Revenues as a Percent of Full Market Property Value

This indicator is referred to as the "property tax burden" since it indicates the funding capacity available to support debt based on the wealth of the service area. Property tax revenues as a percent of full market property value measures the capacity of the community to support additional debt. In other words, this figure estimates the ability of the local government to levy increased property taxes to fund additional borrowings. Financial information from the City was used for this measure since CRW does not have taxing authority. Also, the value for the full market value of real property excludes the value of tax-exempt properties within the City, and property tax revenues include revenues from overlapping entities (County and School District property taxes).

Table 7-23: Worksheet 7: Property Tax Revenues as a Percentage of Full Market Property Value

Description	Amount
Full Market Value of Real Property	$1,586,229,000
Property Tax Revenues	$73,271,394
Ratio	4.6%

As shown in the table, the City's property tax revenues comprise 4.6 percent of its taxable full market property value. The US-EPA has established the following indicator ranges for property tax revenues as a percentage of full market property value in the financial capability assessment. According to **Table 7-24**, the City falls in the "Weak" category for this measure.

Table 7-24: Property Tax Revenues as a Percentage of Full Market Property Value

Rating	Ratio
Weak	Above 4 percent
Mid-Range	2 percent to 4 percent
Strong	Below 2 percent

Worksheet 8: Property Tax Revenue Collection Rate

The property tax revenue collection rate reveals inefficiencies in the tax collection system by reporting the difference between the levied tax amount and the collected tax amount. The collected tax revenue for the City in FY 2016, excluding overlapping tax revenue, are shown in **Table 7-25**.

Table 7-25: Worksheet 8: Property Tax Revenue Collection Rate

Description	Amount
Property Tax Revenue Collected	$15,375,462
Property Tax Levied	$17,515,445
Property Tax Collection Rate	87.8%

As shown in the table, the City's property tax collection rate is 87.8 percent. The US-EPA has established the following indicator ranges for the property tax revenue collection rate in the financial capability assessment. According to **Table 7-26**, the City falls in the "Weak" category for this measure.

Table 7-26: Property Tax Revenue Collection Rate Benchmarks

Rating	Ratio
Weak	Below 94%
Mid-Range	94% to 98%
Strong	Greater than 98%

7.6.1.2.4 Worksheet 9: Summary of Results of System Financial Capability Indicators (City)

Based on this analysis, an overall Financial Capability Indicator score of 1.3 was calculated, which corresponds to a "Weak" Financial Capability Indicator rating based on the US-EPA methodology. The following table summarizes the financial indicators, the rating associated with each indicator and the City's score for each indicator. The average score for all indicators is used to determine the overall indicator score.

Table 7-27: Worksheet 9: Financial Capability Indicator Score

Indicator	Actual Value	Rating	Score
Bond Rating (CRW)	A+	Strong	3
*Overall Net Debt as a Percentage of Full Market Value	18.6%	Weak	1
Unemployment Rate	14.3%	Weak	1
Adjusted Median Household Income	$34,604	Weak	1
*Property Tax Revenues as a Percentage of Full Market Property Value	4.6%	Weak	1
*Property Tax Revenue Collection Rate	87.8%	Weak	1
Overall Financial Capability Indicator Score			1.3

* Indicators that are less relevant to a municipal authority, such as CRW, which does not have taxing authority.

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7.6.1.3 Worksheet 10: The Financial Capability Matrix (City)

Using the US-EPA methodology, the results of the Residential Indicator and the Financial Capability Indicator assessments were combined into a Financial Capability Matrix to evaluate the level of financial burden that WWT and Program Plan costs would impose on CRW and the City of Harrisburg. According to in the 1997 CSO Guidance Document, the stated purpose of the matrix was to assist the utility and regulatory agencies in establishing a Program Plan implementation schedule. The Financial Capability is shown in **Table 7-28.**

Table 7-28: Worksheet 10: Financial Capability Matrix Score

Financial Capability Indicators Score	Residential Indicator (Cost per Household as a Percent of MHI		
	Low – Less than 1.0%	Mid-Range – 1.0% to 2.0%	High – Greater than 2.0%
Weak – Below 1.5	Medium Burden	High Burden	High Burden
Mid-Range (1.5 to 2.5)	Low Burden	Medium Burden	High Burden
Strong (Above 2.5)	Low Burden	Low Burden	Medium Burden

Based on a "High" financial impact Residential Indicator of 2.0 percent and a "High" Financial Capability Indicator score of 1.3, the financial capability matrix score for CRW and the City was classified as "High Burden".

7.7 Long-Term Financial Projections and Rate Impacts

The US-EPA 1997 Guidance provides a "snapshot" of financial capability for a utility, but this method is limited in its ability to account for the impact that the program costs will have on overall affordability. Further, the US-EPA financial capability assessment guidance document allows consideration of unique circumstances and conditions. To present a more comprehensive picture of the City's financial capability and customer affordability, a comprehensive long-term financial planning and affordability model was prepared that is based on the model that CRW uses to evaluate budgets and set wastewater rates. Based on this analysis, projections of the average annual residential wastewater and stormwater bills for City retail customers were calculated in each year of the program.

The following discussion provides a summary of the methodology, key assumptions, and inputs used to develop the long-term financial planning and affordability model, followed by the resulting forecast for CRW's recommended capital plan.

7.7.1 Key Assumptions

The following key assumptions were incorporated into the financial projection. It should be noted that any changes in these assumptions could have a material effect on the findings included as part of this section of the Program Plan.

7.7.1.1 Wastewater and Stormwater Revenues

The revenues from wastewater user charges comprise the majority of revenue used to recover the costs of CRW's wastewater operations. Annual growth in the volume of billed flows applicable to the retail wastewater volumetric rate was assumed to be 0.1 percent per year in future years, based on a review of historical changes in retail customer accounts and water consumption per account. Annual growth in the volume of billed flows from suburban wholesale customers was assumed to remain flat in future years, based on a review of historical annual flow volumes from these customers.

Other miscellaneous revenues, such as interest income and miscellaneous fees provide a small portion of the total revenue. As of the date of this report, CRW has not implemented a separate stormwater fee to recover a portion of costs related to stormwater management. However, based on discussions with CRW, it intends to implement a stormwater fee separate from wastewater user charges as early as 2019. Therefore, revenues from implementing a stormwater fee have been included in this analysis and approximately $5.0 million of annual costs have been assumed to be recovered with stormwater fee revenues, instead of wastewater user charge revenues.

The levels of future revenues from wastewater operations and a new stormwater fee were projected based on the anticipated wastewater and stormwater revenue requirements (described below) and based on meeting CRW's established fiscal management policies. These policies included maintaining unrestricted cash reserves not less than 180 days of O&M expenses, and a debt service coverage ratio of not less than 1.35 times. These policies will help CRW borrow money for capital projects at favorable interest rates and help CRW maintain a relatively strong fiscal condition. CRW's wastewater Trust Indenture requires net revenues (operating revenues minus operating expenses) to be at least 120 percent of the annual debt service attributable to all outstanding senior lien debt. In addition, the covenant requires a minimum debt service coverage requirement of 100 percent on all outstanding subordinate lien debt.

7.7.1.2 Wastewater and Stormwater Revenue Requirements

The wastewater and stormwater rate revenue requirements consist of the revenues required to operate and maintain both the wastewater and stormwater systems, consisting of the amounts needed to cover O&M expenses and capital expenditures, including debt service payments. CRW's wastewater and stormwater systems O&M expenses are comprised of salaries and wages, benefits, insurance, electricity, chemicals, legal costs, and other expenses. The projection of these expenses over the forecast period were based on their FY 2018 budgeted amounts and certain cost escalation assumptions which were developed in part with discussions with CRW management. The escalation assumptions are shown in **Table 7-29**.

It is anticipated that additional, or incremental, O&M expenses would be incurred in future years as a result of implementing the City Beautiful H_2O program. The financial forecast includes incremental O&M expenses equal to 2.0 percent of the cost of planned green infrastructure projects. Furthermore, additional incremental O&M expenses were incorporated into the forecast the reflect the addition of an environmental compliance coordinator, collection and interceptor system inspection and cleaning, and neighborhood plan and concept development, which totaled approximately $900,000 per year.

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Table 7-29: Expense Category Cost Escalation Rates

Expense Category	2018-2022	2023-2032	2033-2047
Salaries and Wages	3.5%	3.5%	3.5%
Benefits	6.0%	4.0%	4.0%
Insurance	3.0%	3.0%	3.0%
Electricity	3.1%	3.1%	3.1%
Chemicals	4.0%	3.0%	3.0%
Water	5.1%	4.1%	4.1%
Other Expenses	2.8%	3.0%	3.0%

The annual capital expenditures associated with City Beautiful H_2O and other wastewater and stormwater capital needs were included in the affordability model at a level that would keep the annual combined residential wastewater and stormwater bill for City residents at or below 2.0 percent of the projected MHI for the City. CRW anticipates paying for the planned capital expenditures with a combination of long-term debt and current revenues from wastewater user charges. Approximately 50 percent of the total capital project costs over the long-term forecast period was assumed to be funded with long-term debt, and the remaining was assumed to be funded with current revenues on a pay-as-you-go basis. This level of cash funding of the capital program was required for CRW to meet its debt service coverage ratio targets and to keep CRW's debt burden at manageable levels. Further, CRW anticipates utilizing the state revolving loan fund program, administered through PENNVEST, to the maximum extent possible. However, to reflect the likelihood that CRW will not be able to fund all eligible projects through PENNVEST loans, blended debt financing assumptions were used in the long-term financial forecast. Debt service was calculated on future debt issues assuming the following financing terms:

- Interest Rate: 5.5 percent per year
- Term: 25 years
- Debt Issuance Cost: 1.5 percent of the amount of borrowed funds

The long-term forecast includes debt service payments on existing debt in addition to new debt service that would result from financing future capital projects.

7.7.2 Capital Expenditures and Rate Impacts

The long-term financial projection and affordability model results are presented in Table 7-31 for the 20-year period from 2018 to 2037. As shown in the table, it is anticipated that CRW can potentially include a total of $315 million (escalated), or $253 million (in 2017 dollars) in capital expenditures in its long-term 20-year financial plan, while keeping the annual combined residential wastewater and stormwater cost as a percentage of MHI for City customers at or below the 2.0 percent threshold, while also satisfying its cash and debt service coverage

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requirements, and keeping its debt burden at manageable levels. Of the $315 million, approximately $214 million is anticipated to be needed to address aging infrastructure issues Therefore no more than approximately $101 million for direct Program Plan-related projects will be available over the period.

Furthermore, as shown in the summary in **Table 7-30** and in **Table 7-31**, the amount of capital expenditures projected within the first ten years of the plan (totaling $225 million) is much more significant than in the remaining ten years (totaling $90 million) of the 20-year period. As a result, the financial plan indicates that significant wastewater rate increases will be needed over the first ten years of the plan. For example, including the 7.1 percent rate increase that was adopted by CRW in 2017 for 2018, cumulative increases in retail wastewater rates of 106.7 percent were forecasted to be required from 2018 to 2027, while cumulative retail rate increases of only 43.7 percent were forecasted to be required from 2028 to 2037. It should be noted that after 2027, the residential bill as a percentage of MHI approaches 2.0 percent and remains at this level throughout the remaining portion of the 20-year forecast period (2028 to 2037).

Table 7-30: Summary of Projected R&R and Program Plan Capital Expenditures (escalated)

Projected Type	Years 1-10	Years 11-20	Total
Rehabilitation & Replacement	$164,700,000	$49,200,000	$213,900,000
Wet Weather Control	$60,200,000	$41,100,000	$101,300,000
Total	$224,900,000	$90,300,000	$315,200,000

Note: Amounts escalated to future dollars.

While the capital costs included in the long-term financial plan and affordability model were structured and scheduled to allow for the total annual wastewater and stormwater bill for a typical residential customer to be maintained at or below the 2.0 percent threshold, it is anticipated that the annual bill amount for these services will far exceed 2.0 percent for some City customers in future years. For example, the typical annual residential wastewater and stormwater bill as a percentage of average census block income projected for FY 2027 is shown at the census block group level in **Figure 7-10**.

The projected annual wastewater and stormwater bills in this year reflect the annual rate adjustments shown in Table 7-31. As shown in Figure 7-10, the annual bill as a percentage of income for some census blocks within the City were anticipated to exceed 2.0 in many areas, with several areas being expected to exceed 3.0 percent. This indicates that the increases in retail wastewater and stormwater bills from implementing capital investments in the system would result in significant economic hardship for certain residential customers within the City.

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Table 7-31: Long Term Financial Plan and Affordability Projection

Description	1 2018	2 2019	3 2020	4 2021	5 2022	6 2023	7 2024	8 2025	9 2026	10 2027	11 2028	12 2029	13 2030	14 2031	15 2032	16 2033	17 2034	18 2035	19 2036	20 2037
Capital Project Funding (in Future $s)																				
Annual Wastewater (WW) CIP ($ millions)	$34	$19	$15	$18	$21	$17	$23	$25	$16	$7	$5	$5	$6	$6	$4	$4	$4	$4	$4	$4
Cumulative WW CIP ($ millions)	$34	$53	$68	$86	$107	$123	$146	$171	$188	$194	$200	$205	$211	$216	$220	$224	$228	$231	$235	$240
Annual Stormwater (SW) CIP ($ millions)	$0	$3	$3	$3	$3	$3	$3	$4	$4	$4	$4	$4	$4	$4	$4	$5	$5	$5	$5	$5
Cumulative SW CIP ($ millions)	$0	$3	$6	$9	$13	$16	$20	$23	$27	$31	$35	$39	$43	$47	$52	$56	$61	$66	$71	$76
Total Cumulative WW and SW CIP ($ millions)	**$34**	**$56**	**$74**	**$95**	**$119**	**$139**	**$165**	**$194**	**$214**	**$225**	**$234**	**$244**	**$253**	**$263**	**$272**	**$280**	**$288**	**$297**	**$306**	**$315**
Capital Financing - WW																				
Debt ($ millions)	$5	$12	$7	$10	$13	$9	$15	$17	$8	$0	$1	$1	$0	$1	$0	$0	$0	$0	$0	$0
Cash ($ millions)	$26	$7	$7	$7	$8	$8	$8	$8	$8	$7	$4	$4	$6	$4	$4	$4	$4	$4	$4	$4
Grants ($ millions)	$2	$1	$1	$1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Debt Service (DS) Coverage (All-in)	1.59	2.05	2.02	1.89	2.03	1.90	1.64	1.55	1.38	1.37	1.49	1.48	1.38	1.36	1.37	1.37	1.37	1.37	1.45	1.45
Cash Reserves (Days of O&M)	633	655	613	549	545	531	451	373	255	184	205	229	193	181	181	180	182	181	183	182
Total WW Annual Budget ($ millions)	$24	$24	$25	$27	$28	$30	$32	$34	$36	$35	$33	$34	$36	$35	$35	$36	$37	$38	$38	$38
Debt Service (DS) ($ millions)	$5	$6	$6	$7	$8	$9	$10	$11	$12	$12	$12	$12	$12	$12	$12	$12	$12	$12	$11	$11
DS as % of Total Budget	20.4%	24.2%	25.0%	26.6%	28.7%	29.7%	31.4%	33.3%	33.6%	34.6%	36.6%	36.4%	34.1%	34.8%	34.7%	34.0%	33.4%	32.5%	29.5%	28.8%
Rate Increase - Wastewater (WW) City	7.1%	10.0%	10.0%	10.0%	10.0%	8.0%	7.0%	6.0%	6.0%	5.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Cumulative Rate Increase WW City	7.1%	17.1%	28.1%	40.2%	53.5%	65.2%	76.3%	86.4%	97.2%	106.7%	110.7%	114.8%	118.9%	123.1%	127.5%	131.9%	136.4%	141.0%	145.6%	150.4%
Annual City Residential WW Bill (4,000 gal/mo)	$336	$369	$406	$447	$491	$531	$568	$602	$638	$670	$683	$697	$711	$725	$739	$754	$769	$785	$800	$816
Rate Increase - Stormwater (SW) City		0.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
Cumulative Rate Increase SW City		0.0%	3.0%	6.0%	9.1%	12.3%	15.6%	18.9%	22.4%	26.0%	29.7%	33.5%	37.4%	41.4%	45.6%	49.9%	54.3%	58.8%	63.5%	68.3%
Annual City Residential SW Bill	$0	$93	$95	$98	$101	$104	$107	$111	$114	$117	$121	$124	$128	$132	$136	$140	$144	$149	$153	$158
Total WW and SW City Residential Bill	$336	$462	$501	$545	$592	$635	$675	$712	$752	$787	$804	$821	$839	$857	$875	$894	$914	$933	$953	$974
Median Household Income (MHI) City	$34,604	$35,054	$35,510	$35,971	$36,439	$37,077	$37,726	$38,386	$39,058	$39,741	$40,536	$41,347	$42,173	$43,017	$43,877	$44,755	$45,650	$46,563	$47,494	$48,444
Lowest Quintile (LQ) Household Income (HI) City	$13,207	$13,379	$13,553	$13,729	$13,907	$14,151	$14,398	$14,650	$14,907	$15,167	$15,471	$15,780	$16,096	$16,418	$16,746	$17,081	$17,423	$17,771	$18,127	$18,489
Annual WW & SW Bill as % of MHI (City)	1.0%	1.3%	1.4%	1.5%	1.6%	1.7%	1.8%	1.9%	1.9%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Annual WW & SW Bill as % of LQ HI (City)	2.5%	3.5%	3.7%	4.0%	4.3%	4.5%	4.7%	4.9%	5.0%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.2%	5.3%	5.3%	5.3%

Note: Annual WW & SW bills as a % of MHI (City) equaling the high-burden threshold of 2.0 percent have been highlighted in Red.

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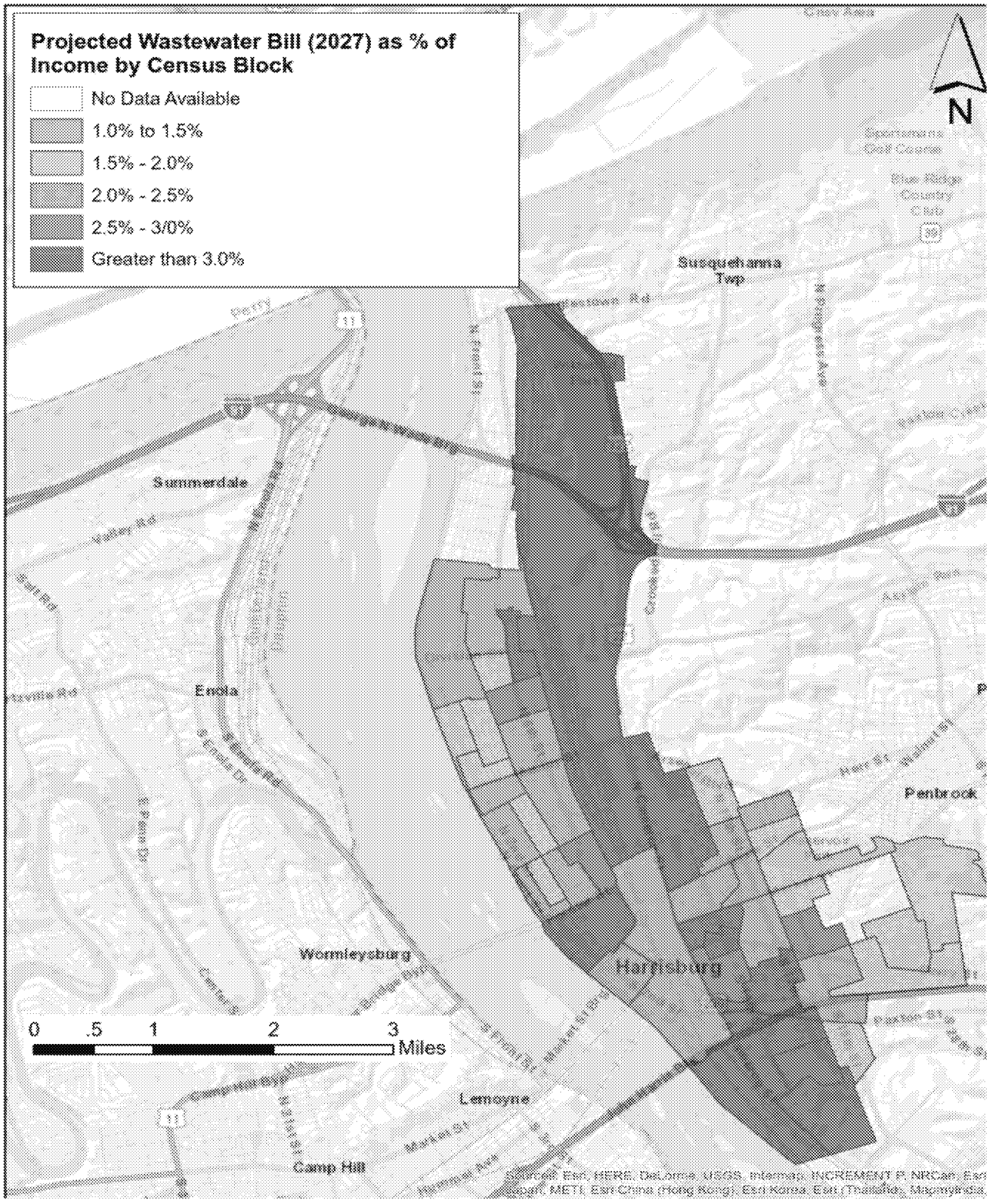

Figure 7-10: Distribution of Future Residential Wastewater and Stormwater Bill as Percentage of MHI (2027)

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7.8 Conclusions

The following are the conclusions of the Financial Capability and Affordability Assessment:

- The City of Harrisburg has experienced significant financial distress for several years, entering state-mandated receivership in 2011. In 2012, the City's debt per capita was among the highest of any city in the U.S. Although the City has since left formal receivership, it continues to be under state oversight through the State of Pennsylvania's Municipalities Financial Recovery Act (No. 47) and concerns remain regarding future economic growth within the area.

- The poverty rate in the City of Harrisburg has ranged between 31.2 and 33.9 percent over the last five years, from 2012 to 2016, with these rates being at least twice the national, state, and county (Dauphin County) poverty levels. Some reasons for the high poverty rates in the City include fewer married-couple households, lower educational attainment, and a high unemployment rate. This level of poverty within the City demonstrates the presence of significant economic hardship.

- The MHI within the City of Harrisburg is significantly lower than national, state, and local MHI levels. For example, in 2015, the MHI in the City was $33,289, which was more than $20,000 less than the national, state, and local (Dauphin County) MHI's in the same year. Furthermore, the MHI of CRW's service area was $52,732 in 2015, which is approximately 58.4 percent higher than in the City of Harrisburg. This demonstrates that there is a significant disparity in income levels within CRW's service area, with many communities having higher, or in some cases, significantly higher MHI's than the City of Harrisburg.

- To compound the City's already low MHI, households with lower incomes are more likely to be burdened with high housing costs relative to their income level. These households spend a significant proportion of their incomes on housing, and thus have fewer funds to spend on other necessary expenses, such as water and wastewater services. Within the City, 69 percent of owner-occupied housing units earning less than $35,000 per year have a housing burden at or above 30 percent of their annual household income, with this comprising approximately one-third of all owner-occupied housing units within the City. In addition, 78 percent of all renter-occupied housing units with household incomes less than $35,000 per year have a housing burden at or above 30 percent of their annual household income, with this comprising approximately 62 percent of all renter-occupied housing units within the City.

- Approximately 25 percent of households within the City currently have annual wastewater bills that exceed 2.0 percent of their income, and approximately 30 percent have combined water and wastewater bills that exceed 4.5 percent of their income. By 2027, it is projected that about half of all households will have annual wastewater bills that exceed 2.0 percent of their incomes, while approximately 45 percent of all households will have annual combined water and wastewater bills that exceed 4.5 percent of their incomes. In addition, roughly 15 percent of all households within the City have annual wastewater bills that are at least 3.4 percent of their household income and combined annual water and wastewater bills that are at least 8.8 percent of their income.

- The FCA analysis using the EPA approach indicated that a capital program of approximately $185 million in 2017 dollars was the maximum amount capital spend that could be incurred by CRW while keeping the Residential Indicator at the threshold of "High" financial impact. CRW has identified approximately $120 million in capital costs (in 2017 dollars) needed to be spent to address aging infrastructure issues over the next 10 years. This leaves a capacity of only approximately $65 million for Program Plan-related costs until the Residential Indicator reaches 2.0 corresponding to "High" financial impact.

- A comprehensive year-by-year, long-term financial plan and affordability model was developed to assess the impact of capital program alternatives on customer bills and CRW's financial position. This model indicates that CRW can only include a total of $315 million (escalated), or $253 million (in 2017 dollars) in capital expenditures in its long-term 20-year financial plan, while keeping the annual combined residential wastewater and stormwater cost as a percentage of MHI for City customers at or below the 2.0 percent threshold, while also satisfying its cash and debt service coverage requirements, and keeping its debt burden at manageable levels. Of the $315 million, approximately $214 million is anticipated to be needed to address aging infrastructure issues over the 20-year period.

- No more than approximately $101 million for direct Program Plan-related projects will be available over this period. This limitation on capital expenditures will continue for at least 30 years until current and near-term debt necessitated by the near-term capital improvements is paid off.

- While the capital plan included in the long-term financial plan and affordability model was designed to keep total annual City residential customer cost for wastewater and stormwater service at or below 2.0 percent of MHI, it is anticipated that there will be significant and severe affordability issues for some customers within the City, with some customers experiencing wastewater and stormwater costs as a percentage of income exceeding 3.0 percent.

- The jurisdictional scope of this FCA and affordability assessment is pursuant to paragraph V-E (18) of the Consent Decree, which addresses the Harrisburg Sewer System as defined in paragraph IV-8(w). Moreover, CRW is required to allocate costs between the municipalities proportionately to the causes of cost pursuant to its inter-municipal service agreements, the Pennsylvania Municipality Authorities Act and federal regulations. More specifically, since CRW provides only treatment, and in some cases conveyance, services to the suburban communities, and since the suburban municipalities own, operate, and manage their own wastewater collection systems, CRW is unable to pass on a large portion of its Program Plan-related costs to these suburban municipalities. The affordability and financial capability assessment presented above reflects a proportionate allocation of future capital costs between the CRW municipalities.

Given these considerations, CRW should receive the maximum schedule relief possible for implementing its City Beautiful H_2O program. The implementation schedule presented in this report is a reasonable timeline, taking into consideration affordability, concerns in the more vulnerable areas of the CRW's service area, and CRW's maintenance of a secure financial position over the term of the program.

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Section 8

Development and Evaluation of Alternative Control Strategies

8.1 Overview: Alternative Approaches to Meeting LTCP Goals

The Partial Consent Decree (PCD) requires that the *City Beautiful H_20 Program Plan* (Program Plan) assess the potential size and cost of alternative control technologies to reach various levels of control. This evaluation defined the level of CSO discharge control (i.e. the reduction in the frequency, volume and duration of discharges during typical year precipitation) that could be achieved by each technology over a range of sizes. The Capital Region Water (CRW) hydrologic and hydraulic (H&H) model was used to perform what is called a "knee-of-the curve" cost performance evaluation, required by the PCD. These cost-performance curves were used to indicate the level of control needed to reach certain control objectives:

- A Baseline Level of Control, defined as the level of CSO control achieved through implementation of system rehabilitation measures laid out in Section 4 coupled with additional controls discussed in Section 8.2.
- An affordable level of control, defined as additional wet weather controls that can be implemented within the financial capabilities of CRW's ratepayers, as defined in Section 7.
- A cost-effective level of control, defined as the additional wet weather controls at the "knee of the curve" cost-effectiveness, where the inflection point along each cost curve indicates the level of control above which any additional control measures would be less cost effective.
- A presumptive level of control, defined as the controls necessary to capture and treat 85 percent of the systemwide combined sewage during the typical year.

The following *alternative control strategies* are developed by combining a unique set of the stormwater/wet weather control technologies presented in Section 6:

- ***Systemwide control strategies*** that further enhance control of stormwater / wet weather flow within CRW's conveyance and treatment systems, i.e., the Advanced Wastewater Treatment Facility (AWTF), major pump stations, interceptors, and/or regulators):
    - *Systemwide Strategy 1:* Increase conveyance/treatment (i.e., the existing conveyance capacity) by upgrading interceptors, regulators, major pump stations, and the AWTF.
    - *Systemwide Strategy 2:* Build a deep tunnel to collect/store combined sewage flows exceeding the existing conveyance capacity, with post-storm dewatering to AWTF.
- ***Local control strategies*** within CRW's collection system to address both neighborhood flooding and water quality impacts of discharges to receiving waters:

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- *Local Strategy 1: Decentralized controls* (green-grey) within neighborhoods to reduce CSOs/SSOs/unauthorized discharges, and MS4 discharges; maximize triple bottom line benefits, and leverage non-traditional funding sources.
- *Local Strategy 2: Satellite controls* that employ storage/treatment/conveyance facilities placed near outfalls to control CSOs (limited control for unauthorized, MS4 discharges).
- *Local Strategy 3: Separation* of stormwater and wastewater within a portion of the collection system, accompanied by green infrastructure sized to treat stormwater.

Local control strategies are presented for each of the 15 program planning areas shown on Figure 5-2 to better illustrate facility siting priorities and benefits.

Each alternative control strategy is evaluated to determine which provides the best balance between wet weather performance, cost, and triple bottom line (TBL) benefits over the level of control range under evaluation, while rehabilitating CRW assets. These evaluation factors are discussed in more detail in Section 5.

The engineering cost opinion and combined sewer overflow control effectiveness of each alternative is presented in the form of a cost-performance, or "knee-of-the-curve" plot. These plots allow a straightforward comparison of the combined sewer system (CSS) performance and the present value of the cost of each alternative to the utility. However, these plots do not capture the full range of environmental, social, and economic costs and benefits of each alternative. To evaluate these factors, various triple bottom line (TBL) criteria are weighed for each alternative control strategy and level of control to support selection of a preferred control strategy.

8.2 Baseline Level of Control

8.2.1 Baseline Level of Control Definition of Controls

The baseline level of control involved multi-objective projects that provide priority remedial repairs to CRW's AWTF and conveyance system, as defined in Section 4, coupled with low cost, high performance projects that optimize the existing sewer system. Relatively low-cost operating changes, repairs, and small-scale capital projects that can improve the capacity, efficiency, and performance of the CSS in the near term (i.e., as a nine minimum control or an early-action project). Optimization and enhancement opportunities within a Baseline Level of Control are summarized in **Table 8.2-1**. Other opportunities, such as flow diversion modifications, in-system storage, and hydraulic bottleneck or constriction removal within the collection system will be identified and addressed as part of the local control strategy for each planning area.

The Baseline Level of Control includes making modifications to the CSO regulator structures to maximize the capture of CSO discharges and optimize hydraulic performance. As depicted in **Table 8.2-2**, these modifications include raising the crest elevations of the diversion dams, removal of the existing Brown and Brown (B&B) mechanical regulating devices, increasing the control orifice size, expanding the diameter of the connecting pipe, and/or CSO outfall repairs, including those to the backflow prevention gates that prevent flood flow from entering the interceptor system.

Table 8.2-1: Baseline Level of Control Optimization and Enhancement Opportunity Descriptions

Opportunities	Description
Regulator/Outfall Enhancements	
▪ **Outfall/River Intrusion Gate Repair**	Replace or repair of existing flap gates to prevent receiving water intrusion into the collection system and interceptor.
▪ **Regulator/Weir Change**	Adjusting regulator/weir dimensions to maximize combined sewage capture.
Interceptor Rehabilitation/ Enhancement	Lining structurally-deficient portions of the interceptor to increase resiliency and minimize dry weather infiltration/exfiltration.
Pump Station Rehabilitation/ Enhancement	Major rehabilitation of the Front Street and Spring Creek pump stations to increase resiliency and enhance total pumping capacity to 80 MGD (i.e., limit that can be accommodated by existing structures).
AWTF Rehabilitation/ Enhancement	New headworks/screening facilities and major rehabilitation of treatment processes to increase resiliency and enhance total primary treatment capacity to 80 MGD (i.e., limit that can be accommodated by existing structures).

Table 8.2-2: Baseline Rehabilitation and Enhancement of the Regulator & Outfall Structures

Catchment	Planning Area	Repair Outfall/ Gates	Raise Weir	Remove Restriction*	Expand Connector Pipe	Interceptor Backflow Prevention
S-004	Riverside	✓	✓	✓		✓
S-005	Riverside	✓	✓	✓		✓
S-049	Uptown	✓	✓			✓
S-050	Uptown	✓	✓			✓
S-051	Uptown	✓				✓
S-006	Uptown	✓	✓			✓
S-007	Uptown	✓	✓			✓
S-008	Uptown	✓				✓
S-009	Uptown	✓				✓
S-010	Uptown	✓				✓
S-011	Uptown	✓				✓
S-012	Middle Front Street		✓	✓		✓
S-013	Middle Front Street	✓	✓			✓
S-014	Middle Front Street		✓	✓		✓
S-015	Middle Front Street		✓	✓		✓
S-016	Middle Front Street		✓	✓		✓
S-052	Middle Front Street		✓			✓
S-053	Middle Front Street	✓	✓			✓
S-054	Middle Front Street		✓	✓		✓
S-055	Middle Front Street		✓			✓
S-056	Middle Front Street		✓	✓		✓
S-017	Lower Front Street		✓			✓
S-018	Lower Front Street	✓	✓			✓
S-019	Lower Front Street	✓	✓	✓		✓
S-020	Lower Front Street	✓	✓			✓
S-057	Lower Front Street	✓				✓
S-058	Lower Front Street	✓				✓
S-021	Upper Paxton Creek - West	✓	✓	✓		✓
S-022	Upper Paxton Creek - West	✓				✓
S-024	Upper Paxton Creek - West	✓	✓	✓		✓

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Table 8.2-2: Baseline Rehabilitation and Enhancement of the Regulator & Outfall Structures

Catchment	Planning Area	Repair Outfall/ Gates	Raise Weir	Remove Restriction*	Expand Connector Pipe	Interceptor Backflow Prevention
S-027	Upper Paxton Creek - West	✓				✓
S-028	Upper Paxton Creek - West	✓	✓			✓
S-023	Upper Paxton Creek - East	✓	✓	✓		✓
S-025	Upper Paxton Creek - East	✓	✓			✓
S-026	Upper Paxton Creek - East	✓		✓		✓
S-030	Middle Paxton Creek - West	✓	✓			✓
S-032	Middle Paxton Creek - West	✓	✓			✓
S-037	Middle Paxton Creek - West	✓	✓	✓	✓	✓
S-038	Middle Paxton Creek - West	✓				✓
S-041	Middle Paxton Creek - West	✓	✓			✓
S-029	Middle Paxton Creek - East	✓	✓	✓		✓
S-031	Middle Paxton Creek - East	✓	✓	✓	✓	✓
S-033	Middle Paxton Creek - East	✓		✓		✓
S-034	Middle Paxton Creek - East	✓		✓		✓
S-039	Middle Paxton Creek - East	✓	✓	✓		✓
S-040	Middle Paxton Creek - East	✓		✓		✓
S-042	Lower Paxton Creek	✓	✓	✓		✓
S-043	Lower Paxton Creek	✓	✓	✓		✓
S-044	Lower Paxton Creek	✓	✓			
S-045	Lower Paxton Creek	✓	✓			✓
S-046	Lower Paxton Creek	✓	✓			✓
S-048	Lower Paxton Creek	✓	✓	✓		✓
S-059	Lower Paxton Creek		✓	✓		
S-060	Hemlock Street	✓	✓			✓
S-061	Hemlock Street	✓	✓	✓		✓
S-062	Hemlock Street	✓	✓	✓		✓
S-063	Hemlock Street	✓	✓	✓	✓	✓
S-064	Hemlock Street	✓	✓	✓		✓
					Total Opinion of Probable Cost:	**$2,214,000**

*Restriction could be Brown & Brown or orifice plate

The Baseline Level of Control also includes the rehabilitation of the existing interceptor systems to correct observed structural deficiencies and restore the structural integrity of the pipe network. Under the Baseline Level of Control, the Front Street and Spring Creek Pump Stations will be rehabilitated and expanded to restore reliability, reduce the risk of a major failure, and increase hydraulic capacity to a systemwide peak capacity of 80 MGD. Improvements to the AWTF will also be made to increase the wet weather primary treatment capacity to 80 MGD. **Table 8.2-3** itemizes the costs associated with each of these rehabilitation and enhancement projects.

Table 8.2-3: Baseline Level of Control Project Costs and Priorities

Project Name	Description	Priority	Estimated Cost
Regulator Rehabilitation/ Enhancement	The following enhancements will be made at selected regulator structures: raise weirs to increase in-system storage, increase capacity to AWTF, prevent river intrusion, perform structural repairs	High	$2,214,000
Interceptor Rehabilitation ▪ Paxton Creek ▪ Asylum Run ▪ Front Street ▪ Spring Creek	Restore the structural integrity of major interceptors to avoid failures, maintain hydraulic capacity.	 High High High High	 $8,723,000 $993,000 $9,400,000 $2,500,000
Pump Stations ▪ Front Street ▪ Spring Creek	Upgrade 50-year old mechanical, electrical systems while increasing hydraulic capacity within existing structures.	 High Medium	 $9,700,000 $7,500,000
AWTF ▪ Headworks ▪ Primary Clarifiers	Improve operations, resiliency of AWTF while increasing hydraulic capacity within existing structures.	 High High	 $3,586,000 $9,827,000
		Total Opinion of Probable Cost:	**$54,443,000**

8.2.2 Baseline Level of Control Cost Performance Evaluation

This section presents cost and performance of the Baseline Level of Control. Baseline improvements would rehabilitate and upgrade existing CRW assets to optimize their hydraulic performance, wet weather control, and long-term resiliency utilizing technologies that are relatively low-cost and simple changes, including minimum control measures, operational changes, and simple structural refinements, that optimize or enhance the existing system. The following reductions in CSOs are achieved under the Baseline Level of Control during the typical year:

- Decrease the average annual CSO discharge volume from 796 million gallons per year to 372 million gallons per year (i.e., a decrease of 423 million gallons per year).
- Increase the average annual CSO volume capture from 54 percent to 78 percent, ranging between 45 percent to 98 percent across the combined catchments, as depicted in **Figure 8.2-1**.
- Reduce the system-wide frequency of CSO discharges from 53 to 26 on average throughout the CSO catchments; to a range between 2 to 57 CSO discharges per year at various combined catchments.

The total opinion of probable cost for the improvements within the Baseline Level of Control is estimated at $54.4 million. This performance point will be added to the knee-of-the curve cost analysis addressed later in this report section. Priority will be given to increasing the level of control achieved in under-performing combined catchments under the various control strategies summarized in this section.

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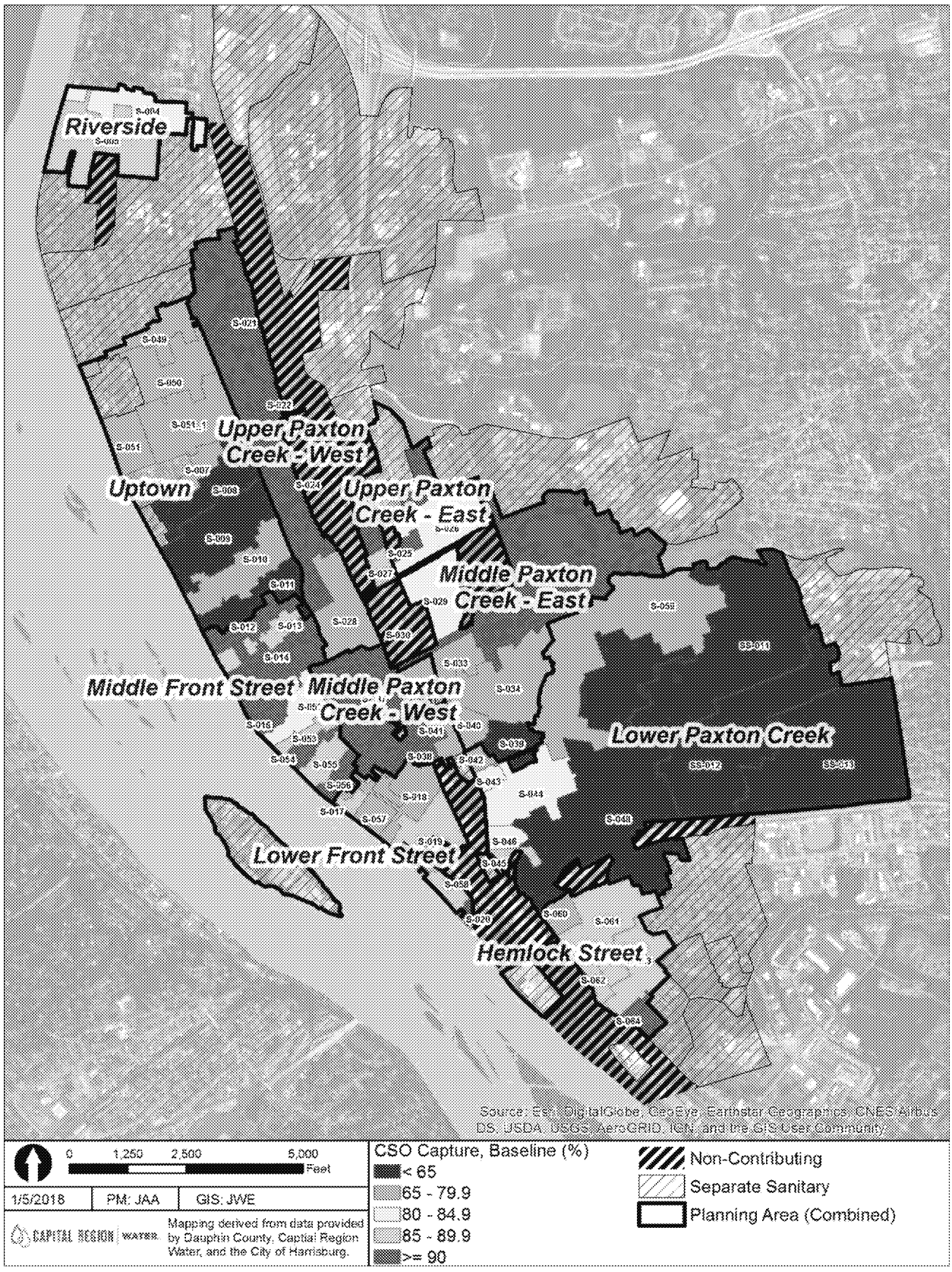

Figure 8.2-1: CSO Volume Capture by Catchment under the Baseline Level of Control

8.3 Systemwide Control Strategies

Systemwide control strategies that further enhance control of stormwater / wet weather flow within CRW's conveyance and treatment systems, i.e., the AWTF, major pump stations, interceptors, and/or regulators):

- *Systemwide Strategy 1:* Increase conveyance/treatment (i.e., the existing conveyance capacity) by upgrading interceptors, regulators, major pump stations, and the AWTF.
- *Systemwide Strategy 2:* Build a deep tunnel to collect/store combined sewage flows exceeding the existing conveyance capacity, with post-storm dewatering to AWTF.

8.3.1 Systemwide Control Strategy 1: Enhanced Conveyance and Increased Capacity at AWTF

8.3.1.1 Definition of Control Levels

Systemwide Control Strategy 1, illustrated in **Figure 8.3-1**, involves increasing the capacity of CRW's conveyance system and AWTF over a range of control levels, and the resulting effect on CSO control, water quality enhancement, and other TBL objectives. The following levels of control points are examined:

First and Second Control Points: The first control point under Systemwide Control Strategy 1 is the baseline improvement control level described in Section 8.2. The second control point would increase conveyance and treatment capacity to the hydraulic capacity of the Front Street and Paxton Creek interceptors (approximately 120 MGD) by adding the following improvements:

- Additional modifications would be made to selected regulator structures to further increase the hydraulic capacity.
- Expansion of the pump station buildings at the Paxton Creek and Spring Creek pumping stations, coupled with additional pumping capacity to achieve a net hydraulic capacity of 120 MGD.
- Utilization of backup headworks capacity (total capacity = 120 MGD), coupled with additional primary treatment capacity at the AWTF.
- The average annual CSO volume capture under typical year precipitation would increase to 1,360 million gallons, or 82 percent capture systemwide.
- The systemwide CSO discharge frequency would be reduced to 30 times per year and the discharge frequency at individual outfalls would range from 0 to 73 times per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $71 million.

Third Control Point: The third control point under Systemwide Control Strategy 1 would include all the previous improvements and add the following improvements:

- New parallel interceptors of equal transmission capacity at the existing Paxton Creek and Front Street interceptors (net capacity of 240 MGD), installed along the same routes taken by existing interceptors.

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- Further expansion of the Front Street and Spring Creek pump stations and the AWTF to achieve a net hydraulic capacity / primary treatment capacity of 240 MGD.
- In the Paxton Creek Corridor, construction of a parallel interceptor could be completed in conjunction with stream corridor enhancement to improve water quality.
- The average annual CSO volume capture under typical year precipitation would increase to 1,420 million gallons or 86 percent capture systemwide.
- The systemwide average CSO discharge frequency would be reduced to 15 times per year and the discharge frequency at individual outfalls would range from 0 to 15 times per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $360 million.

Fourth Control Point: The fourth control point would include all the previous improvements and add the following improvements:

- Increase the interceptor capacity, pumping station capacity and the treatment capacity of the AWTF so that the peak hydraulic and treatment capacities of the CRW system are 400 MGD.
- The average annual CSO volume capture under typical year precipitation would increase to 1,600 million gallons or 97 percent capture systemwide.
- The systemwide average CSO discharge frequency would be reduced to 10 times per year and the discharge frequency at individual outfalls would range from 0 to 10 times per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $640 million.

Fifth Control Point: The fifth control point would include all the previous improvements and add the following improvements:

- Improve the interceptor system and pumping station, and increase the treatment capacity of the AWTF so that the peak hydraulic and treatment capacities of the CRW system are 700 MGD.
- The average annual CSO volume capture under typical year precipitation would increase to 1,630 million gallons.
- The systemwide average CSO discharge frequency would be reduced to 4 times per year and the discharge frequency at individual outfalls would range from 0 to 4 times per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $930 million.

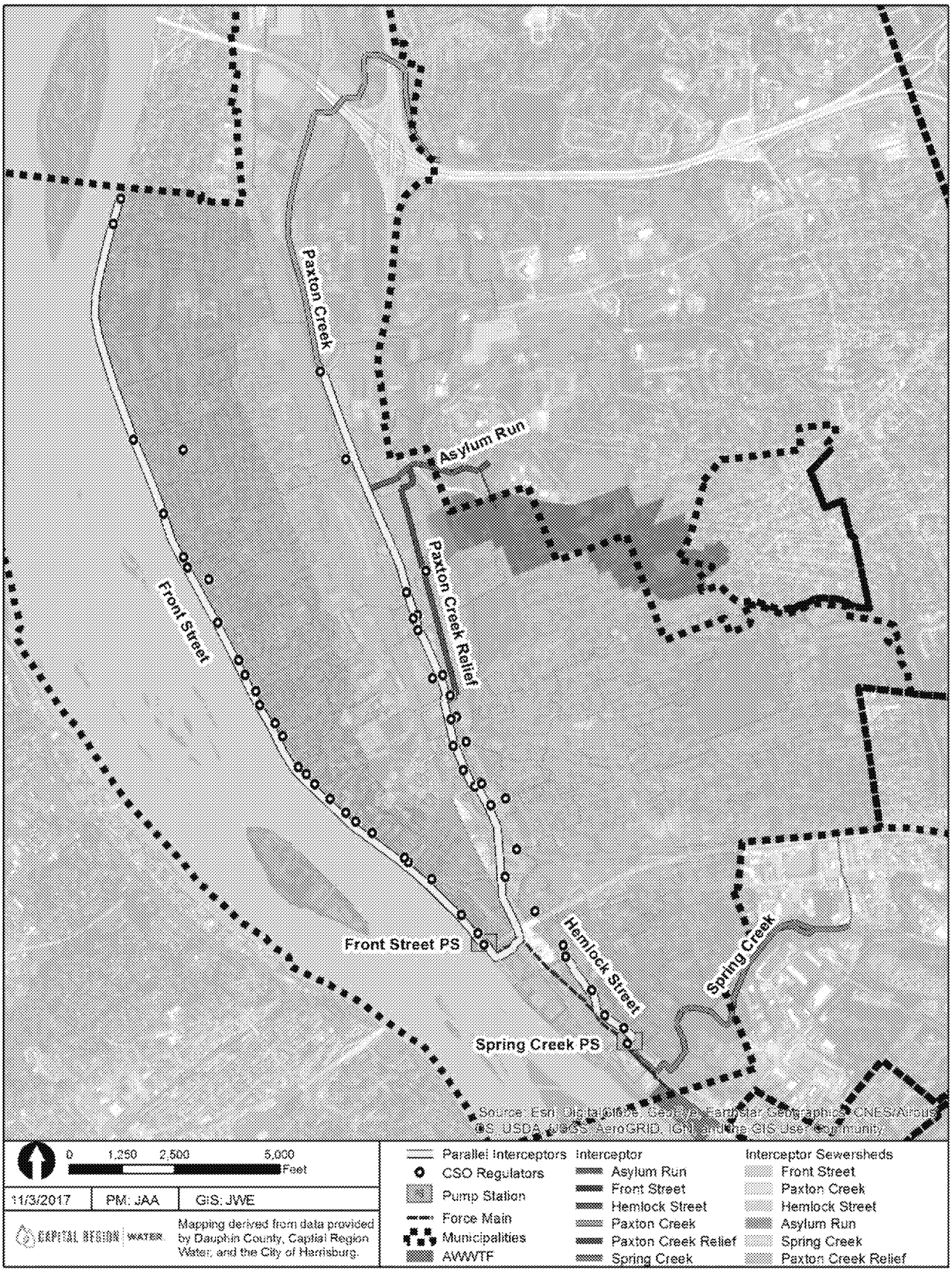

Figure 8.3-1: Location of Systemwide Control Strategy 1 Facilities: Enhanced Conveyance and Increased Capacity at AWTF

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Sixth Control Point: The sixth and final control point would include all the previous improvements and add the following improvements:

- Further improve the interceptor system, and further expand the pumping station and the treatment capacity of the AWTF so that the peak hydraulic and treatment capacities of the CRW system are 1,200 MGD.
- The average annual CSO volume capture under typical year precipitation would increase to 1,660 million gallons.
- The systemwide CSO discharge frequency would be reduced to zero per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $1.43 billion.

8.3.1.2 Cost Performance Evaluation

This section presents cost and performance of each control level evaluated under Systemwide Control Strategy 1. **Figure 8.3-2** presents a cost-performance curve for this control strategy, with a "knee-of-the-curve" created by connecting the alternative levels of control illustrating the optimal or "cost-effective" level of control. The other two levels of control under consideration are presented in Section 8.1 (i.e., the presumptive level of control) and Section 7 (the affordable level of control).

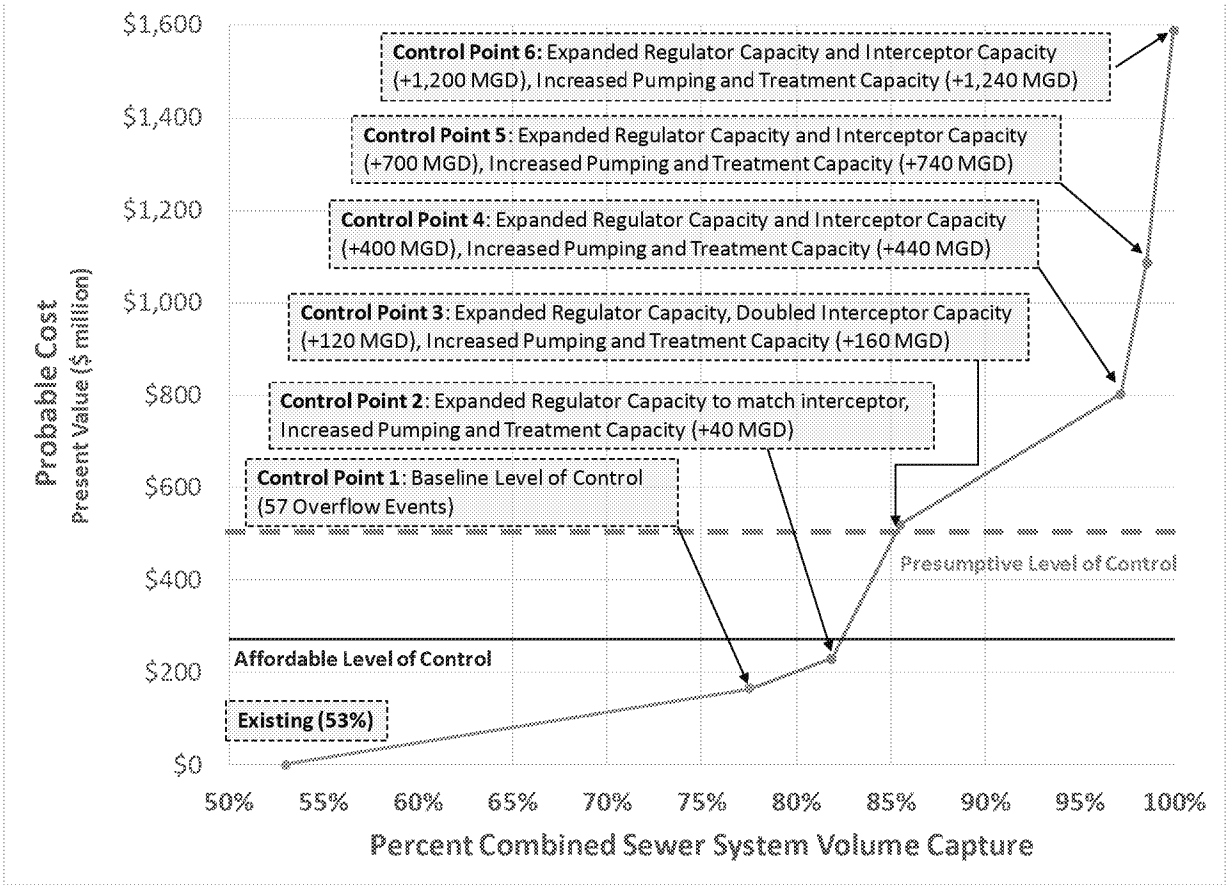

Figure 8.3-2: Enhanced Conveyance and Increased Capacity at AWTF CSO Capture Performance and Opinion of Probable Cost Estimate

8.3.2 Systemwide Control Strategy 2: Deep Tunnel Storage / Conveyance

8.3.2.1 Definition of Controls

Systemwide Control Strategy 2 seeks to reduce CSO volume, frequency, and duration using a traditional tunnel storage system. Combined sewage is stored temporarily and dewatered to the AWTF. **Figure 8.3-3** illustrates the major components of this systemwide control strategy consisting of the following components:

- New conveyance / consolidation conduits to transmit the desired design flow to the tunnel drop shafts.
- Approximately seven drop shafts to convey flow from consolidation sewers to the tunnel.
- Storage tunnels and associated infrastructure approximately parallel to existing interceptor sewers and perpendicular to existing trunk sewers. Two tunnel lengths were examined:
    - A minimum length of 30,000 feet for each tunnel was set where CSO regulators become less dense – CSO-049 on the Front Street Interceptor and CSO-023 on the Paxton Creek Interceptor and the range of length is bookended by the terminal trunk sewers on the north end of the system – CSO-004 on the Front Street Interceptor and CSO-021 on the Paxton Creek Interceptor.
    - A full-length tunnel of 45,000 feet, adequate to connect all CSOs to the AWTF.

A range of tunnel inner diameter was examined, starting with the approximate minimum feasibly constructible - about 10 feet, and increasing as necessary to provide additional storage.

To increase CSO management performance of the storage tunnel, it was necessary to expand the capacity of the AWTF to include additional high rate treatment depending on the peak capacity needed to reach full combined sewer overflow capture and treatment.

First Control Point: The first control point under Systemwide Control Strategy 2 is the baseline control described in Section 8.3.1.1.

Second Control Point: The second control point under systemwide Control Strategy 2 would add the following improvements:

- Approximately 14 million gallons of tunnel storage would be provided. A 10-ft diameter tunnel would extend from the AWTF to CSO-049 along Front Street. A 10-ft diameter tunnel would extend along the Paxton Creek Interceptor from the AWTF to CSO-023.
- The average annual CSO volume capture under typical year precipitation would increase to 1,520 million gallons, or 92 percent capture systemwide.
- The systemwide average CSO discharge frequency would be reduced to 7 times per year and the discharge frequency at individual outfalls would range from 13 to 25 times per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $715 million.

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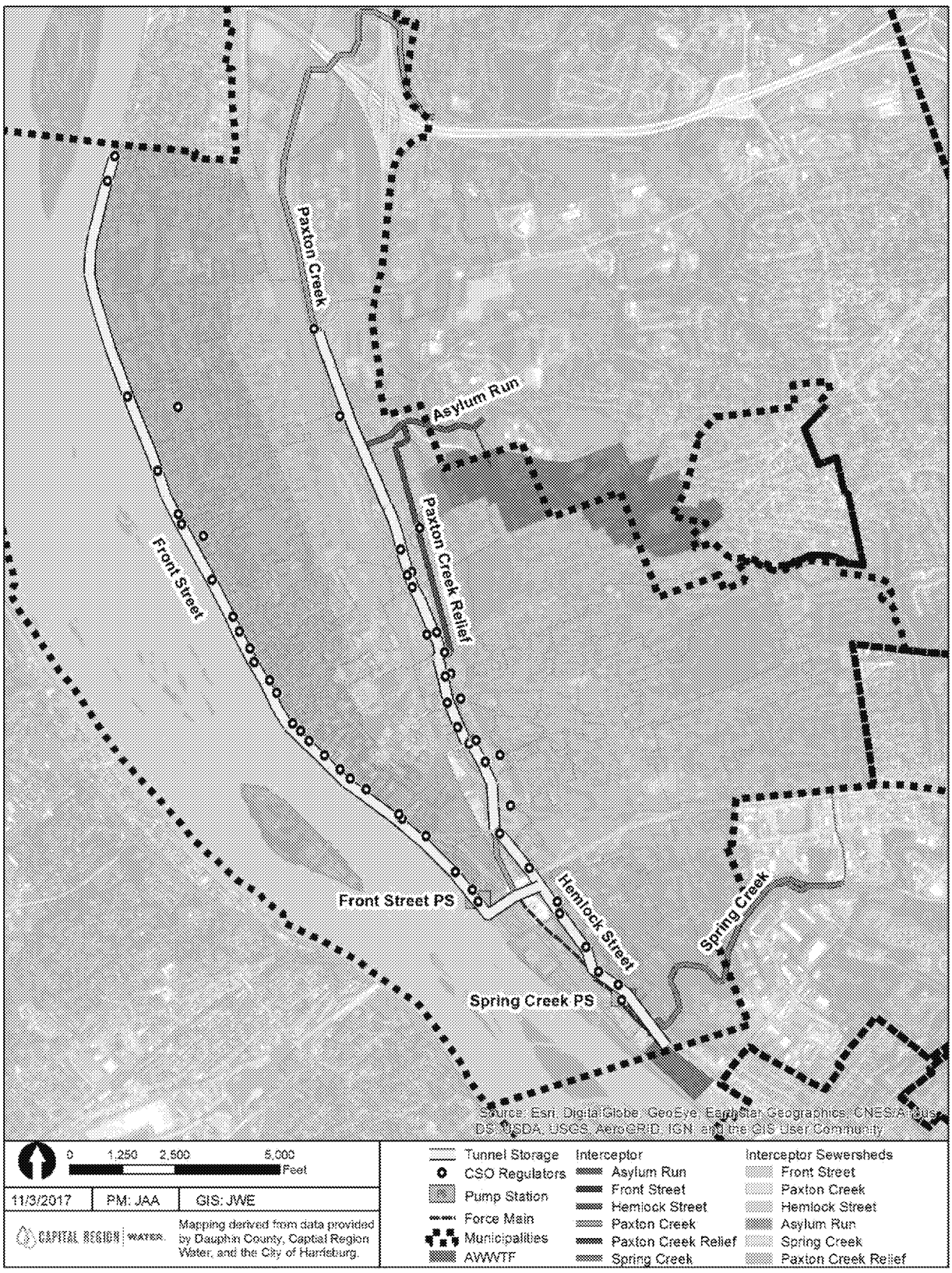

Figure 8.3-3: Location of Systemwide Control Strategy 2: Deep Tunnel Storage/Conveyance

Third Control Level Point: The third control level under Systemwide Control Strategy 2 would include the following improvements:

- Approximately 32 million gallons of tunnel storage would be provided. A 15-ft diameter tunnel would extend from the AWTF to CSO-049 along Front Street. A 15-ft diameter tunnel would extend along the Paxton Creek Interceptor from the AWTF to CSO-023.
- The average annual CSO volume capture under typical year precipitation would increase to 1,600 million gallons or 97 percent capture systemwide.
- The systemwide annual average CSO discharge frequency would be reduced to 4 times per year and the discharge frequency at individual outfalls would range from 13 to 25 times per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $860 million.

Fourth Control Level Point: The fourth and final control level under systemwide Control Strategy 2 would include the following improvements:

- Approximately 63 million gallons of tunnel storage would be provided. A 15-ft diameter tunnel would extend along the Paxton Creek Interceptor from the AWTF to CSO-021. A 15-ft diameter tunnel would extend from the connection to the Paxton Creek Tunnel near CSO-048 to CSO-004 along Front Street.
- The average annual CSO volume capture under typical year precipitation would increase to 1,630 million gallons or 100 percent capture systemwide.
- The systemwide annual CSO discharge frequency would be reduced to zero per year under typical year rainfall.
- The total opinion of probable cost associated with these additional improvements is $1.2 billion.

8.3.2.2 Cost Performance Evaluation

This section presents the cost and performance of each alternative control point analyzed under Systemwide Control Strategy 2, which is based upon deep tunnel storage. **Figure 8.3-4** presents a knee-of-the-curve cost-performance curve for the control strategy, illustrating the optimal "cost-effective" level of control.

A dashed line is shown connecting the Baseline Level of Control point with the 14 million gallon storage tunnel control level point because there is no "real" connection. Theoretically one could construct a deep tunnel system with short tunnel segments, but realistically, it could not be cost effective because of the large sunk cost for the tunnel boring machine and the construction shafts.

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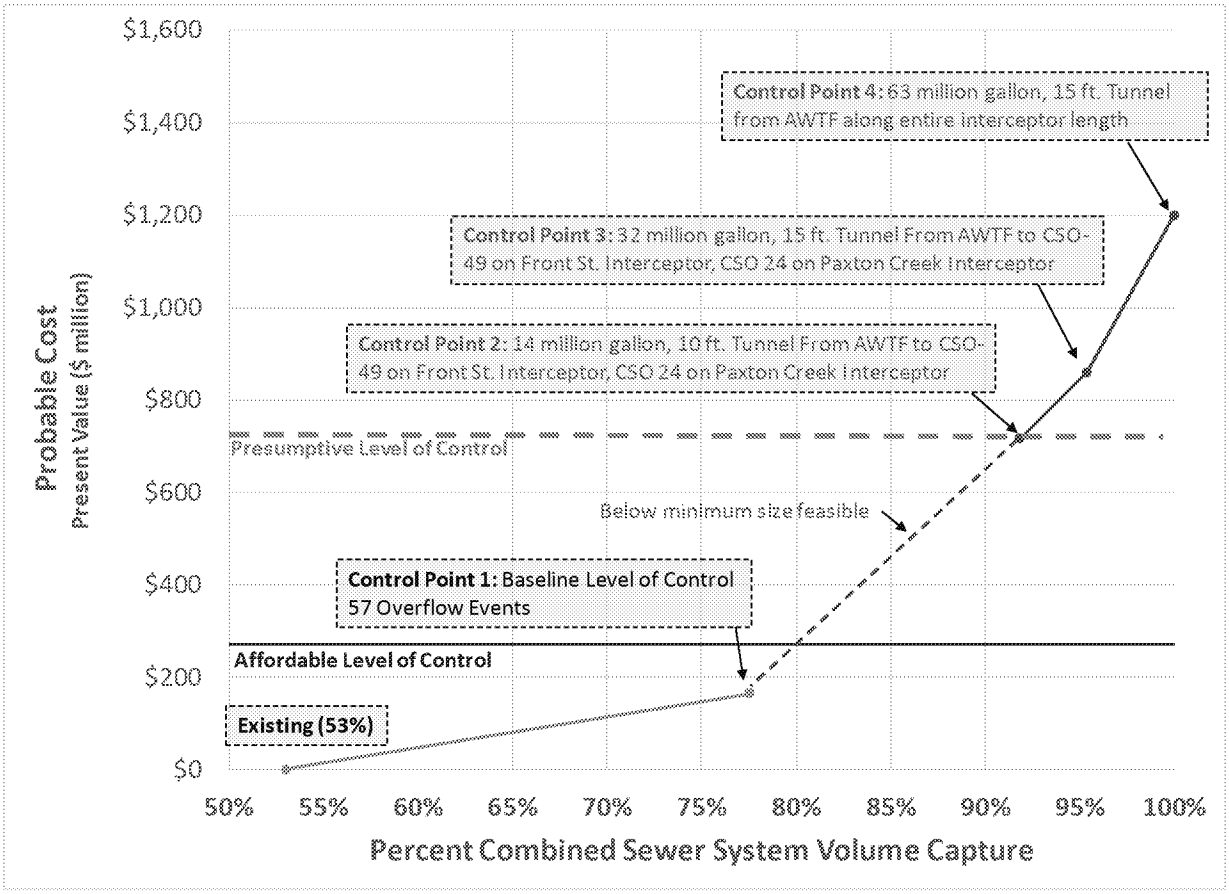

Figure 8.3-4: Deep Tunnel Storage / Conveyance CSO Capture Performance and Opinion of Probable Cost Estimate

8.3.3 Systemwide Control Strategy Findings

The following conclusions can be drawn from the cost performance evaluation of the two systemwide control strategies.

- ***Systemwide Control Strategy 1: Enhanced Conveyance and Increased AWTF Capacity*** (presented in Section 8.3.1) only provides a single control option within CRW's affordable level of control range. This option, the second control point, provides increased AWTF and pumping capacity equivalent to CRW's existing interceptor capacity. This option also presents distinct disadvantages when compared to the local control strategies presented later in this chapter:
  - It offers no opportunity to address unauthorized releases from the combined sewer system and relieve significant health and safety impacts to CRW's customers.
  - It involves significant major capital projects, restricting CRW's ability to address critical collection system rehabilitation needs.
- ***Systemwide Control Strategy 2: Deep Tunnel Storage / Conveyance*** (Presented in Section 8.3.2) is not a feasible control strategy for CRW's system. The smallest feasible control level under this strategy, a 14 million gallon tunnel, has the same disadvantages when compared to the local control strategies as Systemwide Control Strategy 1. In addition:

- It is unable to be phased / financed within CRW's remaining financial capability,
- It costs approximately four times more than the upper limit of CRW's affordable level of control range,
- It costs over twice as much as Enhanced Conveyance and Increased AWTF Capacity (systemwide strategy 1) to achieve an equivalent level of CSO control.

8.4 Localized Control Strategy

Alternative local control strategies include decentralized green stormwater and/or grey infrastructure implementation, satellite treatment and/or storage with consolidation, and further separation of catchments which are already partially separated. The intent of the local control strategies is to assist with solving existing problems regarding CSOs, SSOs, unauthorized releases, MS4 discharges, and significant structural deterioration. The local control strategy is better adept to address SSOs, unauthorized releases of combined sewage (i.e. sewage backups into basements and manhole flooding onto streets) and collection system structural integrity than systemwide strategies, which focus CSO control near receiving waters.

Three local control strategies are formulated within each of the program planning areas, each building upon the Baseline Level of Control presented in Section 8.2.

- *Local Strategy 1:* A *decentralized control strategy* that focuses controls (a) within catchments where the baseline strategy does not achieve the desired CRW level of control and (b) to achieve multi-objective benefits (e.g., reduce CSOs/SSOs/unauthorized discharges, and MS4 discharges; maximize triple bottom line benefits, leverage non-traditional funding sources).
- *Local Strategy 2:* A *satellite control strategy* that employs storage/treatment/conveyance facilities focused on CSO control within catchments where the baseline level of control is less than 85 percent capture.
- *Local Strategy 3:* A *sewer separation strategy* within catchment areas where the baseline level of control is less than 85 percent capture, defining various percentages and areas of the collection system to separate to enhance CSO control; and install GSI with new separate storm sewers to prevent an increase in pollutant loading to receiving waters to achieve desired control levels.

A range of control levels is evaluated for each Local Control Strategy/Planning Area in order to progressively evaluate the cost performance of the control technologies appropriate for each strategy.

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8.4.1 Riverside Planning Area

The Riverside Planning Area, shown on **Figure 8.4.1-1**, encompasses a 104 acre area within the Front Street Interceptor Sewershed. It is roughly bounded by the Susquehanna River on the west, Seventh Street on the east, Graham Street on the south, and Vaughn Street on the north. The Riverside Planning Area largely consists of single-family residential development, with only a few commercial properties located along Front Street and in the eastern portion of S-004, and an overall impervious area of 54 acres. It encompasses combined sewer catchments S-004 and S-005, delineated on Figure 8.4.1-1, all discharging to the Front Street Interceptor and/or overflowing to Susquehanna River. Figure 8.4.1-1 also identifies locations where capacity/flooding issues, moderate river intrusion, relatively high CSO frequency/low capture, and some identified structural issues exist.

8.4.1.1 Definition of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.1-1** for the Riverside Planning Area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: Medium priority gate repairs have been identified for CSOs 004 and 005 to prevent river intrusion at the 2-year flood stage. No outfall pipe repairs were identified.
- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising both weirs at 004 and 005.
- **Adjust Orifice Openings**: During wet weather, according to H&H modeling, both orifice restrictions (Brown and Brown) contribute to CSOs. High priority is given to removing these B&Bs and orifice restrictions, replacing them with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.
- **Expand Connection Pipes:** H&H modeling did not reveal any locations for affordable and cost-effective connection pipe expansion. The existing pipe connections are of adequate size.
- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Riverside Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber or metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSO 005.

Table 8.4.1-1: Riverside - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-004	✓	✓	✓		✓	$21,000	$15,000	
S-005	✓	✓	✓		✓	$21,000	$15,000	
					Total Cost:	**$42,000**	**$30,000**	

Priority:	High	Medium	Low	None

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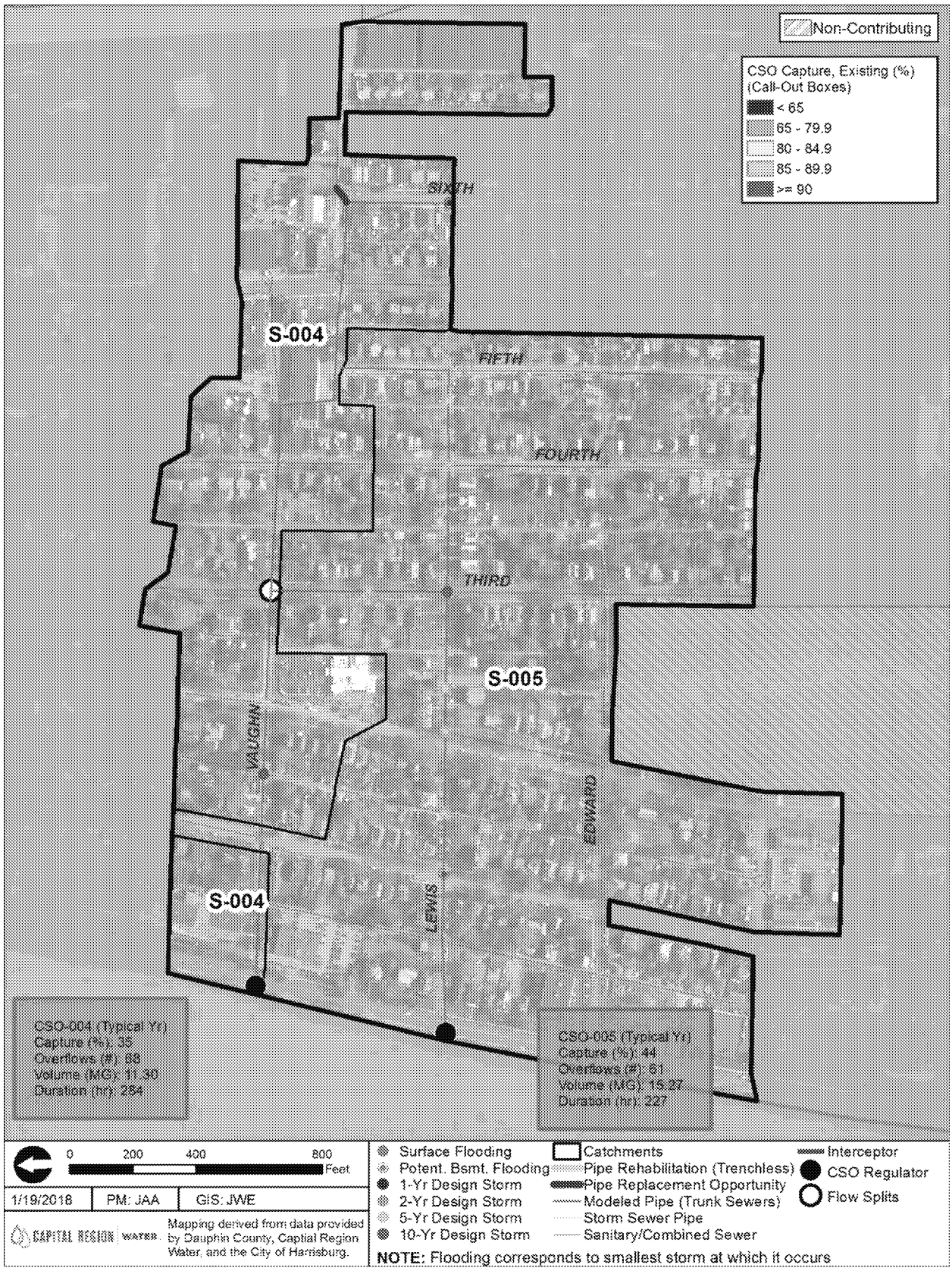

Figure 8.4.1-1: Riverside - Existing Hydraulic and Structural Problems

Table 8.4.1-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Riverside Planning Area:

- CSO performance is greatly increased in CSOs 004 (+49% capture and a reduction of 44 overflow events) and 005 (+43% capture and a reduction of 45 overflow events) by raising weirs.
- Planning area CSO capture increases from 40% to 86% with these modest changes.
- CSO frequency is reduced from 65 to 20, on average, during the typical year.

Table 8.4.1-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Riverside Planning Area nearly meet or exceed the presumptive (85% capture) levels of control. As such, the local control strategy should focus on locations where H&H modeling indicates unauthorized releases more often than annually, with additional CSO control assigned a long-term priority. The following local control strategies will be considered to achieve these objectives.

Table 8.4.1-2: Riverside – Existing/Baseline CSO Performance During Typical Year

	S-004	S-005	Total
Impervious Drainage Area (acres)	18.2	33.8	52
CSO Volume Captured (MG)			
• Existing Conditions	6.0	11.9	18.0
• Baseline Level of Control	14.6	23.5	38.1
CSO Volume (MG)			
• Existing Conditions	11.3	15.3	26.6
• Baseline Level of Control	2.7	3.6	6.4
• Volume Reduced	8.5	11.6	20.2
CSO Capture (%)			
• Existing Conditions	35%	44%	40%
• Baseline Level of Control	84%	87%	86%
CSO Events			Max | Avg.
• Existing Conditions	68	61	68 65
• Baseline Level of Control	24	16	24 20
Estimated Implementation Cost			
• Per Vol Reduced ($/1000 MG)	$4.24	$3.10	$3.56

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized

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technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized controls (green-grey) can be placed at many locations within the Riverside Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.1-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.1-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control, is nearly achieved throughout the Riverside Planning Area and that additional CSO control is not a priority in this Planning Area.

- ***GSI implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.1-2** indicate impervious areas assigned the highest priority for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a lower priority for control with green/decentralized infrastructure. **Table 8.4.1-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.1-3: Riverside - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-004	1.82	0.00	1.82	4.47	2.62	7.08	8.90
S-005	5.05	0.01	5.06	10.2	6.81	17.0	22.1
Total	**6.87**	**0.02**	**6.88**	**14.6**	**9.43**	**24.1**	**31.0**
of Total Impervious	**13%**	**0%**	**13%**	**28%**	**18%**	**46%**	**60%**

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates a high risk that unauthorized releases from the combined collection system will occur during the 1-year design storm, as depicted on **Figure 8.4.1-1**.

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

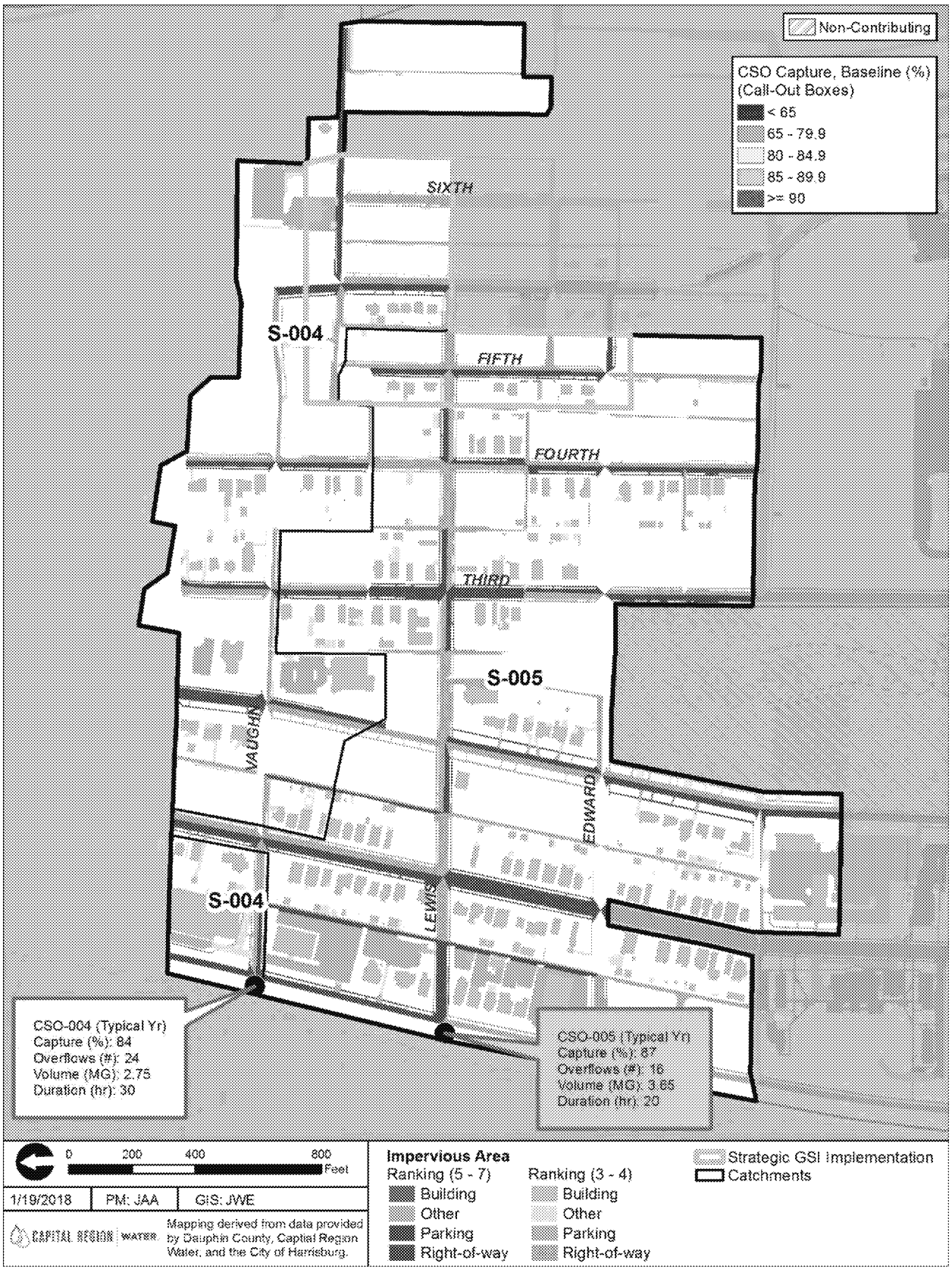

Figure 8.4.1-2: Riverside - Decentralized Green and Grey Infrastructure Opportunities

Strategic GSI Implementation Areas, indicate where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits. In the Riverside Planning Area, the streets where H&H modeling indicates a high risk of unauthorized releases on more than an average annual basis (e.g., 5th Street between Alricks Street and Edward Street, 6th Street between Alricks Street and Lewis Street) are designated Strategic GSI Implementation Areas.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.1-3 illustrates the major components of the Satellite Control Strategy within the Riverside Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a storage/treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to Susquehanna River. This strategy focuses on CSO control and does not address unauthorized releases or structural integrity within the collection system. The Satellite Control Strategy builds upon the Baseline Level of Control, adding the following technologies described below.

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.
- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.
- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

High potential satellite control sites are located in CSO catchments where the baseline level of control already exceeds the affordable level of control (approximately 80 percent capture) and take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Moderate potential satellite control sites are located in CSO catchments where the baseline level of control already exceeds the presumptive level of control and/or present moderate site constraints. The satellite storage/treatment strategy developed for the Riverside Planning Area involves placing a 12 to 47 MGD satellite high rate treatment facility within the Capital Area Greenbelt at Lewis Street, with 600 feet of consolidation sewer along Front Street between CSO-004 and 005. This Facility is assigned a moderate potential.

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.1-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

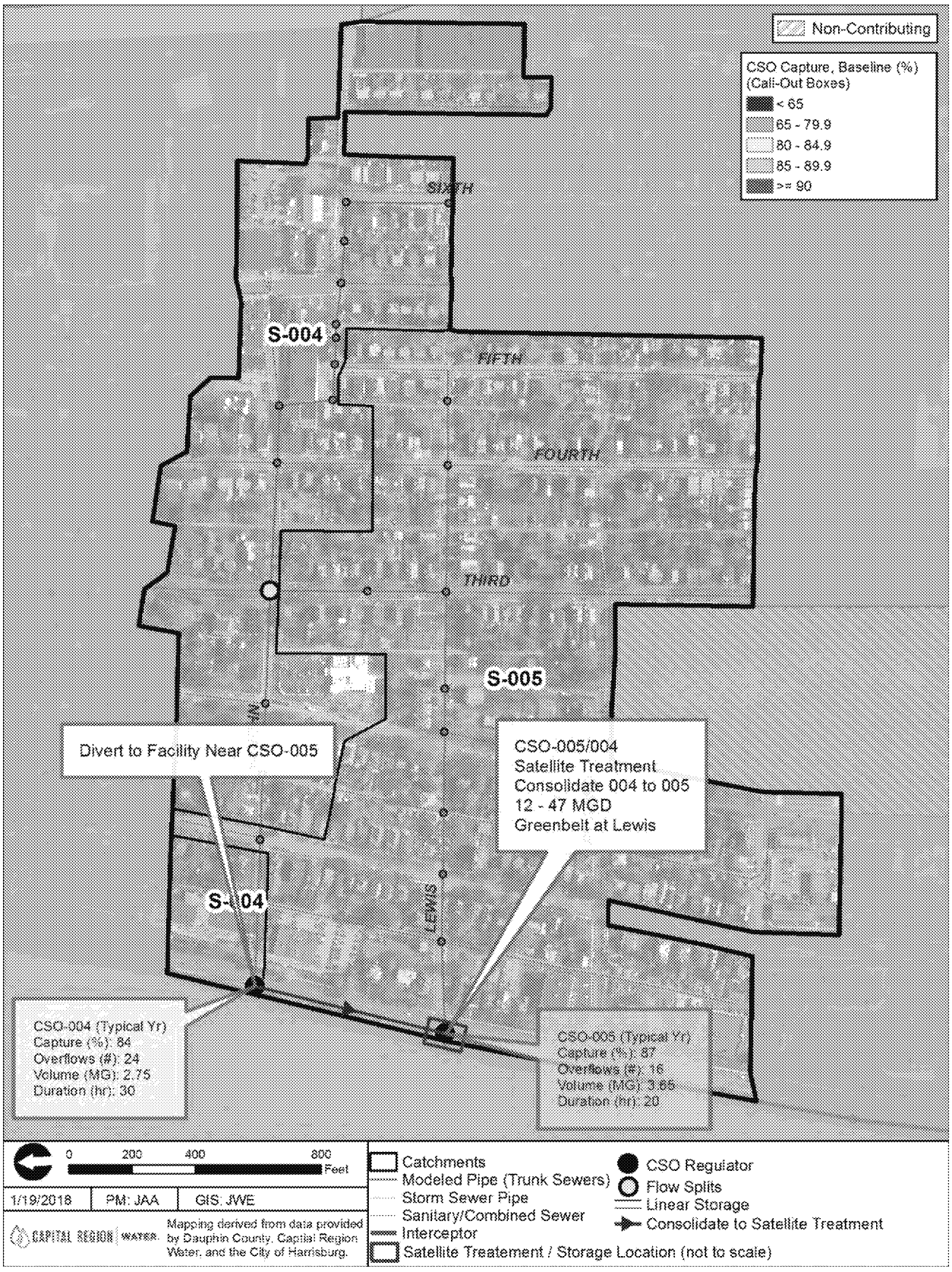

Figure 8.4.1-3: Riverside - Satellite Treatment / Storage Opportunities

Table 8.4.1-4: Riverside – Levels of Control (Local Control Strategy 3)

Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	None	0	0	
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	S-004, S-005	8.9	65	$8
Full Separation	S-004, S-005	53.7	386	$48

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas occur where a limited number sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. No opportunities for cost-effective separation of an entire catchment exist in the Riverside Planning area.

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. Cost-effective opportunities for sanitary flow rerouting exist within 17% of the impervious area in the planning area: 1.5 acres of Catchment S-004 and 7.3 acres of Catchment S-005.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. Cost-effective opportunities for stormwater disconnection exist within 17% of the impervious area in the planning area: 1.5 acres of Catchment S-004 and 7.3 acres of Catchment S-005.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. **Table 8.4.1-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment.

8.4.1.2 Cost Performance Evaluation

Figure 8.4.1.4 presents cost performance curves for each of the local control strategies developed for the Riverside Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control evaluated by the Plan.

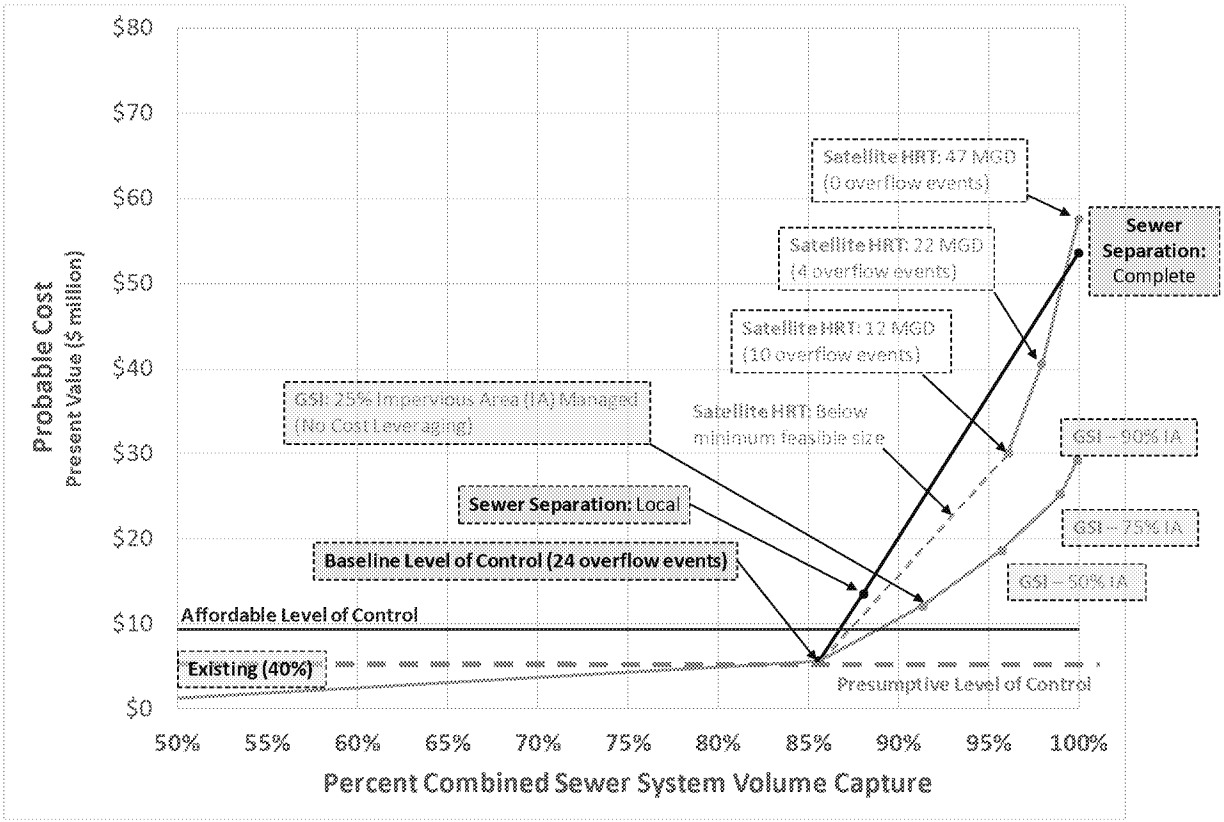

Figure 8.4.1-4: Riverside - CSO Capture Performance and Opinion of Probable Cost Estimate

Figure 8.4.1-5 presents a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

- The ***baseline level of control*** captures 86 percent of the combined sewage volume generated within the Riverside Planning Area during the typical year. Approximately $5.6 million of the cost of CRW's baseline level of control is apportioned to the Riverside Planning Area, including $72,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved exceeds the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a low priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control*** is defined as the level of control achieved through expenditures determined to be affordable to CRW's customers based on the Financial Capabilities Analysis presented in Section 7. The affordable level of control, as apportioned to the Riverside Planning Area is $9.4 million, with $5.6 million already allocated to the baseline level of control. Investments within this range should focus on collection system rehabilitation and/or control of unauthorized releases within this Planning Area during the 20-year planning horizon.

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- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address these collection system rehabilitation and/or unauthorized releases. The cost-performance curve indicates that the decentralized control strategy is less costly than the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. The smallest satellite treatment/ storage facility feasible to implement within the Riverside Planning Area – a 12 MGD satellite HRT – costs three to five times the affordable level of control range for this planning area. Since the Riverside Planning Area has a low priority for additional CSO control, and this technology is ineffective at control of unauthorized releases, this control strategy is not recommended for this planning area.

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. The cost performance curves clearly show that complete sewer separation is both more costly than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

8.4.1.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving CSO control within the Riverside Planning Area. An additional investment of up to $5 million is considered affordable for control of unauthorized releases and/or collection system rehabilitation within this planning area. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. While this planning area will not be prioritized for additional CSO controls, any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

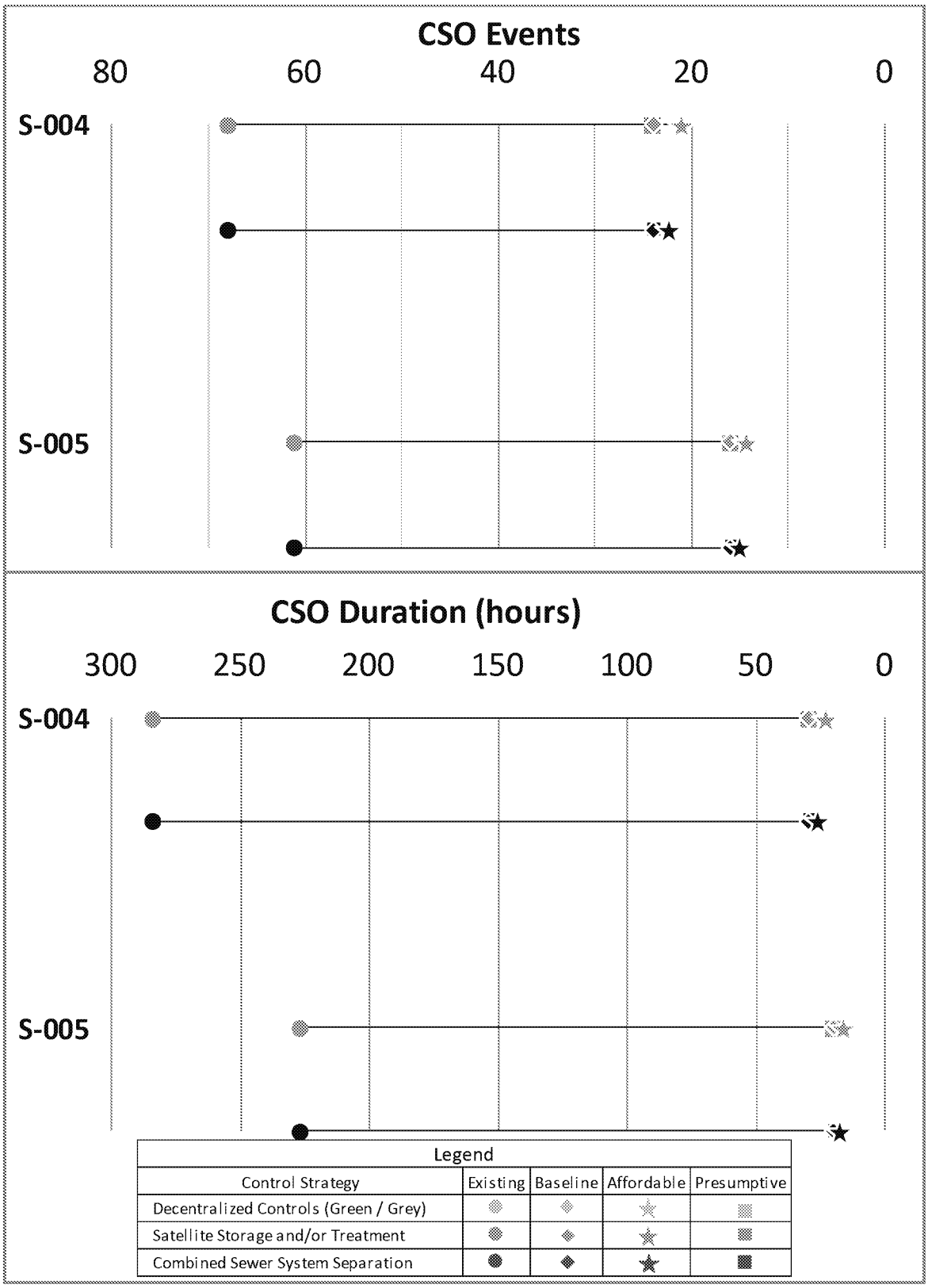

Figure 8.4.1-5: Riverside - Annual CSO Event Frequency and Duration Performance by Control Strategy

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8.4.2 Italian Lake Planning Area

The Italian Lake Planning Area, shown on **Figure 8.4.2-1,** encompasses a 295 acre area within the Front Street Interceptor Sewershed. It is roughly bounded by Susquehanna River on the west, Seventh Street on the east, Graham/Lewis Street on the north, and Schuykill Street on the south. The Italian Lake Planning Area consists primarily of single-family residential development, a small amount of commercial development, and two large properties, Italian Lake Park and Harrisburg School District. It encompasses separate sanitary catchments SS-001, SS-002, and SS-003, delineated on Figure 8.4.2-1. The following existing problems have been identified within the Italian Lake Planning Area:

- Pole-camera inspections identified one separate sanitary sewer at Second Street and Radnor Street exhibiting high priority structural rehabilitation needs.
- H&H modeling conducted for the Separate Sanitary System (SSS) Capacity Assessment Report submitted in April 2017 identified a single manhole, at Wiconisco & Third Streets, that exhibits sewer surcharging within six feet of the ground elevation during the 5-year design storm.
- Stormwater discharges regulated under DEP MS4 Permit requirements contribute pollutant loading to the Susquehanna River and Chesapeake Bay. A Joint Pollution Reduction Plan (PRP) submitted with CRW's MS4 permit application proposes pollutant controls to be implemented over the next five years, focused primarily on stream restoration projects addressing the Paxton Creek TMDL. No stormwater PRP project were identified for the Italian Lake Planning Area.

8.4.2.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves cost-effective measures to control SSOs and rehabilitate sewer assets. The following Baseline controls are assigned an immediate priority within the Italian Lake Planning area:

- **Sewer Rehabilitation.** Use an appropriate trenchless technology to repair 313 feet of separate sanitary sewer along Second Street south of Radnor Street, at an estimated capital cost of $86,000.
- **Water in Basement.** Monitor potential sewer surcharging at Wiconisco and Third where H&H modeling indicates a potential for basement backups. If unauthorized releases are identified, installation of backflow prevention on buildings where water in basement caused by sewer surcharging may be considered.
- **Sewer Redirection.** No sewer redirection is recommended in this planning area.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.2-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.2-1** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

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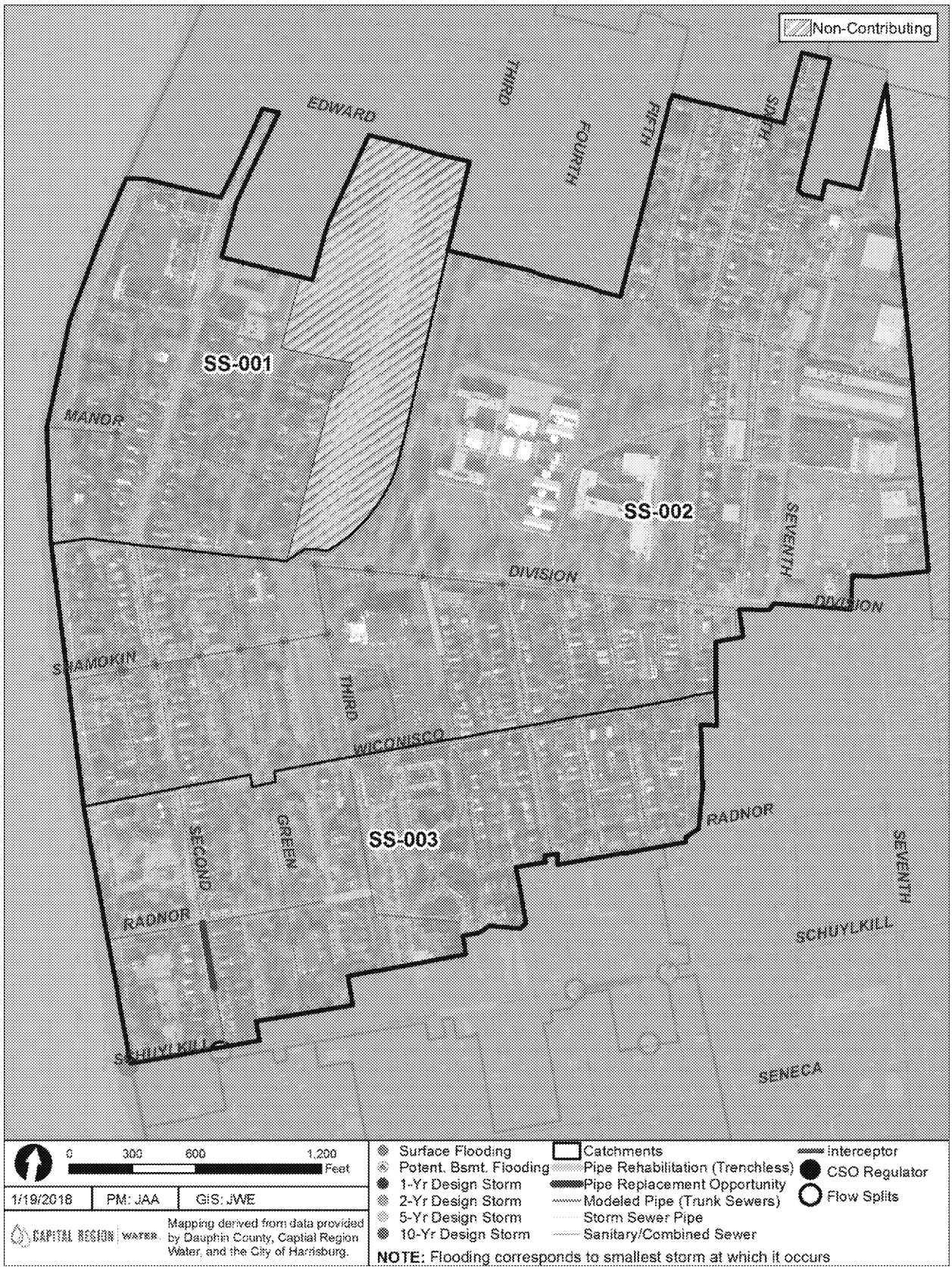

Figure 8.4.2-1: Italian Lake - Existing Hydraulic and Structural Problems

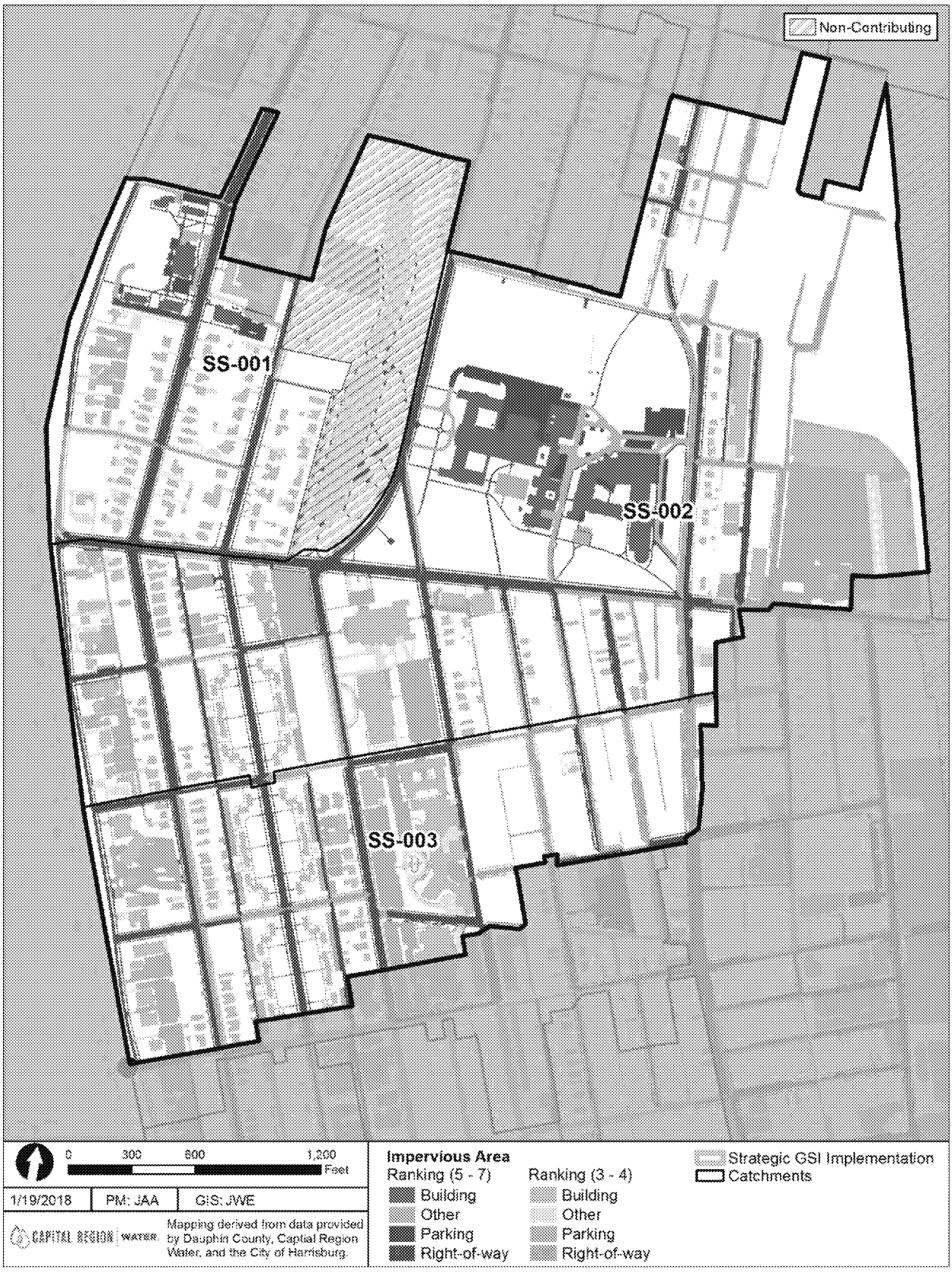

Figure 8.4.2-2: Italian Lake - Green Stormwater Infrastructure / Sediment Reduction Opportunities

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Table 8.4.2-1: Italian Lake - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
SS-001	8.67	1.04	9.71	6.32	4.85	11.17	20.88
SS-002	21.04	6.33	27.36	25.20	13.22	38.42	65.78
SS-003	7.89	0.08	7.97	14.79	8.27	23.06	31.03
Total	**37.60**	**7.44**	**45.04**	**46.31**	**26.34**	**72.65**	**117.69**
of Total Impervious	**24%**	**5%**	**29%**	**30%**	**17%**	**46%**	**75%**

Local Control Strategy 2: Satellite Storage and/or Treatment

The Italian Lake Planning Area is served by separate storm and sanitary sewers. Flow monitoring and H&H modeling do not indicate levels of sewer surcharging or flooding that present a high risk of SSOs. As such, the satellite storage/treatment control strategy is not applicable to this planning area.

Local Control Strategy 3: Combined Sewer System Separation

The Italian Lake Planning Area is served by separate storm and sanitary sewers. As such, the sewer separation control strategy is not applicable to this planning area.

8.4.2.2 Cost Performance Evaluation

Cost-performance evaluations are only used to evaluate control strategies for combined sewer overflow control. As such, they are not applicable to this planning area.

8.4.2.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving wet weather control objectives in the Italian Lake Planning Area. Recommended control consists of sewer rehabilitation in up to 320 feet of separate sanitary sewer. The total estimated opinion of probable cost of these recommended controls is $86,000. This planning area does not have any CSO discharges and therefore will not be prioritized for additional stormwater controls, but further wet weather improvements can be achieved with decentralized green-grey controls integrated into private redevelopment and decentralized controls integrated into utility repair and replacement projects to control unauthorized releases and MS4 discharges within the planning area.

8.4.3 Uptown Planning Area

The Uptown Planning Area, shown on **Figure 8.4.3-1**, encompasses a 341 acre area within the Front Street Interceptor Sewershed, largely coinciding with the Uptown neighborhood of the City of Harrisburg. It is roughly bounded by the Susquehanna River on the west, Sixth Street on the east, Schuylkill Street/Radnor Street on the north, and Verbeke Street on the south. The Uptown Planning Area largely consists of single-family residential development, with pockets of non-single family residential development along Front Street, 2nd Street, 3rd Street, Maclay Street, Schuylkill Street, Reily Street, and Verbeke Street, with an overall impervious area of 246 acres. It encompasses the nine combined sewer catchments and the separate sanitary/stormwater catchment SS-004 delineated on **Figure 8.4.3-1**, all of which discharge to the Front Street interceptor and/or overflow to the Susquehanna River. Figure 8.4.3-1 also identifies locations where capacity/flooding issues, river intrusion, relatively high CSO frequency/low capture, and identified structural issues exist.

8.4.3.1 Definition of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2, and are summarized in **Table 8.4.3-1** for the Uptown Planning Area, and prioritized for implementation as follows:

- **Outfall/Gate Repairs**: High priority gate repairs have been identified for CSO 006 to prevent river intrusion at the 1-year flood stage. Medium priority gate repairs have been identified for CSOs 051, 007, 008, 009, 010 and 011 to prevent river intrusion at the 2-year flood stage. Low priority gate repairs have been identified for CSOs 049 and 050 to prevent river intrusion at the 5-year flood stage. High priority outfall pipe repairs have been identified for CSO 007, while lower priority outfall pipe repairs have been identified for CSOs 006 and 010.

Table 8.4.3-1: Uptown - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-049	✓	✓			✓	$11,000		$26,000
SS-004						$0		
S-050	✓	✓			✓	$11,000		$26,000
S-051	✓				✓	$10,000	$15,000	
S-006	✓	✓			✓	$37,000		
S-007	✓	✓			✓	$37,000		
S-008	✓				✓	$10,000	$15,000	
S-009	✓				✓	$10,000	$15,000	
S-010	✓				✓	$10,000	$26,000	
S-011	✓				✓	$10,000	$15,000	
					Total Cost:	**$146,000**	**$86,000**	**$52,000**

Priority:	High	Medium	Low	None

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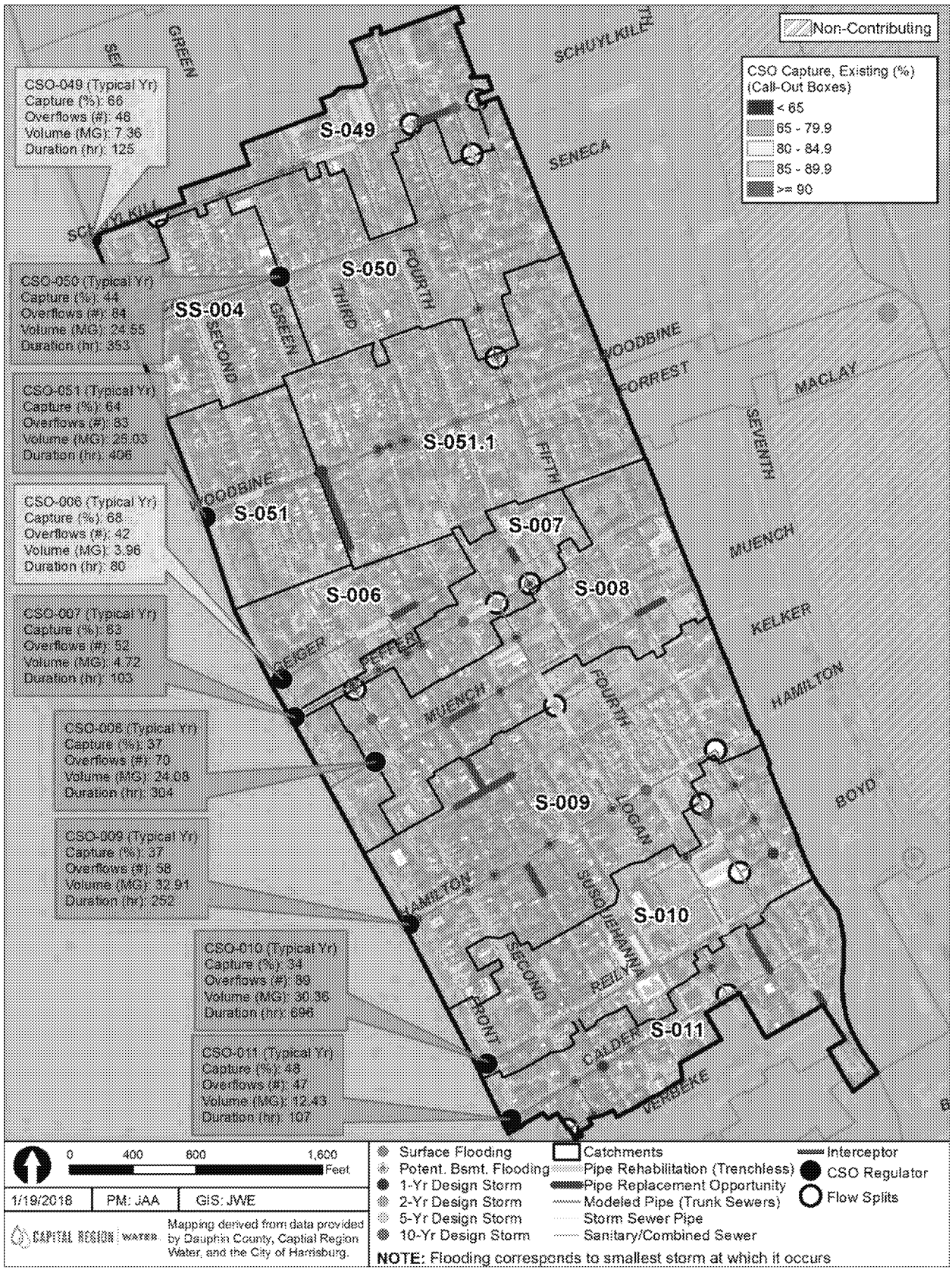

Figure 8.4.3-1: Uptown - Existing Hydraulic and Structural Problems

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at CSOs 049, 050, 006, and 007. H&H modeling did not find additional weir adjustments to be effective.

- **Adjust Orifice Openings**: No restrictive orifice settings were found at the regulators within the Uptown Planning Area, most likely due to the limited capacity of the interceptor along these catchments.

- **Expand Connection Pipes:** H&H modeling did not reveal any locations for affordable and cost-effective connection pipe expansion.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Uptown Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber and metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSOs 051, 006, 008, 009, and 010.

Table 8.4.3-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Uptown Planning Area:

- CSO performance is greatly increased in the following catchments with weir and regulator connector pipe changes:
  - S-050 (+45% capture and a reduction of 43 overflow events).
  - S-010 (+38% capture and a reduction of 21 overflow events).
  - S-049 and S-051 have increases of 12% and 7% capture, respectively, and reductions of 18 and 45 overflow events, respectively.
  - S-006, S-007, S-008, S-009, and S-011also improve performance modestly.
  - S-006 decreases performance, as this is the regulator at the lowest elevation along the Front St. interceptor so more frequent increases in interceptor depth reduce the ability of gravity flow through this trunk system.

- Planning area CSO capture increases from 49% to 68% with these modest changes.

- CSO frequency is reduced from 64 to 43, on average, during the typical year.

Table 8.4.3-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Uptown Planning Area achieve a moderate level of CSO reduction. As such, the local control strategy should place a high priority on implementing controls to further reduce CSOs and address unauthorized releases projected to occur more often than annually. The following local control strategies will be considered to achieve these objectives.

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Table 8.4.3-2: Uptown – Existing/Baseline CSO Performance During Typical Year

	S-049	S-050	S-051	S-006	S-007	S-008	S-009	S-010	S-011	Total
Impervious Drainage Area (acres)	17.5	24.3	15.1	12.6	11.4	29.4	44.5	29.7	22.7	207
CSO Volume Captured (MG)										
▪ Existing Conditions	14.4	19.2	44.4	8.1	8.2	13.4	19.3	15.9	11.5	155
▪ Baseline Level of Control	17.0	39.1	49.4	5.4	9.0	18.7	32.1	33.1	14.6	218
CSO Volume (MG)										
▪ Existing Conditions	7.4	24.5	25.0	3.9	4.7	23.2	32.9	30.4	12.4	164
▪ Baseline Level of Control	4.8	4.7	20.0	6.6	4.0	18.2	20.1	13.1	9.3	101
▪ Volume Reduced	2.6	19.8	5.0	-2.7	0.7	5.1	12.8	17.3	3.1	64
CSO Capture (%)										
▪ Existing Conditions	66%	44%	64%	67%	64%	35%	37%	34%	48%	49%
▪ Baseline Level of Control	78%	89%	71%	45%	69%	50%	61%	72%	61%	68%
CSO Events										Max | Avg.
▪ Existing Conditions	48	84	83	42	52	70	58	89	47	89 64
▪ Baseline Level of Control	30	41	38	47	39	49	37	51	51	51 43
Estimated Implementation Cost										
▪ Per Vol Reduced ($/1000 MG)	$14.23	$1.87	$5.00	($13.70)	$52.86	$4.90	$1.95	$2.08	$8.06	$4.44

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to the Susquehanna River and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Uptown Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.3-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.3-2** define the level of control achieved under the Baseline Level of Control, indicating that the baseline level of control is less than the presumptive level of control in all catchments in the Uptown Planning Area except S-050, and that additional CSO control should receive priority within this Planning Area.

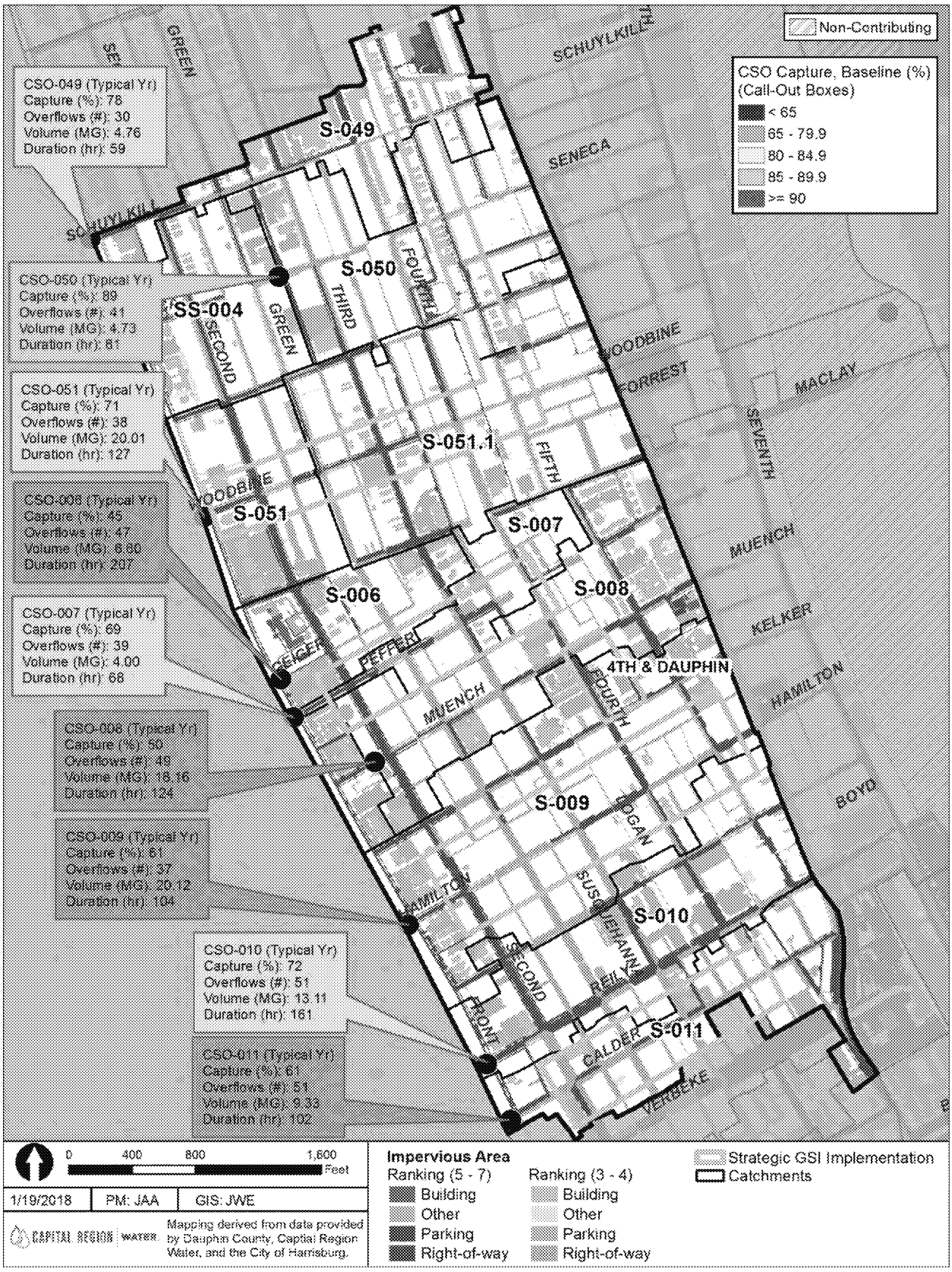

Figure 8.4.3-2: Uptown - Decentralized Green and Grey Infrastructure Opportunities

- ***GSI Implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation, Bold colors on **Figure 8.4.3-2** indicate Impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate potential for control with green/decentralized infrastructure. **Table 8.4.3-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.3-3: Uptown - High and Moderate Potential Opportunities for GSI

Catchment	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-049	4.0	0.6	4.6	5.2	3.5	8.7	13.2
S-050	3.2	0.1	3.3	7.3	2.8	10.1	13.4
S-051	8.4	0.1	8.5	15.5	4.2	19.7	28.1
S-006	3.2	0.4	3.6	3.9	1.4	5.4	8.9
S-007	1.7	0.0	1.7	3.4	0.7	4.0	5.8
S-008	5.0	0.2	5.2	9.1	5.0	14.1	19.2
S-009	8.0	0.1	8.1	13.7	3.5	17.2	25.2
S-010	6.1	0.1	6.2	10.1	1.7	11.8	18.0
S-011	3.5	0.1	3.6	9.1	1.0	10.1	13.6
Total	**43.0**	**1.6**	**44.6**	**77.3**	**23.7**	**100.9**	**145.5**
of Total Impervious	**17%**	**1%**	**18%**	**31%**	**10%**	**41%**	**59%**

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.3-1**.

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

In the Uptown Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- Along Woodbine Street and N. 5th Street, including the former school property at Fifth Street and Radnor Street.

- CRW's Fourth and Dauphin Park Early Action GSI project, and other sites along N. 4th Street.

- Along Hamilton and Peffer Streets, where several vacant lots may be suitable for GSI implementation,

- Within the Calder Street right-of-way.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.3-3 illustrates the major components of the Satellite Control Strategy within the Uptown Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a storage/treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to the Susquehanna River. This strategy focuses on CSO control and does not address unauthorized releases within the collection system. The Satellite Control Strategy builds upon the Baseline Level of Control, adding the following technologies described below.

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.
- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.
- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

High potential satellite control sites are located in CSO catchments that do not satisfy an affordable level of control (approximately 80 percent capture) and take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Moderate potential satellite control sites are located in CSO catchments that do not satisfy a presumptive level of control (approximately 85 percent capture) and/or present moderate site constraints.

High Potential Satellite Control Sites: Construct 6,900 feet of near-surface storage-conveyance conduit along Front Street and/or within Riverside Park between Woodbine and Calder Streets. An initial size of 6 feet x 6 feet would provide 1 MG of storage, achieving an affordable level of control, while a 10 feet x 10 feet box culvert would provide 4 MG of storage, achieving a cost-effective level of control.

Moderate Potential Satellite Control Sites: Add consolidation sewers and satellite treatment facilities to achieve a presumptive level of control.

- 1,900 feet of consolidation sewer along Front Street to collect overflows from CSOs 049, 050, and 051 and convey them to a 6 to 87 MGD treatment facility located near the intersection of Woodbine Street and Front Street.
- 800 feet of consolidation sewer along Front Street to collect overflows from CSOs 008, 007, and 006 and convey them to an 8 to 80 MGD treatment facility located near the intersection of Geiger Street and Front Street.
- 1,500 feet of consolidation sewer along Front Street to collect overflows from CSOs 049, 050, and 051 and convey them to a 9 to 111 MGD treatment facility located near the intersection of Calder Street and Front Street.
- A satellite treatment facility located near the intersection of Woodbine Street and Front Street, sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control.

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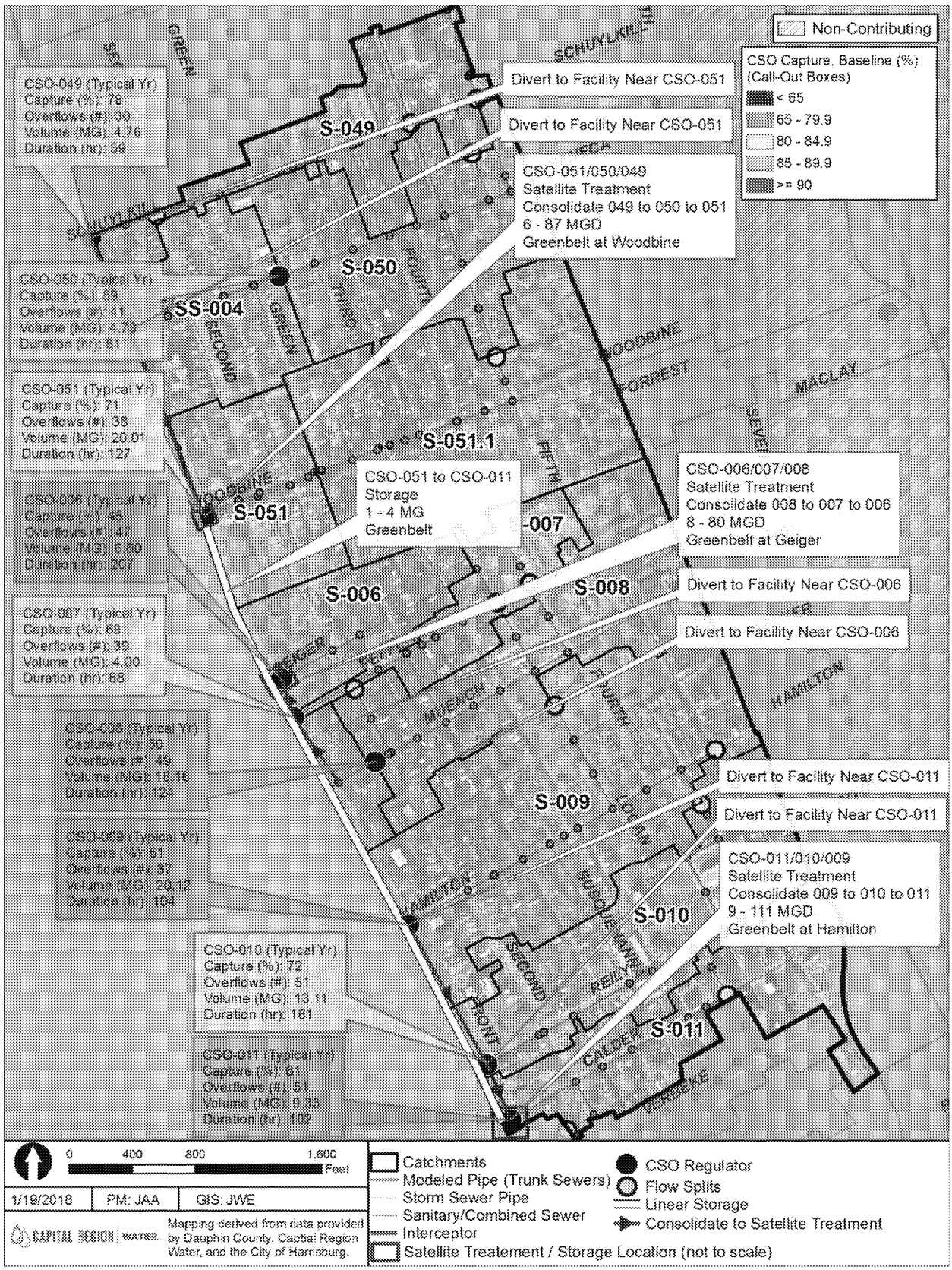

Figure 8.4.3-3: Uptown - Satellite Treatment / Storage Opportunities

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.3-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

Table 8.4.3-4: Uptown – Levels of Control (Local Control Strategy 3)

Type of Separation Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate and Treat Stormwater ($ million)
Cost-Effective Full Separation	None	0	0	
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	S-049, S-051, S-007, S-008, S-009,	12	85	$9.6 M
Full Separation	S-049, S-050, S-051, S-006, S-007, S-008, S-009, S-010, S-011	249	1,562	$212 M

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. No opportunities for cost-effective separation of an entire catchment exist in the Uptown Planning Area.

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. Opportunities for sanitary flow rerouting exist along Front Street within 5% of the impervious area in the planning area: 0.27 acres of Catchment S-007, 0.07 acres of Catchment S-008, 5.06 acres of Catchment S-009, 1.4 acres of Catchment S-049, 5.1 acres of Catchment S-051.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. Opportunities for stormwater disconnection exist within 5% of the impervious area in the planning area: 0.27 acres of Catchment S-007, 0.07 acres of Catchment S-008, 5.06 acres of Catchment S-009, 1.4 acres of Catchment S-049, and 5.1 acres of Catchment S-051.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. Total separation of the entire 341-acre Uptown Planning Area would require installation of new sanitary sewers and/or storm sewers to separate the 1,562 lateral connections needed to achieve complete separation. Full separation would completely eliminate

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CSOs, but require installation of GSI within the new separate stormwater system to prevent increases in pollutant loading.

8.4.3.2 Cost Performance Evaluation

Figure 8.4.3-4 presents cost performance curves for each of the local control strategies developed for the Uptown Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

Figures 8.4.3-5 and 8.4.3-6 present a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the decentralized green-gray control strategy reduces CSO event frequency and CSO duration at nearly all CSO locations in the Uptown Planning Area at an affordable level of control. Instances where CSO frequency or duration increases from the existing condition are likely caused by the increased utilization of the interceptor capacity, thereby reducing acceptance capacity from connector pipes sensitive to higher interceptor flow depths. The satellite storage/treatment control strategy reduces CSO event frequencies and durations more uniformly and at more locations due to the consolidation of overflow volumes into a single location. The partial sewer separation control strategy shows similar performance to the decentralized green-gray control strategy at the presumptive level of control, but as indicated in **Figure 8.4.3-4** the cost is much greater for that performance.

- The ***baseline level of control*** captures 68 percent of the combined sewage volume generated within the Uptown Planning Area during the typical year. Approximately $25 million of the cost of CRW's baseline level of control is apportioned to the Uptown Planning Area, including $284,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved is less than the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a high priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control range*** is defined as the level of control achieved through expenditures determined to be affordable to CRW's customers based on the Financial Capabilities Analysis presented in Section 7. The affordable level of control, as apportioned to the Uptown Planning Area is $43 million, with $25 million already allocated to the baseline level of control.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address both CSO control and unauthorized releases, and can be implemented independently or as part of a larger project (e.g., collection system/utility rehabilitation, land redevelopment). **Figure 8.4.3-4** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Percent of Impervious Area Controlled with GSI		Cost
		CSO Control	Unauthorized Release Control	
Baseline	68%	None	None	$25M
Affordable	75%	15%	included	$43M
Presumptive	85%	38%	Included	$70M

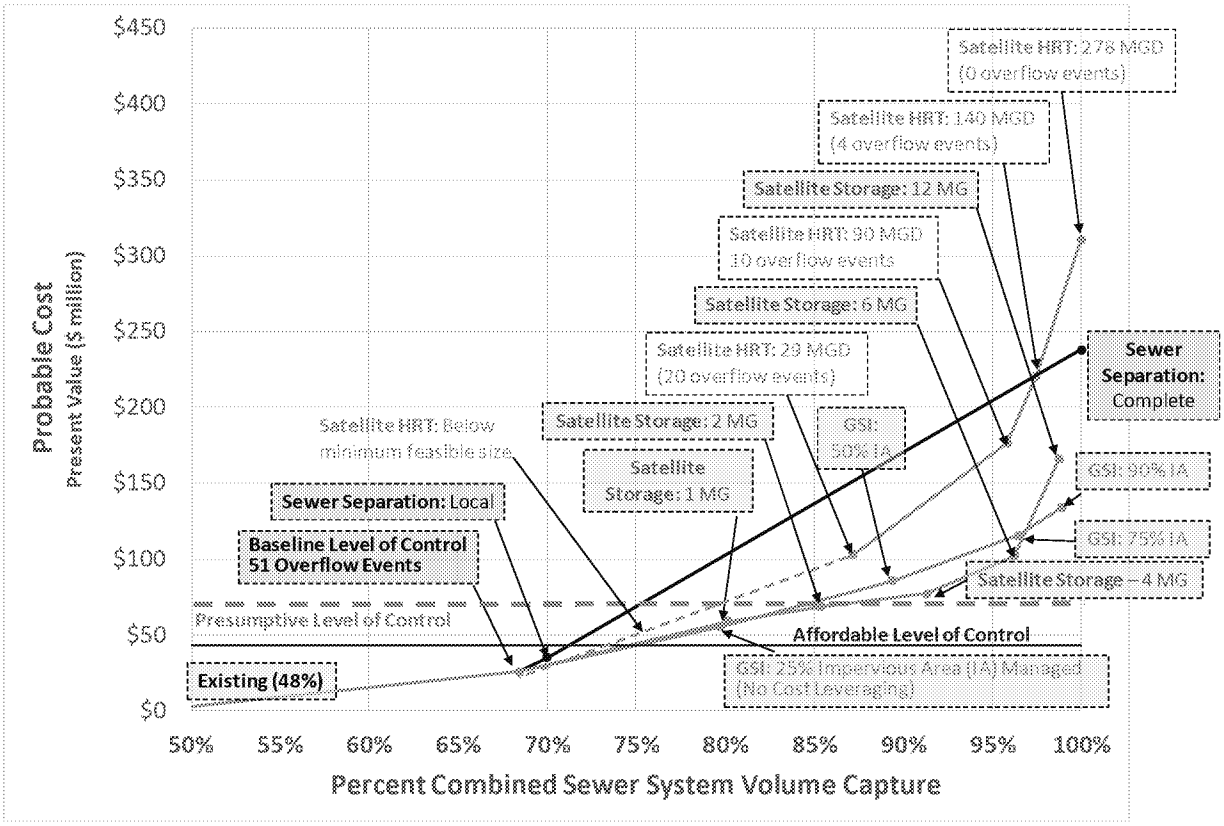

Figure 8.4.3-4: Uptown - CSO Capture Performance and Opinion of Probable Cost Estimate

The cost-performance curve indicates that the decentralized green-grey control strategy is cost-comparative with the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies. It is also best suited to achieve control of both CSOs and unauthorized releases.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. **Figure 8.4.3-4** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Storage/Treatment Capacity	Cost
Baseline	68%	None	$25M
Affordable	75%	0.5 MG	$43M
Presumptive	85%	2 MG	$68M

An estimated 0.5 MG satellite storage facility satellite treatment/ storage facility within the Uptown Planning Area is projected to cost near the affordable level of control, with 2.0 MG of satellite storage projected to approach the presumptive level of control. A satellite treatment/storage strategy is ineffective at control of unauthorized releases

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- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. **Figure 8.4.3-4** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Percent Separation Required	Cost
Baseline	68%	None	$25M
Affordable (high)	73%	13%	$43M
Presumptive	85%	38%	$136M

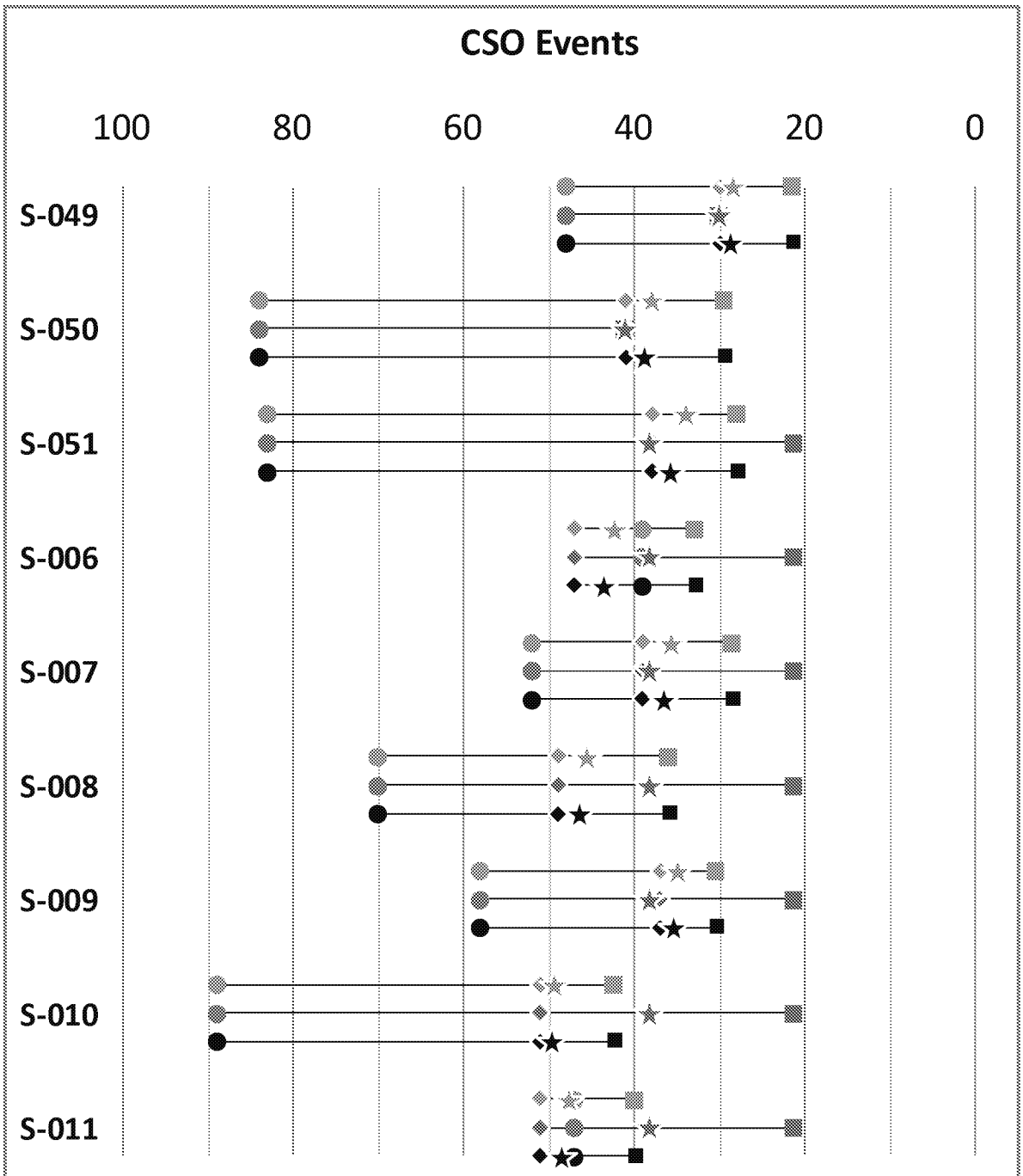
The cost performance curves show that complete sewer separation is both costlier than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

8.4.3.3 Local Control Strategy Findings

Based on this evaluation the Baseline Level of Control improves wet weather performance, increasing the volume of combined sewage captured during the typical year from 48 percent to 68 percent. The cost-performance evaluation presented in this section indicates that CRW has financial capacity to achieve additional wet weather control within this planning area. The cost-performance evaluation also indicates that the decentralized control (green-grey) strategy provides the highest level of additional control for the cost within the affordable level of control range. Therefore, pursuing a Decentralized Control Strategy to supplement the Baseline Level of Control provides CRW with an affordable, flexible approach to increased CSO control within the Uptown Planning Area.

$18 million of CRW's remaining financial capacity is apportioned to the Uptown Planning area for control of CSOs, unauthorized releases and/or collection system rehabilitation within this planning area. Additional controls may be affordable if the remaining financial capability apportioned to other, lower priority planning areas is re-apportioned to the Uptown Planning Area over the 20-year planning horizon. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. This planning area is prioritized for additional CSO controls, and any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

CRW will prioritize the Uptown Planning Area for additional controls beyond the Baseline Level of Control at a cost of up to $9 million (managing the runoff from a total of 8% of the impervious area), while integrating additional decentralized controls into private redevelopment and utility repair and replacement projects to control unauthorized releases within the planning area.



Legend				
Control Strategy	Existing	Baseline	Affordable	Presumptive
Decentralized Controls (Green / Grey)				
Satellite Storage and/or Treatment				
Combined Sewer System Separation				

Figure 8.4.3-5: Uptown - Annual CSO Event Frequency by Control Strategy

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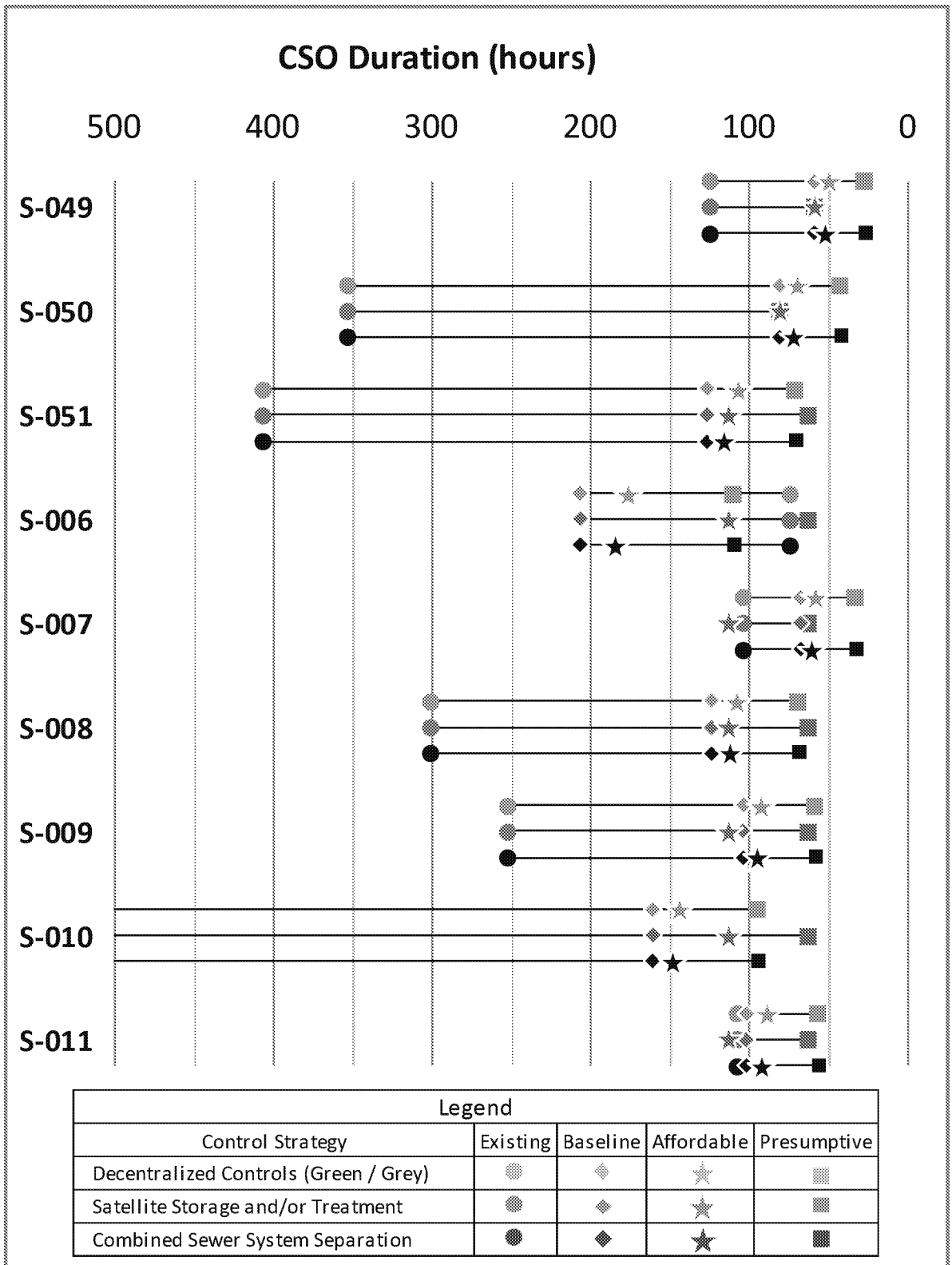

Figure 8.4.3-6: Uptown - Annual CSO Duration by Control Strategy

8.4.4 Middle Front Street Planning Area

The Middle Front Street Planning Area, shown on **Figure 8.4.4-1**, encompasses a 163 acre area within the Front Street Interceptor Sewershed. It is roughly bounded by the Susquehanna River on the west, Sixth/Fourth Street on the east, Strawberry Street on the south, and Verbeke Street on the north. The Middle Front Street Planning Area largely consists of single-family residential development on the north end, with commercial and institutional properties on the south end, with an overall impervious area of 113 acres. It encompasses the 10 combined sewer catchments and separate sanitary/stormwater catchment SS-027 delineated on Figure 8.4.4-1, all of which discharge to the Front Street interceptor and/or overflow to the Susquehanna River. Figure 8.4.4-1 also identifies locations where capacity/flooding issues, river intrusion, relatively high CSO frequency/low capture, and identified structural issues exist.

8.4.4.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2, are summarized in **Table 8.4.4-1** for the Middle Front Street Planning Area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: Low priority gate repairs have been identified for CSO 013 to prevent river intrusion at the 5-year flood stage. High priority outfall pipe repairs have been identified for CSO 053.
- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at all CSOs within the Middle Front Street Planning area.

Table 8.4.4-1: Middle Front Street - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-012		✓	✓		✓	$21,000		
S-013	✓	✓			✓	$11,000		$26,000
S-014		✓	✓		✓	$21,000		
S-015		✓	✓		✓	$21,000		
S-016		✓	✓		✓	$21,000		
S-052		✓			✓	$11,000		
S-053	✓	✓			✓	$37,000		
S-054		✓	✓		✓	$21,000		
S-055		✓			✓	$11,000		
S-056		✓	✓		✓	$21,000		
					Total Cost:	**$196,000**		**$26,000**

Priority:	High	Medium	Low	None

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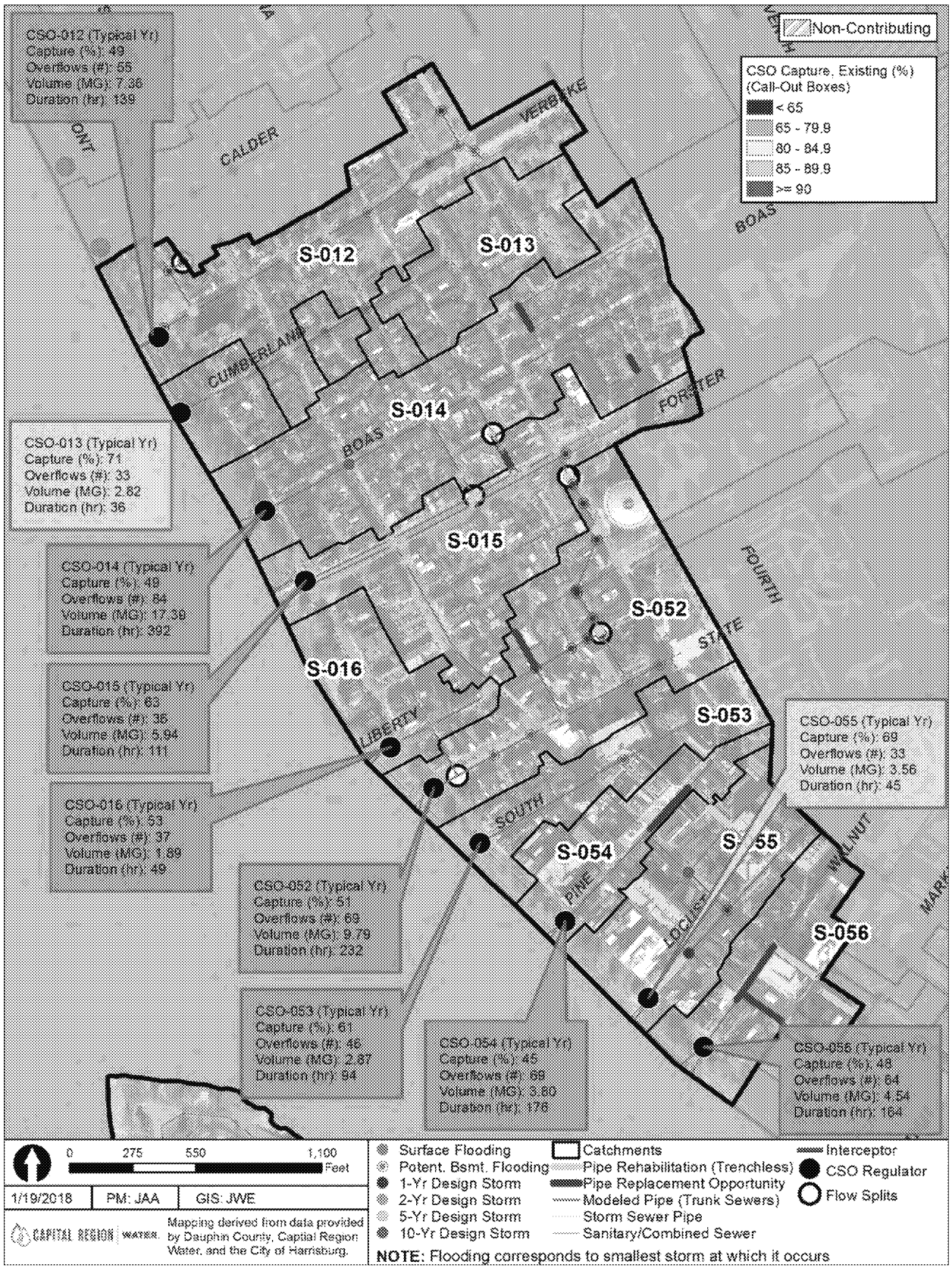

Figure 8.4.4-1: Middle Front Street - Existing Hydraulic and Structural Problems

- **Adjust Orifice Openings**: Brown and Brown (B&B) orifice control devices (see Figure 3-9) exist at CSO regulator structures 012, 015, 016, 054, and 056; and a fixed control orifice (see Figure 3-10) exists at CSO 014. During wet weather, according to H&H modeling, orifice restrictions at CSO regulator structures 012, 014, 015, 016, 054, and 056 contribute to CSOs. High priority is given to removing these B&Bs and orifice restrictions, replacing them with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

- **Expand Connection Pipes:** H&H modeling did not reveal any locations for affordable and cost-effective connection pipe expansion.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Middle Front Street Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber or metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSOs 012 and 014.

- **Additional Baseline Controls:** Diverting the stormwater pipe in S-015 along Forster Street around the regulator and connecting it to the outfall pipe, thereby reducing stormwater flows to the Front Street interceptor, is a high priority for affordable CSO control.

Table 8.4.4-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Middle Front Street Planning Area:

- CSO performance is greatly increased in the following catchments with weir and regulator connector pipe changes:
  - S-012 (+43% capture and a reduction of 40 overflow events)
  - S-014 (+43% capture and a reduction of 65 overflow events)
  - S-015 (+28% capture and a reduction of 20 overflow events)
  - S-016 (+44% capture and a reduction of 26 overflow events)
  - S-052 (+34% capture and a reduction of 35 overflow events)
  - S-053 (+27% capture and a reduction of 29 overflow events)
  - S-054 (+48% capture and a reduction of 55 overflow events)
  - S-056 (+46% capture and a reduction of 52 overflow events)
  - Catchments S-013, and S-055 also improve performance more modestly,
- Planning area CSO capture increases from 55% to 91% with these modest changes.
- CSO frequency is reduced from 51 to 16, on average, during the typical year.

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Table 8.4.4-2: Middle Front Street – Existing/Baseline CSO Performance During Typical Year

	S-012	S-013	S-014	S-015	S-016	S-052	S-053	S-054	S-055	S-056	Total
Impervious Drainage Area (acres)	18.3	10.9	23.7	17.1	4.8	17.5	7.0	6.8	11.9	9.4	127
CSO Volume Captured (MG)											
▪ Existing Conditions	7.0	6.9	16.8	10.1	2.1	10.2	4.5	3.1	7.9	4.2	72.8
▪ Baseline Level of Control	13.1	8.3	31.5	14.5	3.9	17.0	6.5	6.4	10.0	8.2	119
CSO Volume (MG)											
▪ Existing Conditions	7.4	2.8	17.4	5.9	1.9	9.8	2.9	3.8	3.6	4.5	60.0
▪ Baseline Level of Control	1.2	1.4	2.7	1.5	0.1	3.1	0.9	0.5	1.5	0.6	13.4
▪ Volume Reduced	6.1	1.4	14.6	4.4	1.8	6.7	2.0	3.3	2.1	4.0	46.5
CSO Capture (%)											
▪ Existing Conditions	49%	71%	49%	63%	53%	51%	61%	45%	69%	48%	55%
▪ Baseline Level of Control	92%	86%	92%	91%	97%	85%	88%	93%	87%	94%	90%
CSO Events											Max | Avg.
▪ Existing Conditions	55	33	84	36	37	69	46	69	33	64	84 53
▪ Baseline Level of Control	15	21	19	16	11	34	17	14	23	12	34 18
Estimated Implementation Cost											
▪ Per Vol Reduced ($/1000 MG)	$3.44	$26.43	$1.44	$4.77	$11.67	$1.64	$18.50	$6.36	$5.24	$5.25	$4.77

Table 8.4.4-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Middle Front Street Planning Area exceed the presumptive (85% capture) level of control. As such, the local control strategy should focus on locations where H&H modeling indicates unauthorized releases more often than annually, with additional CSO control assigned a long-term priority. The following local control strategies will be considered to achieve these objectives.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to the Susquehanna River and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Middle Front Street Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.4-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

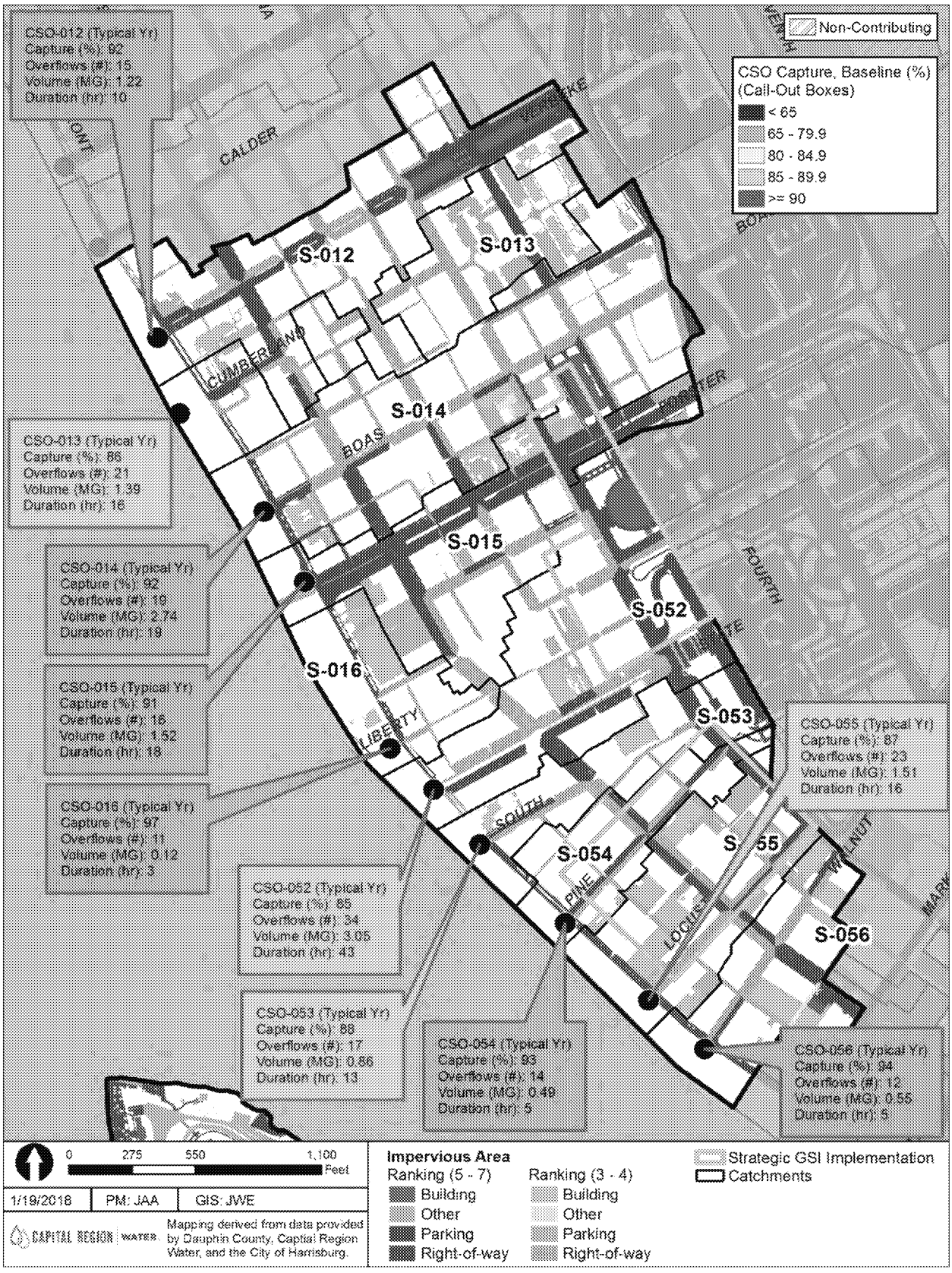

Figure 8.4.4-2: Middle Front Street - Decentralized Green and Grey Infrastructure Opportunities

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.4-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control is achieved throughout the Middle Front Street Planning Area and that additional CSO control is not a priority in this Planning Area.

- ***GSI implementation Potential***, CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.4-2** indicate Impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate potential for control with green/decentralized infrastructure. **Table 8.4.4-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces or buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least 5 of the seven criteria, while moderate potential sites satisfy three or four of the seven criteria.

Table 8.4.4-3: Middle Front Street - High and Moderate Potential Opportunities for GSI

Catchment	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-012	4.35	0.77	5.12	4.44	0.78	5.22	10.3
S-013	0.94	0.00	0.94	4.19	0.66	4.85	5.79
S-014	3.33	0.46	3.79	7.13	1.17	8.30	12.1
S-015	6.34	0.36	6.70	3.70	0.61	4.31	11.0
S-016	0.39	0.00	0.39	1.00	0.98	1.98	2.37
S-052	4.91	0.77	5.68	3.54	0.58	4.12	9.79
S-053	1.80	0.04	1.85	0.80	0.57	1.37	3.22
S-054	1.12	0.02	1.14	1.03	0.19	1.22	2.36
S-055	1.59	0.04	1.63	3.03	2.69	5.72	7.35
S-056	1.08	0.01	1.09	1.53	1.66	3.19	4.28
Total	**25.9**	**2.5**	**28.3**	**30.4**	**9.9**	**40.3**	**68.6**
of Total Impervious	**20%**	**2%**	**22%**	**23%**	**8%**	**31%**	**52%**

- ***H&H Model Projections of Frequent Unauthorized Releases*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.4-1.**

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

In the Middle Front Street Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- Along 3rd Street between State Street and Forster Street, as well as along Susquehanna and Liberty Streets, where H&H modeling indicates the potential for chronic unauthorized releases.

- In the area bounded by Front, Locust, 3rd, and Pine Streets, where H&H modeling indicates the potential for chronic unauthorized releases.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.4-3 illustrates the major components of the Satellite Control Strategy within the Middle Front Street Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Under this strategy, combined sewage is conveyed to a storage/treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to the Susquehanna River. This strategy focuses on CSO control and does not address unauthorized releases within the collection system. The satellite control strategy builds upon the technologies identified as part of the Baseline Level of Control and the following technologies described below.

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.

- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.

- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

High potential satellite control sites are located in CSO catchments that do not satisfy an affordable level of control (approximately 80 percent capture) and take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Moderate potential satellite control sites are located in CSO catchments that do not satisfy a presumptive level of control (approximately 85 percent capture) and/or present moderate site constraints.

Moderate Potential Satellite Control Sites: Add consolidation sewers and satellite treatment facilities to achieve a presumptive level of control.

- A satellite storage and/or treatment facility located near the intersection of Verbeke Street and Front Street, with 1,500 feet of consolidation sewer along Front Street to collect overflows from CSOs 012, 013, 014, and 015, sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control.

- A satellite storage and/or treatment facility located near the intersection of Liberty Street and Front Street, with 1,900 feet of consolidation sewer along Front Street to collect overflows from CSOs 016, 052, 053, 054, 055, and 056, sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control.

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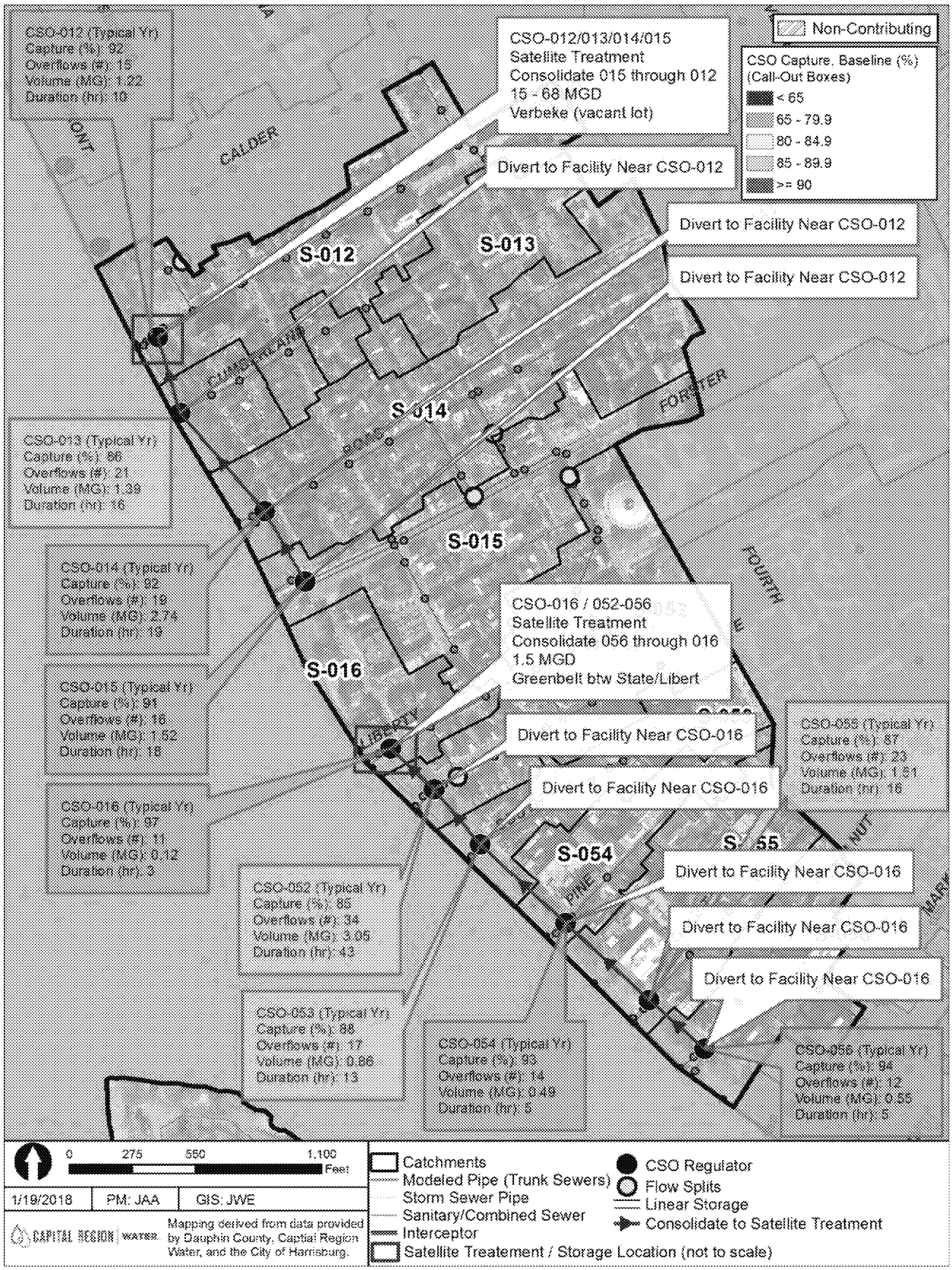

Figure 8.4.4-3: Middle Front Street - Satellite Treatment / Storage Opportunities

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property and reconnection to the new system, and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.4-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

Table 8.4.4-4: Middle Front Street – Levels of Control (Local Control Strategy 3)

Type of Separation Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate and Treat Stormwater ($ million)
Cost-Effective Full Separation	None	0	0	
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	S-014, S-054, S-055, S-056	8.6	47	$7.1
Full Separation	S-012, S-013, S-014, S-015, S-016, S-052, S-053, S-054, S-055, S-056, S-017, S-018, S-057, S-058	131	609	$113

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number of sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. No opportunities for cost-effective separation of an entire catchment exist in the Middle Front Street Planning area.

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. Opportunities for sanitary flow rerouting exist within 7% of the impervious area in the planning area: 0.27 acres of Catchment S-007, 0.07 acres of Catchment S-008, up to 5.06 acres of Catchment S-009, 2.43 acres of Catchment S-014, 1.7 acres of Catchment S-054, 2.43 acres of Catchment S-055, and 2.06 acres of Catchment S-056.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. Opportunities for stormwater disconnection exist within 7% of the impervious area in the planning area: 0.27 acres of Catchment S-007, 0.07 acres of Catchment S-008, up to 5.06 acres of Catchment S-009, 2.43 acres of Catchment S-014, 1.7 acres of Catchment S-054, 2.43 acres of Catchment S-055, and 2.06 acres of Catchment S-056.

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- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. **Table 8.4.4-3** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment. Full separation would completely eliminate CSOs, but require installation of GSI within the new separate stormwater system to prevent increases in pollutant loading.

8.4.4.2 Cost Performance Evaluation

Figure 8.4.4-4 presents cost performance curves for each of the local control strategies developed for the Middle Front Street Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control evaluated by the Plan.

Figures 8.4.4-5 and 8.4.4-6 present a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

- The ***baseline level of control*** captures 90 percent of the combined sewage volume generated within the Middle Front Street Planning Area during the typical year. Approximately $14 million of the cost of CRW's baseline level of control is apportioned to the Middle Front Street Planning Area, including $222,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved exceeds the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a low priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control***, defined as the level of control achieved through expenditures determined to be affordable to CRW's customers based on the Financial Capabilities Analysis presented in Section 7. The affordable level of control, as apportioned to the Middle Front Street Planning Area is $23 million, with $14 million already allocated to the baseline level of control. Investments within this range should focus on collection system rehabilitation and/or control of unauthorized releases within this Planning Area during the 20-year planning horizon.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address these collection system rehabilitation and/or unauthorized releases. The cost-performance curve indicates that the decentralized control strategy is less costly than the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. The smallest satellite treatment/ storage facility feasible to implement within the Middle Front Street Planning Area – a 15 MGD satellite HRT – costs three to five times the affordable level of control range for this planning area. Since the Middle Front Street Planning Area has a low priority for additional CSO control,

and this technology is ineffective at control of unauthorized releases, this control strategy is not recommended for this planning area.

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. The cost performance curves clearly show that complete sewer separation is both more costly than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

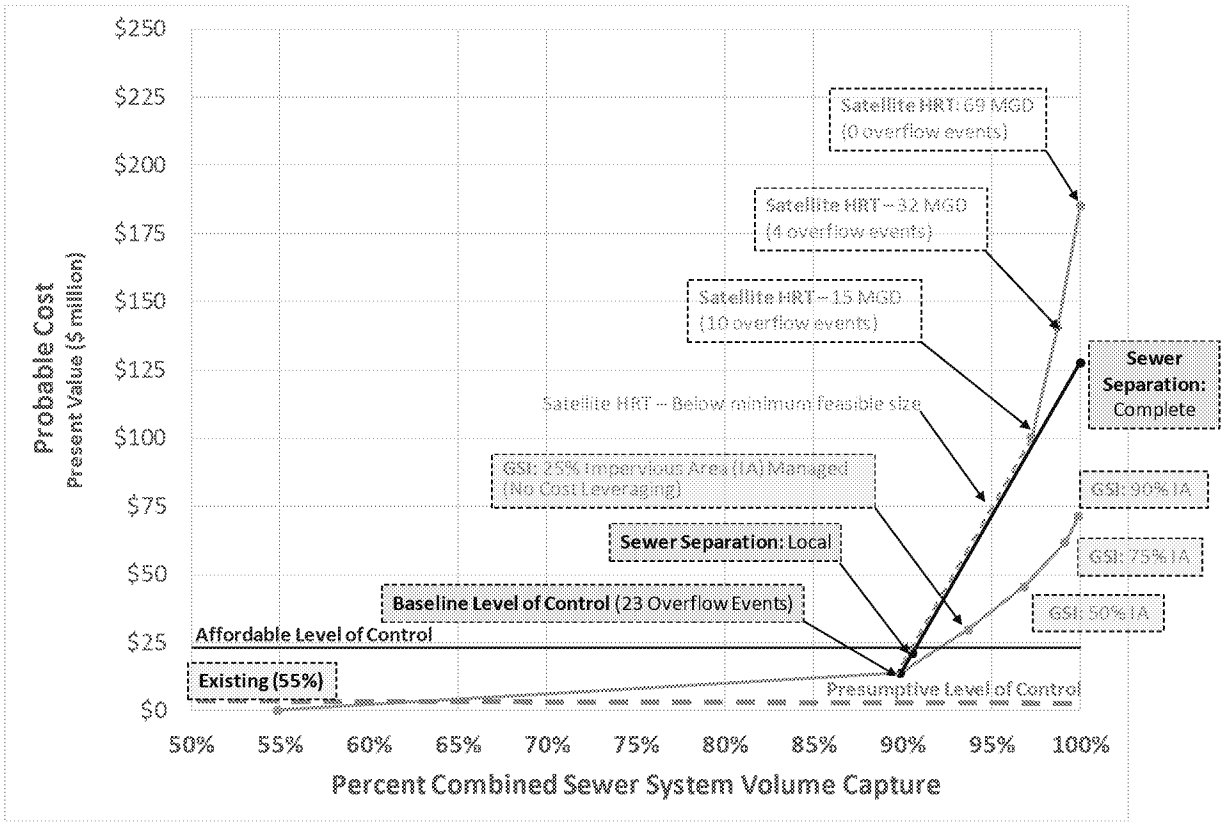

Figure 8.4.4-4: Middle Front Street - CSO Capture Performance and Opinion of Probable Cost Estimate

8.4.4.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving CSO control within the Middle Front Street Planning Area. An additional investment of $9 million is considered affordable for control of unauthorized releases and/or collection system rehabilitation within this planning area. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. While this planning area will not be prioritized for additional CSO controls, any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

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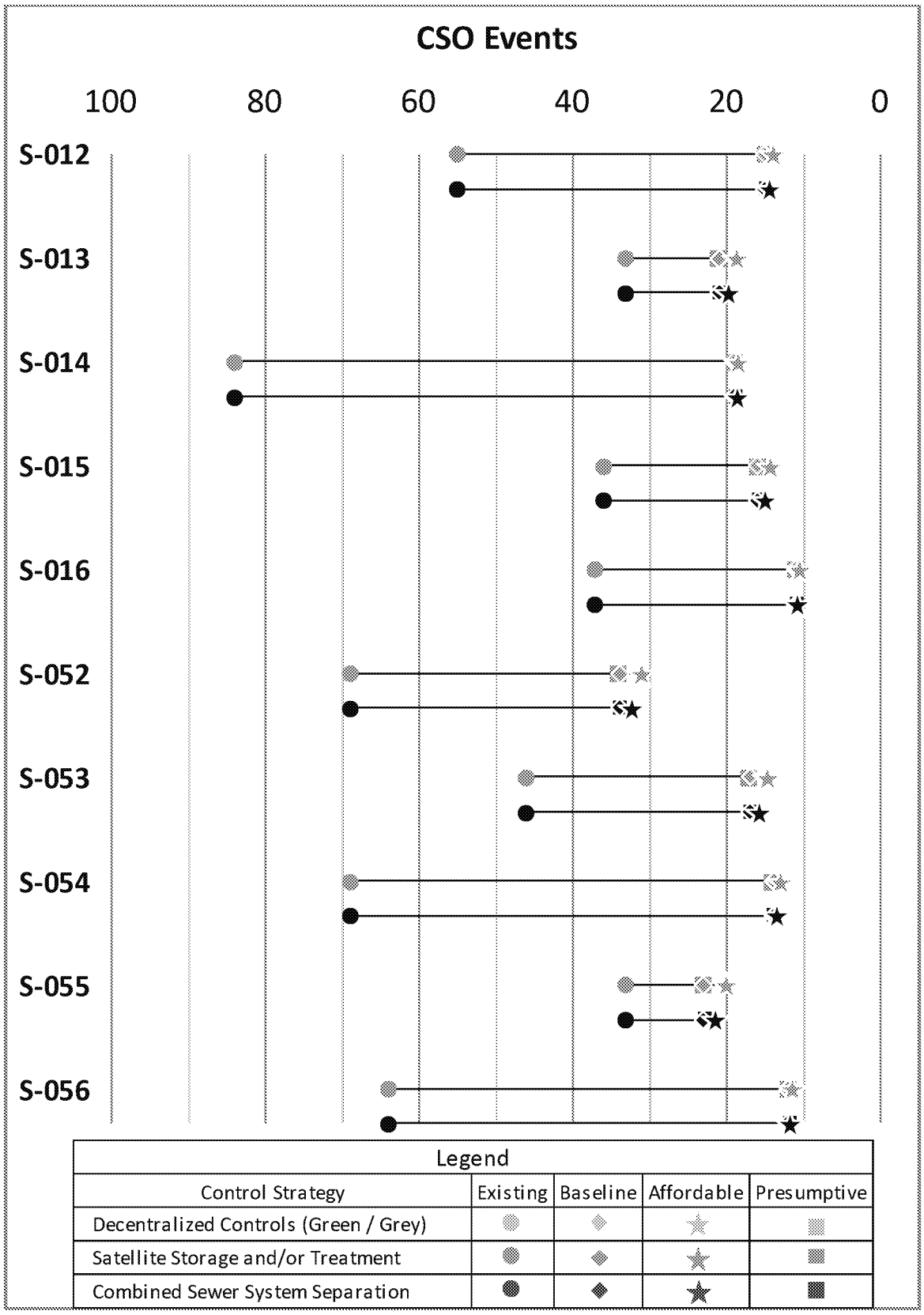

Figure 8.4.4-5: Middle Front Street - Annual CSO Event Frequency by Control Strategy

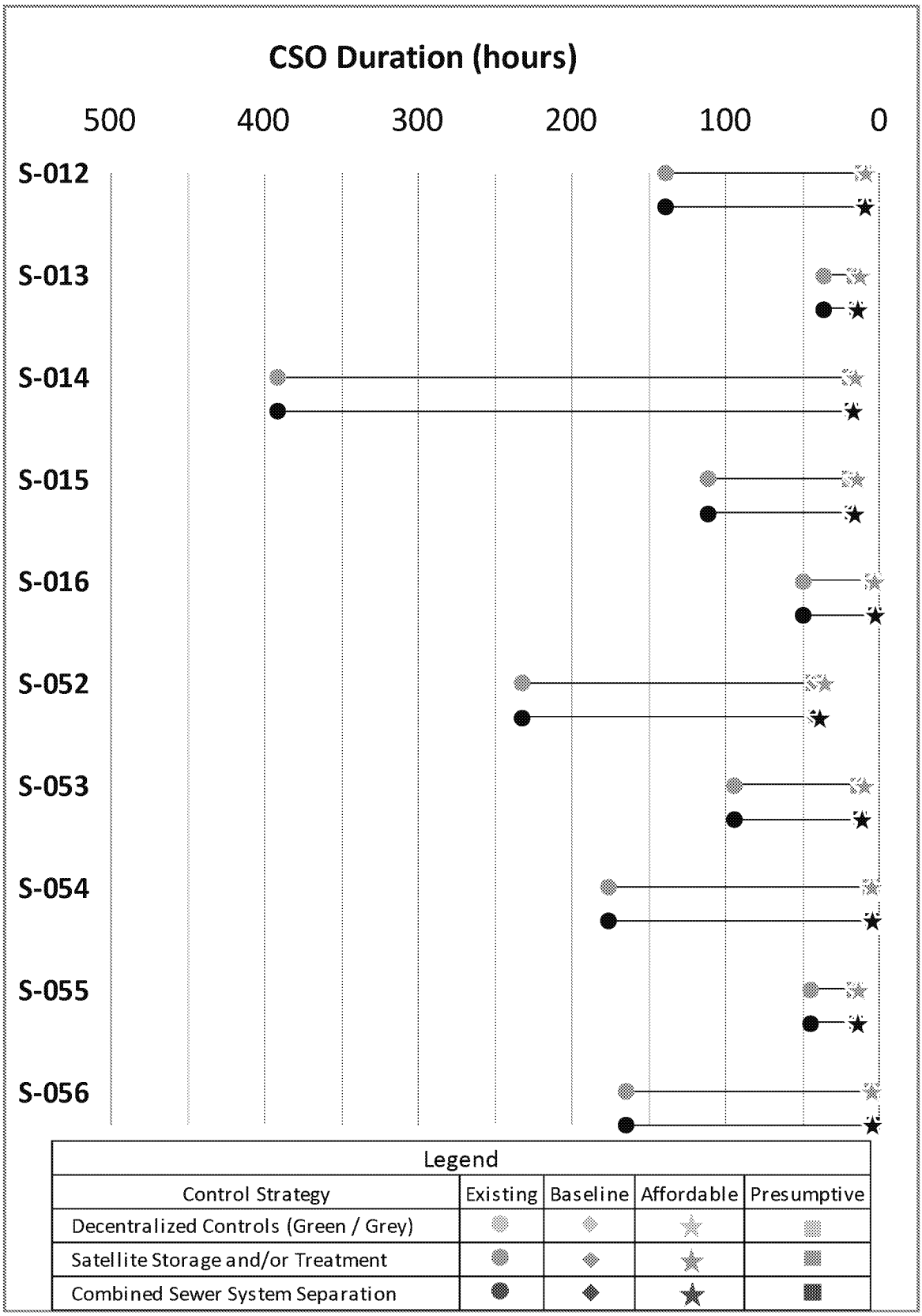

Figure 8.4.4-6: Middle Front Street - Annual CSO Duration by Control Strategy

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8.4.5 Lower Front Street Planning Area

The Lower Front Street Planning Area encompasses an 87 acre area within the Front Street Interceptor Sewershed. It is roughly bounded by the Susquehanna River on the southwest, the railroad corridor on the northeast, I-83 on the southeast, and Strawberry Street on the northwest. The Lower Front Street Planning Area largely consists of commercial/institutional properties in the Downtown area, with residential properties in the Shipoke neighborhood (S-058 and S-020), and an overall impervious area of 59 acres. It encompasses combined sewer catchments S-017, S-057, S-018, S-019, S-058, and S-020, delineated on Figure 8.4.5-1. All of the catchment areas discharge to the Front Street Interceptor and/or overflow to Susquehanna River. Figure 8.4.5-1 also identifies locations where capacity/flooding issues, river intrusion, relatively high CSO frequency and low capture, and some identified structural issues exist.

8.4.5.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.5-1** for the Lower Front Street Planning Area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: High priority gate repairs have been identified for CSOs 058 and 020 to prevent river intrusion at the 1-year flood stage. Medium priority gate repairs have been identified for CSOs 057 and 019 to prevent river intrusion at the 2-year flood stage. Low priority gate repairs have been identified for CSO 018 to prevent river intrusion at the 5-year flood stage. Medium priority outfall pipe repairs have been identified for CSO 019, and low priority outfall pipe repairs have been identified for CSO 018.

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at 017, 018, 019, and 020. H&H modeling did not find additional weir adjustments to be effective.

Table 8.4.5-1: Lower Front Street - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-017		✓			✓	$11,000		
S-057	✓				✓	$10,000	$15,000	
S-018	✓	✓			✓	$11,000		$26,000
S-019	✓	✓	✓		✓	$21,000	$26,000	
S-058	✓				✓	$25,000		
S-020	✓	✓			✓	$26,000		
					Total Cost:	**$104,000**	**$41,000**	**$26,000**

Priority:	High	Medium	Low	None

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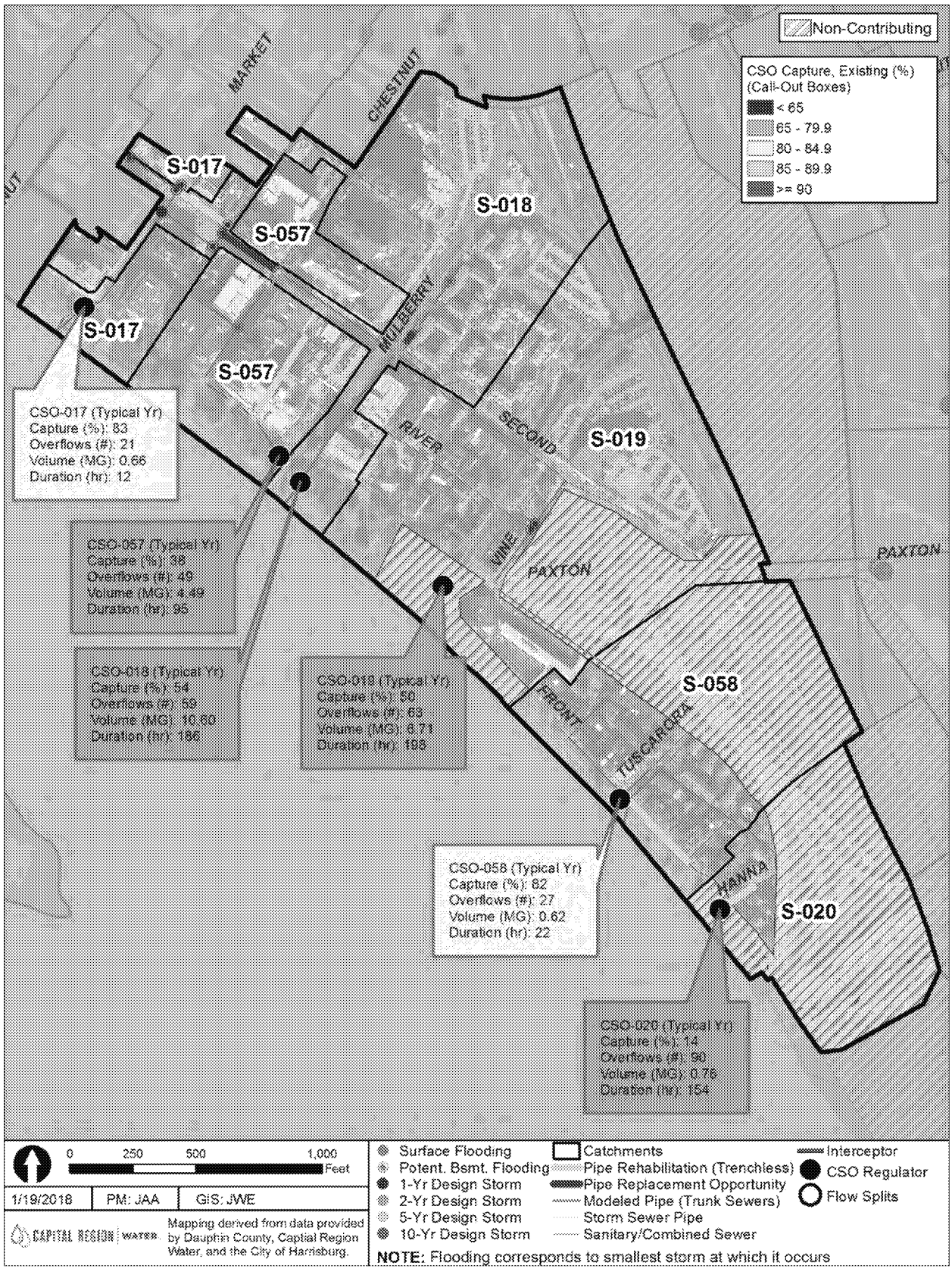

Figure 8.4.5-1: Lower Front Street - Existing Hydraulic and Structural Problems

- **Adjust Orifice Openings**: Brown and Brown (B&B) orifice control devices (see Figure 3-9) exist at all CSO regulator structures within the Lower Front Street Planning Area. During wet weather, according to H&H modeling, the orifice restriction at CSO-019 contributes to CSOs. High priority is given to removing this B&B and orifice restriction, replacing it with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

- **Expand Connection Pipes:** H&H modeling did not reveal any locations for affordable and cost-effective connection pipe expansion.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Lower Front Street Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber or metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSOs 018 and 019.

Table 8.4.5-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Lower Front Street Planning Area:

- CSO performance is greatly increased in CSOs 057 (+37% capture and a reduction of 10 overflow events), 019 (+38% capture and a reduction of 48 overflow events), and 020 (+83% capture and a reduction of 88 overflow events) with weir and regulator connector pipe changes.

- Catchments S-017, S-018, and S-058 also improve performance more modestly.

- Planning area CSO capture increases from 54% to 82% with these modest changes.

- CSO frequency is reduced from 51 to 20, on average, during the typical year.

Table 8.4.5-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Lower Front Street Planning Area nearly meet or exceed the presumptive (85% capture) level of control for the Susquehanna River at CSOs 017, 019, 058, and 020. A moderate level of CSO control is achieved at CSOs 057 and 018. As such, the local control strategy should focus on implementing controls for CSOs 057 and 018, as well as locations throughout the planning area where H&H modeling indicates unauthorized releases occur more often than annually. The following local control strategies will be considered to achieve these objectives.

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Table 8.4.5-2: Lower Front Street – Existing/Baseline CSO Performance During Typical Year

	S-017	S-057	S-018	S-019	S-058	S-020	Total
Impervious Drainage Area (acres)	3.6	11.9	19.6	24.4	8.8	7.7	76
CSO Volume Captured (MG)							
▪ Existing Conditions	3.3	2.7	12.5	6.5	2.8	0.1	28.0
▪ Baseline Level of Control	3.5	5.3	18.0	11.6	3.2	0.9	42.5
CSO Volume (MG)							
▪ Existing Conditions	0.7	4.5	10.6	6.7	0.6	0.8	23.8
▪ Baseline Level of Control	0.4	1.9	5.1	1.6	0.4	0.0	9.4
▪ Volume Reduced	0.2	2.6	5.5	5.0	0.2	0.7	14.4
CSO Capture (%)							
▪ Existing Conditions	83%	38%	54%	49%	83%	15%	54%
▪ Baseline Level of Control	89%	74%	78%	88%	88%	97%	82%
CSO Events							Max | Avg.
▪ Existing Conditions	21	49	59	63	27	90	90 52
▪ Baseline Level of Control	17	39	26	15	19	2	39 20
Estimated Implementation Cost							
▪ Per Vol Reduced ($/1000 MG)	$55.00	$9.62	$6.73	$9.40	$125.00	$37.14	$11.88

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Lower Front Street Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.5-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.5-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control is achieved for CSOs 017, 019, 058, and 020. As such, additional CSO control should receive priority within CSOs 057 and 018.

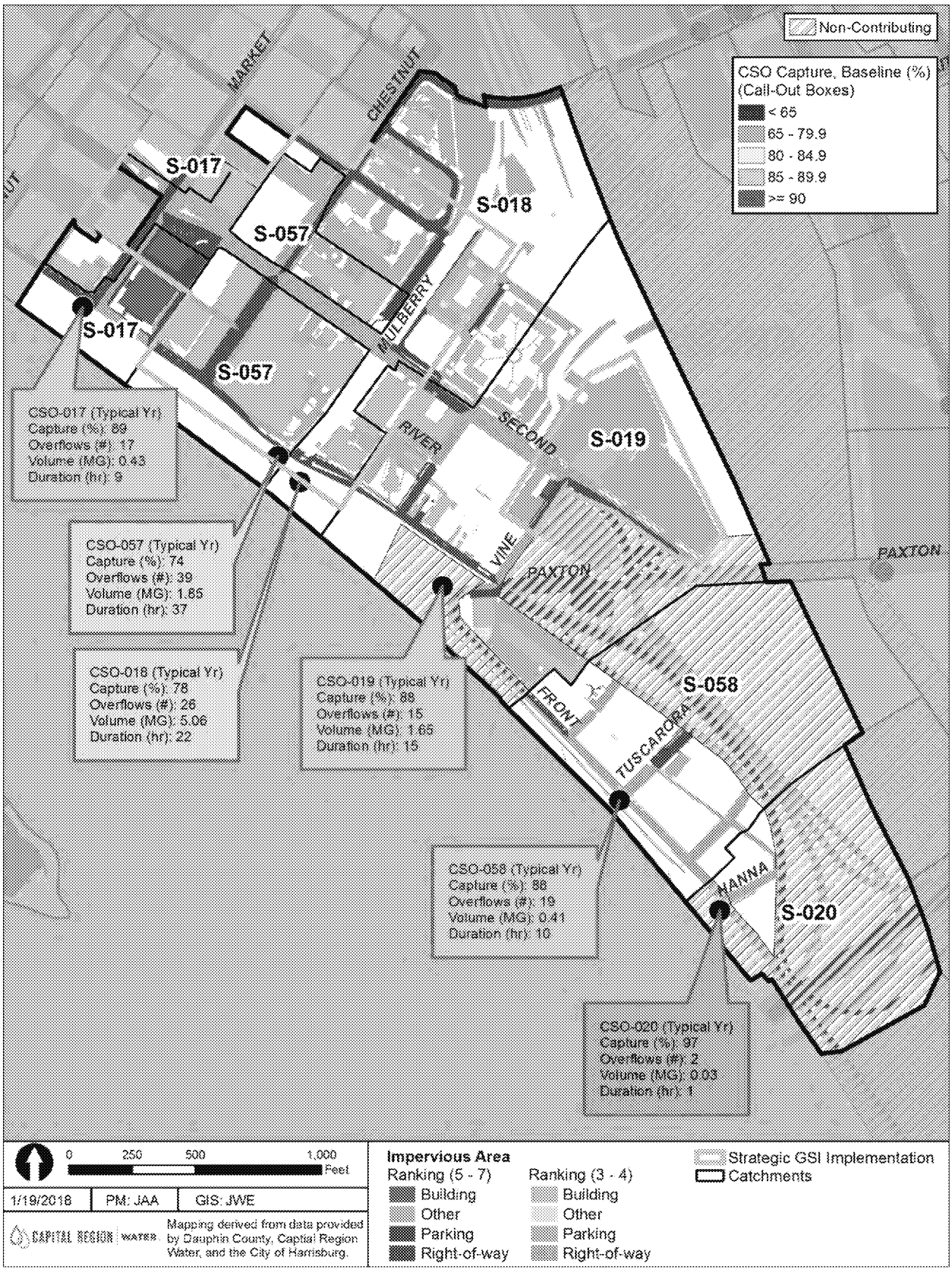

Figure 8.4.5-2: Lower Front Street - Decentralized Green and Grey Infrastructure Opportunities

- ***GSI implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.5-2** indicate Impervious areas assigned high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate potential for control with green/decentralized infrastructure. **Table 8.4.5-3** summarizes green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.5-3: Lower Front Street - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-017	1.20	1.03	2.24	0.67	0.40	1.07	3.31
S-057	1.41	0.00	1.41	2.79	5.84	8.63	10.0
S-018	3.51	0.03	3.54	9.30	3.45	12.8	16.3
S-019	3.61	0.27	3.88	13.4	3.62	17.0	20.9
S-058	1.11	0.00	1.12	4.09	0.05	4.14	5.26
S-020	2.08	0.00	2.08	3.81	0.00	3.81	5.90
Total	**12.9**	**1.34**	**14.3**	**34.0**	**13.4**	**47.4**	**61.7**
of Total Impervious	**17%**	**2%**	**19%**	**45%**	**18%**	**62%**	**81%**

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.5-1**.

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

In the Lower Front Street Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- Blocks between Front Street and 3rd Street, along 2nd Street to reduce the potential for unauthorized releases on more than an average annual basis

- Pinnacle Health parking lots located near the intersection of 2nd and Vine Streets to reduce the potential for unauthorized releases on more than an average annual basis.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.5-3 illustrates the major components of the Satellite Control Strategy within the Lower Front Street Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Under this strategy, combined sewage is conveyed to a storage/treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to Susquehanna River.

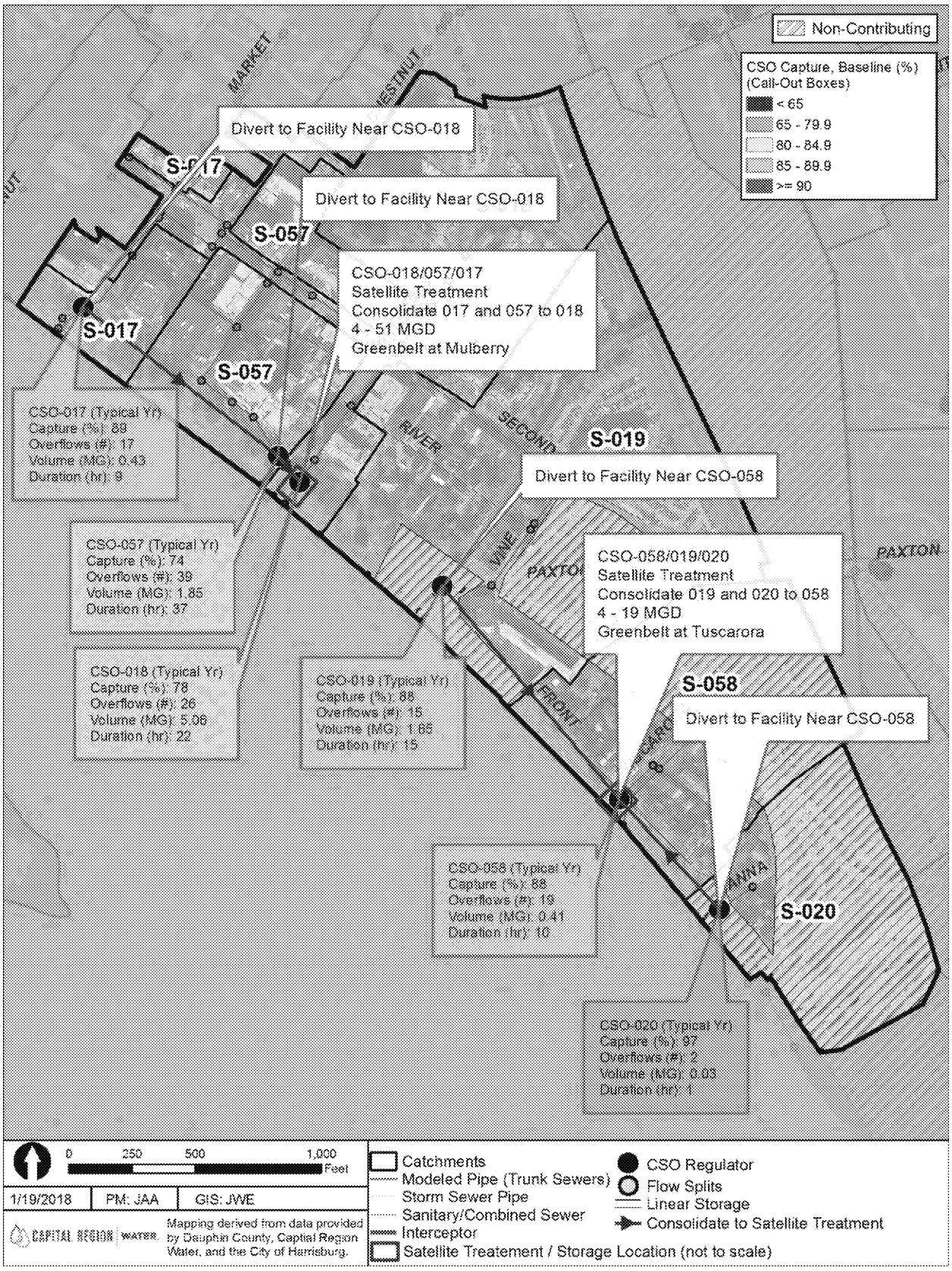

Figure 8.4.5-3: Lower Front Street - Satellite Treatment / Storage Opportunities

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property and reconnection to the new system, and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.5-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

Table 8.4.5-4: Lower Front Street – Levels of Control (Local Control Strategy 3)

Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	None	None	None	
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	None	None	None	
Full Separation	S-017, S-057, S-018, S-019, S-058, S-020	59	166	$47

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. No opportunities for cost-effective separation of partial catchments exist in the Lower Front Street Planning Area.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. No opportunities for cost-effective separation of partial catchments exist in the Lower Front Street Planning Area.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. Total separation of the entire 59 acre Lower Front Street Planning Area would require installation of new sanitary sewers and/or storm sewers to separate the 166 lateral connections needed to achieve complete separation. Full separation would completely eliminate CSOs, but require installation of GSI within the new separate stormwater system to prevent increases in pollutant loading.

8.4.5.2 Cost Performance Evaluation

Figure 8.4.5-4 presents cost performance curves for each of the local control strategies developed for the Lower Front Street Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

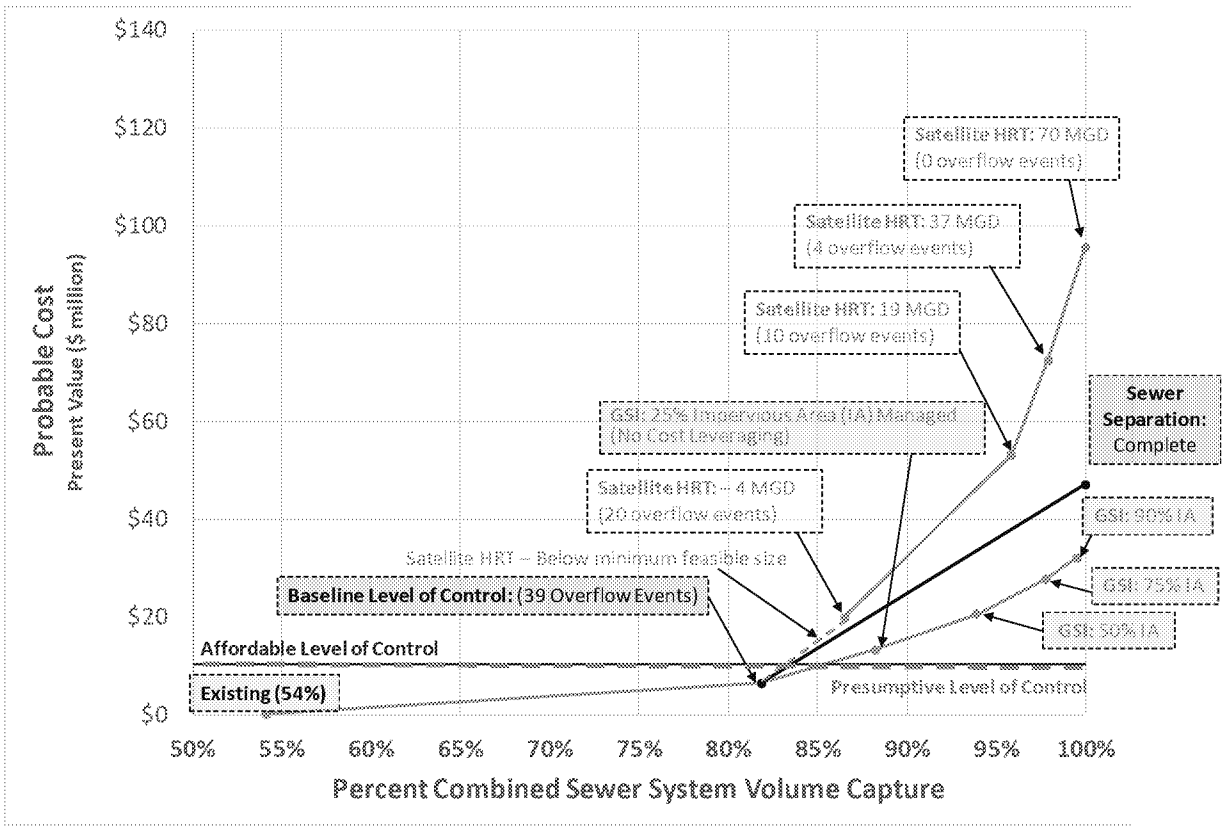

Figure 8.4.5-4: Lower Front Street - CSO Capture Performance and Opinion of Probable Cost Estimate

Figure 8.4.5-5 presents a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

- The ***baseline level of control*** captures 82 percent of the combined sewage volume generated within the Lower Front Street Planning Area during the typical year. Approximately $6.4 million of the cost of CRW's baseline level of control is apportioned to the Lower Front Street Planning Area, including $171,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved is less than the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a high priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control*** is defined as the level of control achieved through expenditures determined to be affordable to CRW's customers based on the Financial Capabilities Analysis presented in Section 7. The affordable level of control, as apportioned to the Lower Front Street Planning Area is $10.3 million, with $6.4 million already allocated to the baseline level of control.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address both CSO control and unauthorized releases, and can be implemented independently or as part of a larger

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project (e.g., collection system/utility rehabilitation, land redevelopment). **Figure 8.4.5-4** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Percent of Impervious Area Controlled with GSI		Cost
		CSO Control	Unauthorized Release Control	
Baseline	82%	None	None	$6.4M
Affordable	85%	15%	Included	$10.3M
Presumptive	85%	15%	Included	$10.3M

The cost-performance curve indicates that the decentralized green-grey control strategy is cost-comparative with the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies. It is also best suited to achieve control of both CSOs and unauthorized releases.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. **Figure 8.4.5-4** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Storage/Treatment Capacity	Cost
Baseline	82%	None	$6.4M
Affordable	82%	None	$6.4M
Presumptive	87%	4 MGD	$16M

The smallest satellite treatment/ storage facility feasible to implement within the Lower Front Street Planning Area – a 4 MGD satellite storage facility – is projected to cost more than the upper limit of the affordable level of control range, but projected to exceed the presumptive level of control. A satellite treatment/storage strategy is ineffective at control of unauthorized releases

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. **Figure 8.4.5-4** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Percent Separation Required	Cost
Baseline	82%	None	$6.4M
Affordable	82%	10%	$10.3M
Presumptive	85%	18%	$13.5M

The cost performance curves clearly show that complete sewer separation is both more costly than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

8.4.5.3 Local Control Strategy Findings

Based on this evaluation the Baseline Level of Control improves wet weather performance, increasing the volume of combined sewage captured during the typical year from 54 percent to 82 percent. The cost-performance evaluation presented in this section indicates that CRW has financial capacity to achieve additional wet weather control within this planning area. The cost-performance evaluation also indicates that the decentralized control (green-grey) strategy provides the highest level of additional control for the cost within the affordable level of control range. Therefore, pursuing a Decentralized Control Strategy to supplement the Baseline Level of Control provides CRW with an affordable, flexible approach to increased CSO control within the Lower Front Street Planning Area.

Up to $4 million of CRW's remaining financial capacity is apportioned to the Lower Front Street Planning area for control of CSOs, unauthorized releases and/or collection system rehabilitation within this planning area. Additional controls may be affordable if the remaining financial capability apportioned to other, lower priority planning areas is re-apportioned to the Uptown Planning Area over the 20-year planning horizon. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. This planning area is prioritized for additional CSO controls, and any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

CRW will prioritize the Lower Front Street Planning Area for additional controls beyond the Baseline Level of Control at a cost of up to $4 million (managing the runoff from a total of 15% of the impervious area), while integrating additional decentralized controls into private redevelopment and utility repair and replacement projects to control unauthorized releases within the planning area.

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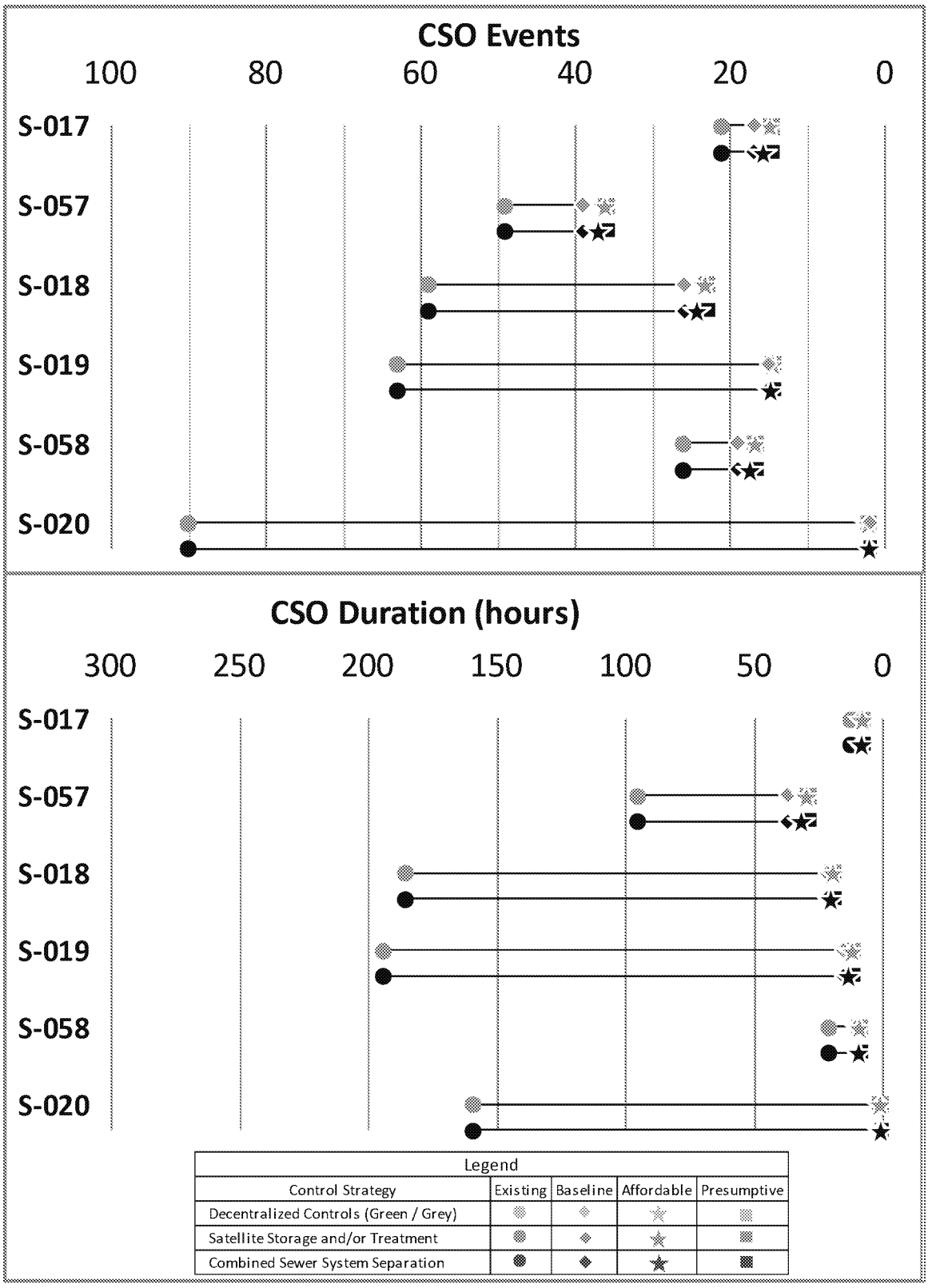

Figure 8.4.5-5: Lower Front Street - Annual CSO Event Frequency and Duration Performance by Control Strategy

8.4.6 Industrial Road Planning Area

The Industrial Road Planning Area encompasses a 634 acre area within the Paxton Creek Sewershed. It is roughly bounded by the railroad corridor on the west, Crooked Hill Road on the east (which includes some unmetered connections just outside the City), following Industrial Road between Linglestown Road and Wildwood Park Drive. The Industrial Road Planning Area encompasses separate sanitary catchments SS-006 and SS-007, shown on **Figure 8.4.6-1**. Catchment SS-006 consists primarily of industrial facilities, while catchment SS-007 consists of the Harrisburg Area Community College campus along with a few unmetered connections from Susquehanna Township. The following existing problems have been identified within the Industrial Road Planning Area:

- Pole-camera inspections did not identify any separate sanitary sewers exhibiting high priority structural rehabilitation needs.
- H&H modeling conducted for the Separate Sanitary System (SSS) Capacity Assessment Report submitted in April 2017 indicated that the separate sanitary trunk sewers within catchments SS-006 and SS-007, tributary to the upper reaches of the Paxton Creek interceptor, are flowing full during the peak 2- to 10-year design storms. Surcharge elevations are within 6 feet of the manhole rims at 6 manholes during the 2- to 10-year design storms. Completed windshield surveys indicate that the structures within the sewershed areas are commercial and industrial facilities constructed on slab foundations, so backups would not occur. Flow data from this catchment exhibits relatively high levels of groundwater infiltration, limiting available hydraulic capacity to accommodate relatively low levels of rainfall-dependent infiltration-inflow.
- Stormwater discharges regulated under DEP MS4 Permit requirements contribute pollutant loading to the Paxon Creek, Wildwood Lake, the Susquehanna River and Chesapeake Bay. A Joint Pollution Reduction Plan (PRP) submitted with CRW's MS4 permit application proposes pollutant controls to be implemented over the next five years, focused primarily on stream restoration projects addressing the Paxton Creek TMDL. No stormwater PRP project were identified for the Industrial Road Planning Area.

8.4.6.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable measures to control SSOs and rehabilitate sewer assets. The following Baseline controls are recommended for the Industrial Road Planning area:

- **Sewer Redirection.** Sanitary flow from SS-006 currently discharges to the regulator chamber for CSO-021. As part of the Baseline Level of Control for Upper Paxton Creek West, which includes S-021, the trunk sanitary sewer for SS-006 will be redirected to connect directly to the Paxton Creek Interceptor, at an estimated capital cost of $100,000.
- **Sewer Rehabilitation.** Install a Cured-In-Place Pipe (CIPP) liner to repair up to 4,900 feet of separate sanitary sewer along industrial Road, at an estimated capital cost of $888,000. Actual project length and cost will be confirmed through CCTV inspection and PACP evaluation. This project is assigned a near-term project priority, and is expected to relieve excessive groundwater infiltration, freeing adequate capacity to accommodate rainfall-dependent infiltration-inflow during the 10-year design storm.
- **Water in Basement.** H&H modeling conducted in this planning area does not indicate sewer surcharging / flooding levels that present a high risk of water in basement or SSOs.

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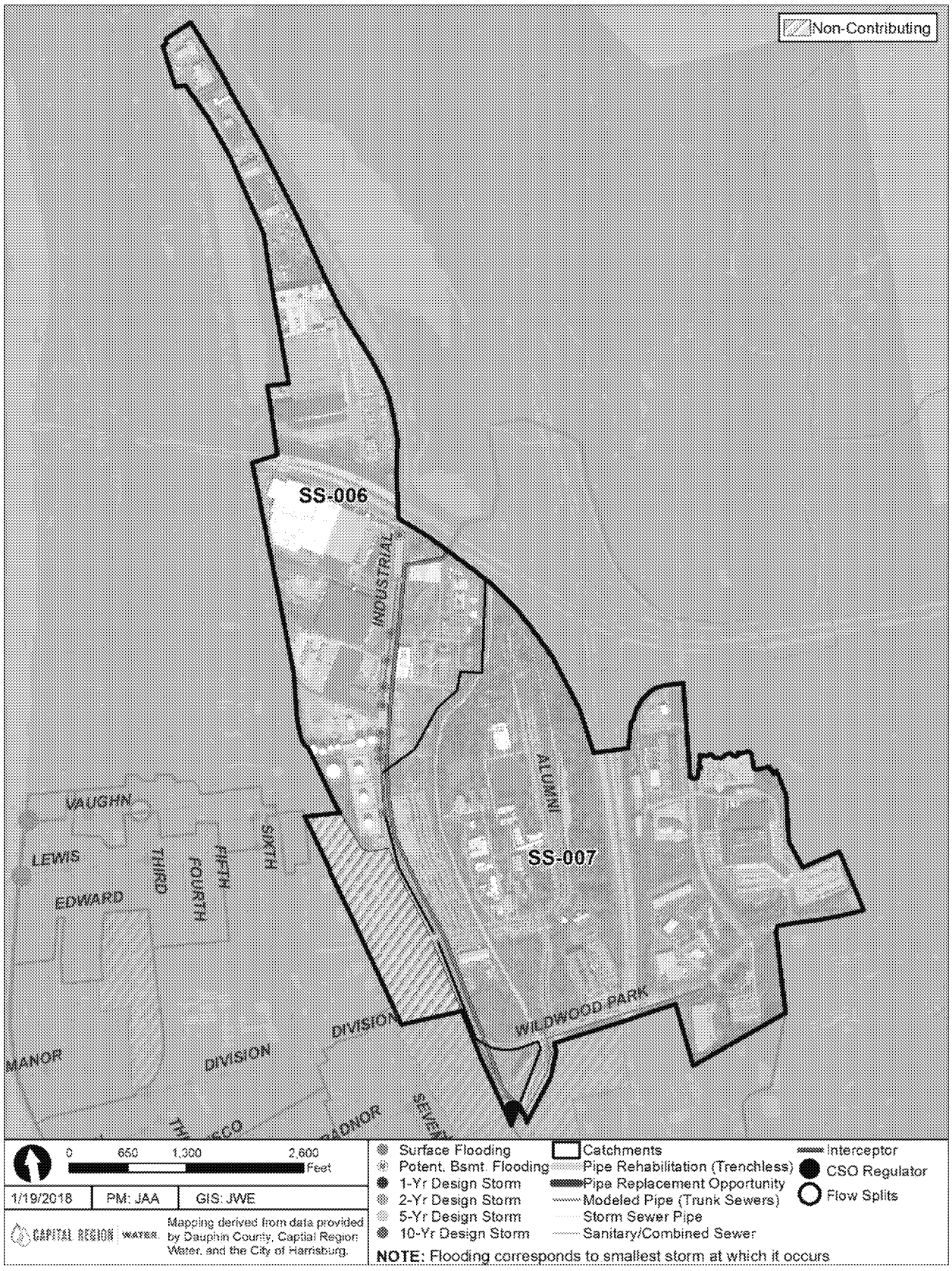

Figure 8.4.6-1: Industrial Road - Existing Hydraulic and Structural Problems

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.6-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.6-1** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.6-1: Industrial Road - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
SS-006	7.37	0.00	7.37	65.20	45.35	110.55	117.92
SS-007	11.34	0.00	11.34	45.10	10.89	56.00	67.33
Total	**18.71**	**0.00**	**18.71**	**110.30**	**56.24**	**166.55**	**185.25**
of Total Impervious	**9%**	**0%**	**9%**	**53%**	**27%**	**80%**	**89%**

Given baseline controls to reduce groundwater infiltration and provide sufficient hydraulic capacity for sanitary sewers, and the PRP approach which does not require specific load reductions for this area for the foreseeable future, the decentralized control (green-grey) strategy is not recommended for the Industrial Road Planning Area at this time.

Local Control Strategy 2: Satellite Storage and/or Treatment

The Industrial Road Planning Area is served by separate storm and sanitary sewers. Flow monitoring and H&H modeling do not indicate levels of sewer surcharging or flooding that present a high risk of SSOs. As such, the satellite storage/treatment control strategy is not applicable to this planning area.

Local Control Strategy 3: Combined Sewer System Separation

The Industrial Road Planning Area is served by separate storm and sanitary sewers. As such, the sewer separation control strategy is not applicable to this planning area.

8.4.6.2 Cost Performance Evaluation

Cost-performance evaluations are only used to evaluate control strategies for combined sewer overflow control. As such, they are not applicable to this planning area.

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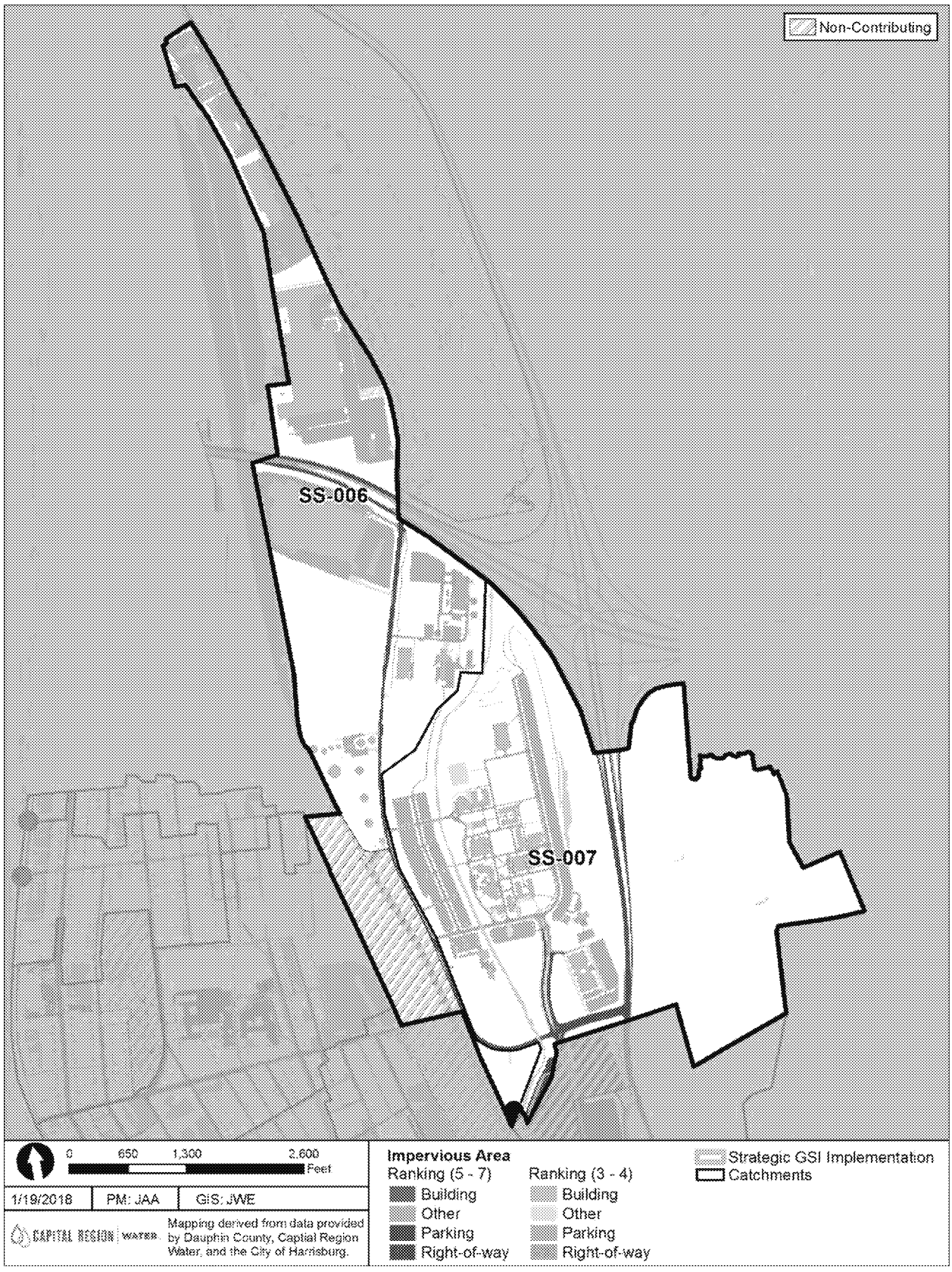

Figure 8.4.6-2: Industrial Road - Green Stormwater Infrastructure / Sediment Reduction Opportunities

8.4.6.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving wet weather control objectives in the Industrial Road Planning Area.

Recommended controls consist of:

- A Cured-In-Place Pipe (CIPP) liner to reduce ground water infiltration in up to 4,900 feet of separate sanitary sewer
- Redirection of the Industrial Road sewer from the CSO-021 regulator chamber to a direct connection to the Paxton Creek interceptor.

The total estimated opinion of probable cost of these recommended controls is $888,000. This planning area does not have any CSO discharges and therefore will not be prioritized for additional stormwater controls, but further wet weather improvements can be achieved with decentralized green-grey controls integrated into private redevelopment and decentralized controls integrated into utility repair and replacement projects to control unauthorized releases within the planning area.

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8.4.7 Upper Paxton Creek West Planning Area

The Upper Paxton Creek West Planning Area encompasses a 392 acre area within the Paxton Creek Interceptor Sewershed. It is roughly bounded by 7th Street on the west, the railroad corridor and adjacent property on the east, Forster Street on the south, and Division Street on the north. The Upper Paxton Creek West Planning Area largely consists of commercial/institutional properties along 7th Street, with most of the residential properties limited to the upstream portion of S-021, and an overall impervious area of 172 acres. It encompasses combined sewer catchments S-021, S-022, S-024, S-027, S-028, and the small, isolated separate sanitary catchment SS-026 (single property), delineated on **Figure 8.4.7-1**. All of the catchment areas discharge to the Paxton Creek Interceptor and/or overflow to Paxton Creek. Figure 8.4.7-1 also identifies where capacity/flooding issues, river intrusion, relatively high CSO frequency and low capture, and some identified structural issues exist.

8.4.7.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.7-1** for the Upper Paxton Creek West Planning Area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: High priority gate repairs have been identified for all CSO structures in the Upper Paxton Creek West Planning Area to prevent river intrusion at the 1-year flood stage. High priority outfall pipe repairs have been identified for CSO 027, while lower priority outfall pipe repairs have been identified for CSOs 021 and 024.

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at CSOs 021, 024, and 028. H&H modeling did not find raising other weirs to be effective.

Table 8.4.7-1: Upper Paxton Creek West - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-021	✓	✓	✓		✓	$147,000*		
S-022	✓				✓	$25,000		
S-024	✓	✓	✓		✓	$47,000		
S-027	✓				✓	$36,000		
S-028	✓	✓			✓	$26,000		
					Total Cost:	$281,000		

Priority:	High	Medium	Low	None

*Indicates additional changes, see notes

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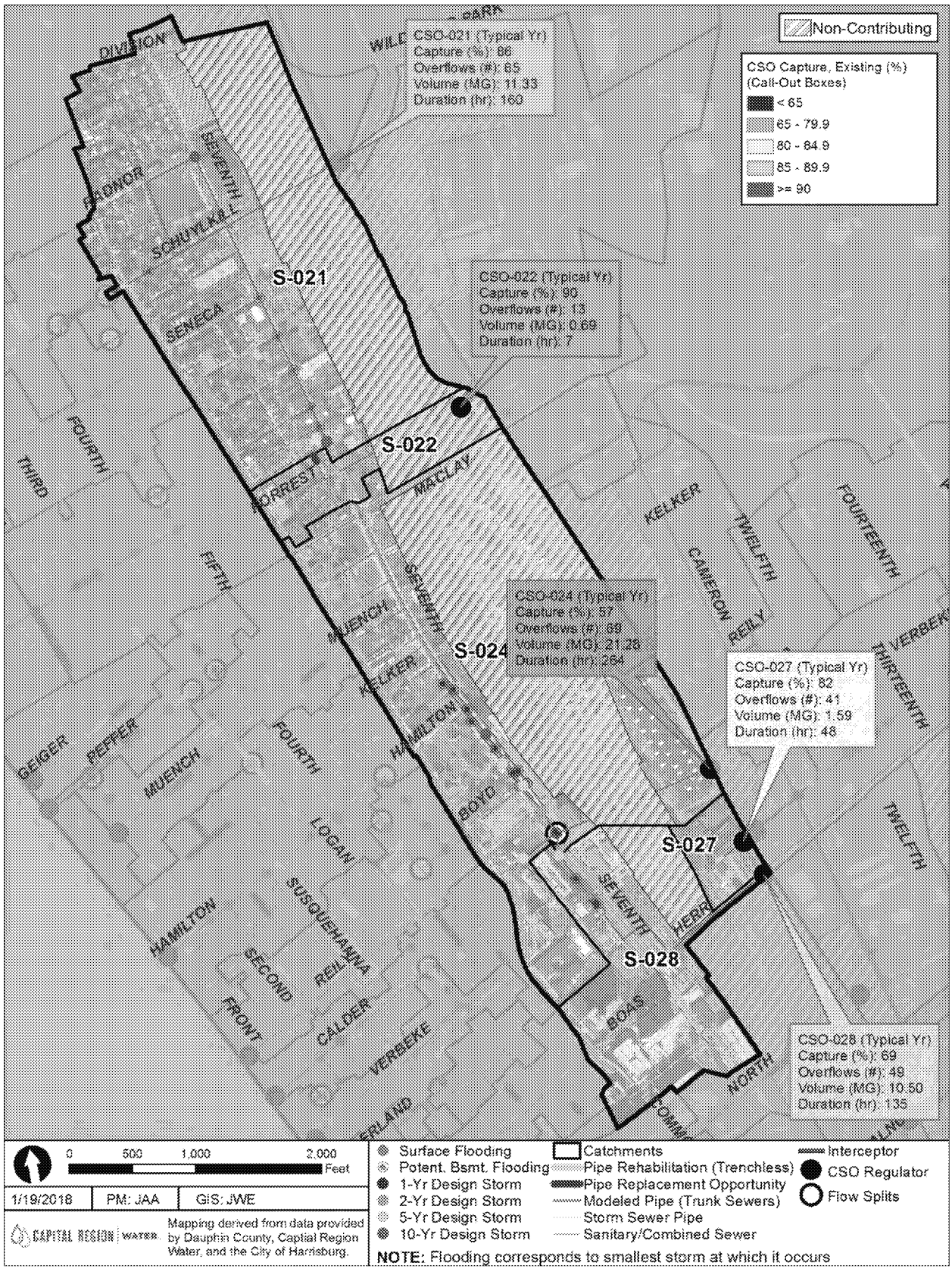

Figure 8.4.7-1: Upper Paxton Creek West - Existing Hydraulic and Structural Problems

- **Adjust Orifice Openings**: Brown and Brown (B&B) orifice control devices (see Figure 3-9) exist at CSO regulator structures 021, 022, 027, and 028; and a fixed orifice control (see Figure 3-10) exists at CSO regulator structure 024. During wet weather, according to H&H modeling, the orifice restriction at CSO regulator structures 021 and 024 contributes to CSOs. High priority is given to removing these B&Bs and orifice restrictions, replacing them with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

- **Expand Connection Pipes:** H&H modeling did not reveal any locations for affordable and cost-effective connection pipe expansion.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Upper Paxton Creek West Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber or metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSOs 024 and 028.

- **Additional Baseline Controls:** Diverting the Industrial Road sanitary sewer from its connection to the regulator of CSO-021, and connecting it directly to the Paxton Creek interceptor, is an immediate priority for affordable and effective CSO control, eliminating the potential for these separate sanitary sewer flows from overflowing at CSO-021 at an estimated capital cost of $100,000.

Table 8.4.7-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Upper Paxton Creek West Planning Area:

- Generally, catchments in the Upper Paxton Creek West Planning Area already achieve relatively good CSO performance under existing conditions, exceeding or nearing the 85% capture presumptive level of control at CSOs 021, 022, and 027. So, there is less opportunity for improving these catchments under the baseline controls.

- CSO performance is greatly increased in CSO-024 (+34% capture and a reduction of 49 overflow events).

- CSO-028 also improves performance more modestly (+11% capture and a reduction of 19 overflow events), while minimal performance improvement occurs for CSOs 022 and 027, which already achieve relatively good performance.

- CSO capture increases slightly at CSO-021, and the diversion of the Industrial Road sanitary sewer reduces the number of overflow events from 65 to 25 events.

- Planning area CSO capture increases from 74% to 91% with these modest changes.

- CSO frequency is reduced from 47 to 24, on average, during the typical year.

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Table 8.4.7-2: Upper Paxton Creek West – Existing/Baseline CSO Performance During Typical Year

	S-021	S-022	S-024	S-027	S-028	Total
Impervious Drainage Area (acres)	70.3	7.4	53.8	2.5	38.2	172
CSO Volume Captured (MG)						
▪ Existing Conditions	65.4	6.0	28.7	7.4	23.1	131
▪ Baseline Level of Control	73.6	6.1	45.9	7.7	26.8	160
CSO Volume (MG)						
▪ Existing Conditions	11.3	0.7	21.3	1.6	10.5	45.4
▪ Baseline Level of Control	3.4	0.6	4.1	1.3	6.8	16.2
▪ Volume Reduced	7.9	0.1	17.1	0.3	3.7	29.2
CSO Capture (%)						
▪ Existing Conditions	85%	90%	57%	82%	69%	74%
▪ Baseline Level of Control	96%	91%	92%	86%	80%	91%
CSO Events						
▪ Existing Conditions	65	13	69	41	49	69 47
▪ Baseline Level of Control	25	13	20	30	30	30 24
Estimated Implementation Cost						
▪ Per Vol Reduced ($/1000 MG)	$18.61	$250.00	$2.75	$120.00	$7.03	$9.62

Table 8.4.7-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) between sewershed areas allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Upper Paxton Creek West Planning Area nearly meet or exceed the presumptive, (85% capture) level of control for the Susquehanna River at CSOs 021, 022, 024, and 027. A moderate level of CSO control is achieved at CSO-028. As such, the local control strategy should focus on implementing controls for CSO-028, as well as locations throughout the planning area where H&H modeling indicates unauthorized releases occur more often than annually. The following local control strategies will be considered to achieve these objectives.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to Paxton Creek and the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Upper Paxton Creek West Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.7-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.7-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control is achieved for CSOs 021, 022, 024, and 027. As such, additional CSO control should receive priority within CSO-028.

- ***GSI implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.7-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.7-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.7-3: Upper Paxton Creek West - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-021	14.5	0.22	14.8	24.7	9.61	34.3	49.1
S-022	2.42	0.53	2.95	1.74	1.12	2.86	5.81
S-024	14.9	3.32	18.2	16.5	10.1	26.6	44.8
S-027	0.15	0.00	0.15	0.75	0.38	1.13	1.28
S-028	13.4	4.20	17.6	12.8	5.60	18.4	36.0
Total	**45.3**	**8.3**	**53.6**	**56.5**	**26.8**	**83.3**	**137**
of Total Impervious	**28%**	**5%**	**33%**	**35%**	**17%**	**52%**	**85%**

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.7-1**.

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.7-2**, were identified based on these factors. In general, these Areas indicate where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent

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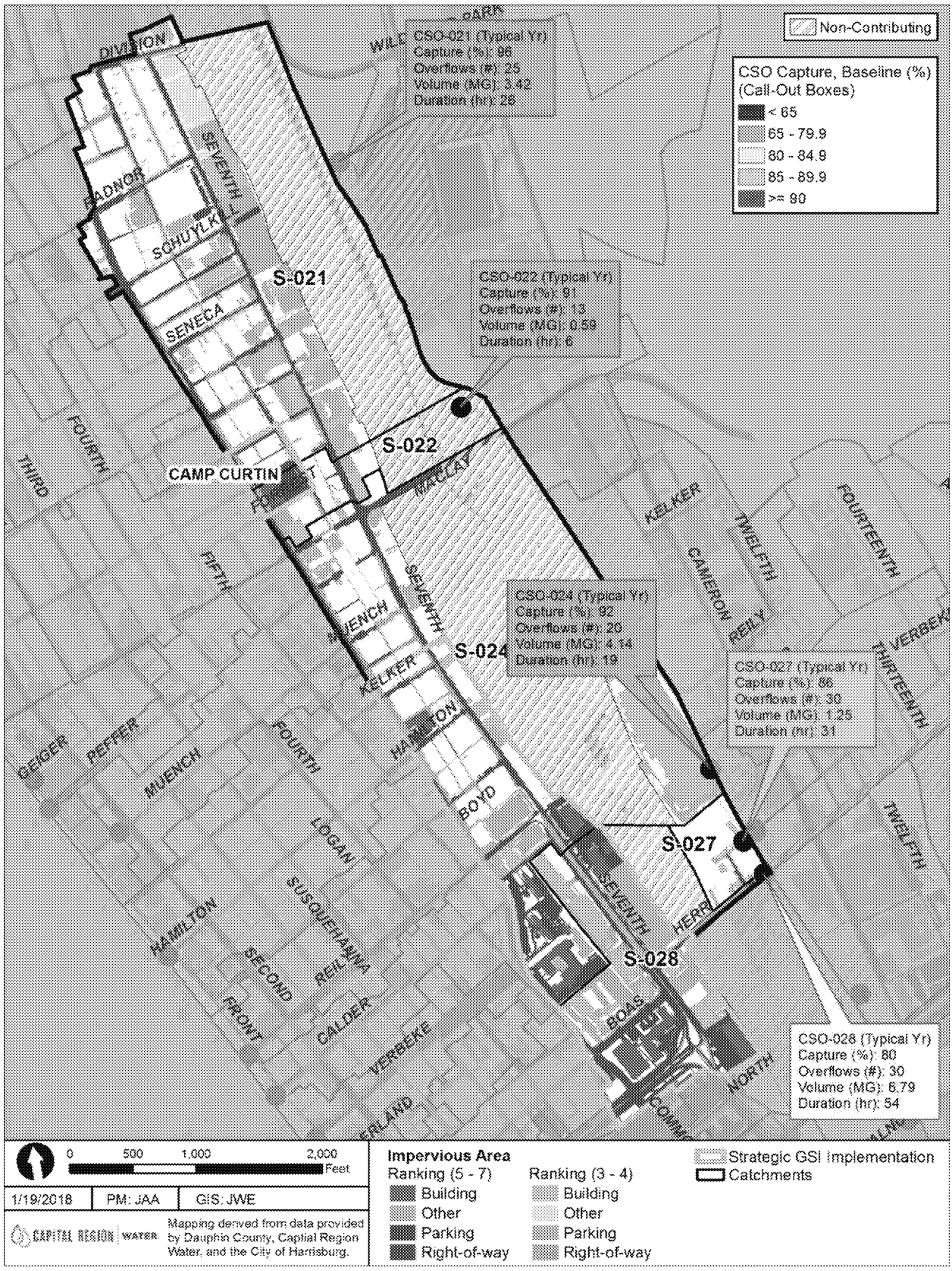

Figure 8.4.7-2: Upper Paxton Creek West - Decentralized Green and Grey Infrastructure Opportunities

unauthorized releases, and other triple bottom line benefits. In the Upper Paxton Creek West Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- The Camp Curtain Pilot GSI project, located at Woodbine Street (between Camp and Forrest Streets) as described in the Community Greening Plan.
- Along 7th Street where H&H modeling indicates the potential for unauthorized releases on more than an average annual basis. The relatively wide 7th Street right-of-way, ongoing redevelopment along the 7th Street corridor, and numerous vacant properties all provide near-term partnership opportunities for implementing GSI.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.7-3 illustrates the major components of the Satellite Control Strategy within the Upper Paxton Creek West Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to Susquehanna River. This strategy focuses on CSO control and does not address unauthorized releases within the collection system. The satellite control strategy builds upon the technologies identified as part of the Baseline Level of Control and the following technologies described below.

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.
- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.
- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

High potential satellite control sites are located in CSO catchments that do not satisfy an affordable level of control (approximately 80 percent capture) and take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Moderate potential satellite control sites are located in CSO catchments that do not satisfy a presumptive level of control (approximately 85 percent capture) and/or present moderate site constraints. Since baseline controls achieve or nearly achieve the presumptive level of control, a moderate potential to implement the satellite controls sites is assumed.

Moderate Potential Satellite Control Sites: Add consolidation sewers and satellite treatment facilities to achieve a presumptive level of control.

- A satellite storage and/or treatment facility located near the intersection of 7th and Herr Streets, with 1,500 feet of consolidation sewer along 7th Street to collect overflows from CSOs 024 and 028, sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control ranging from 16 to 71 MGD.

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- An 8 to 28 MGD treatment facility located near the outfall of CSO-021 to treat/capture overflows from the catchment.
- A 4 to 10 MGD treatment facility located near the outfall of CSO-022 to treat/capture overflows from the catchment.
- A 3 to 8 MGD treatment facility located near the outfall of CSO-027 to treat/capture overflows from the catchment.

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.7-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

Table 8.4.7-4: Upper Paxton Creek West – Levels of Control (Local Control Strategy 3)

Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	S-027	2.5	6	$1.3
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	None	None	None	
Full Separation	S-021, S-022, S-024, S-027, S-028	172	354	$125

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. If utility conflicts are minimal, cost-effective opportunities for total separation exist for S-027.
- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. No opportunities for cost-effective partial separation exist in the Upper Paxton Creek West Planning Area.

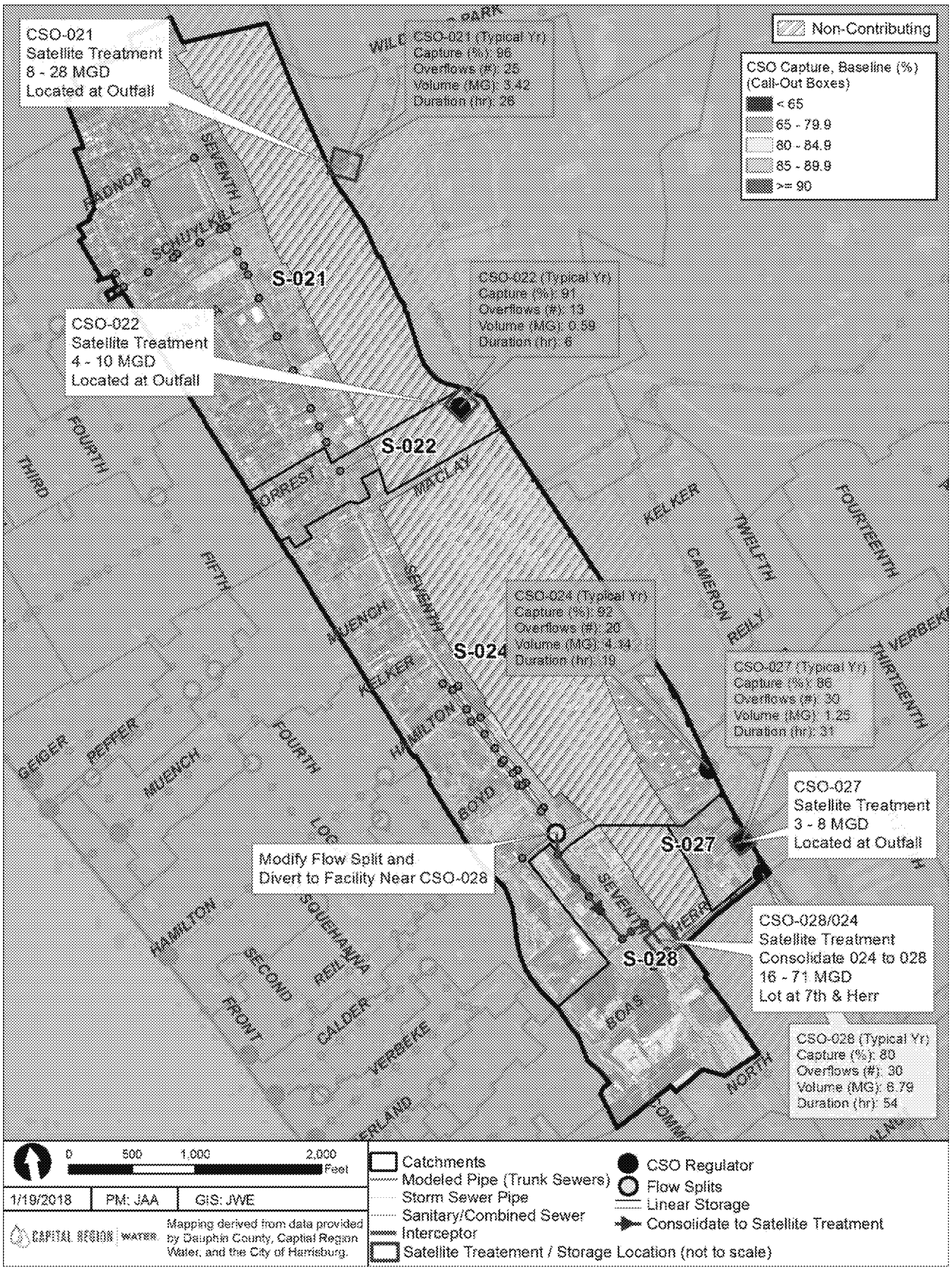

Figure 8.4.7-3: Upper Paxton Creek West - Satellite Treatment / Storage Opportunities

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- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. No opportunities for cost-effective partial separation exist in the Upper Paxton Creek West Planning Area.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. **Table 8.4.7-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment.

8.4.7.2 Cost Performance Evaluation

Figure 8.4.7-4 presents cost performance curves for each of the local control strategies developed for the Upper Paxton Creek West Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

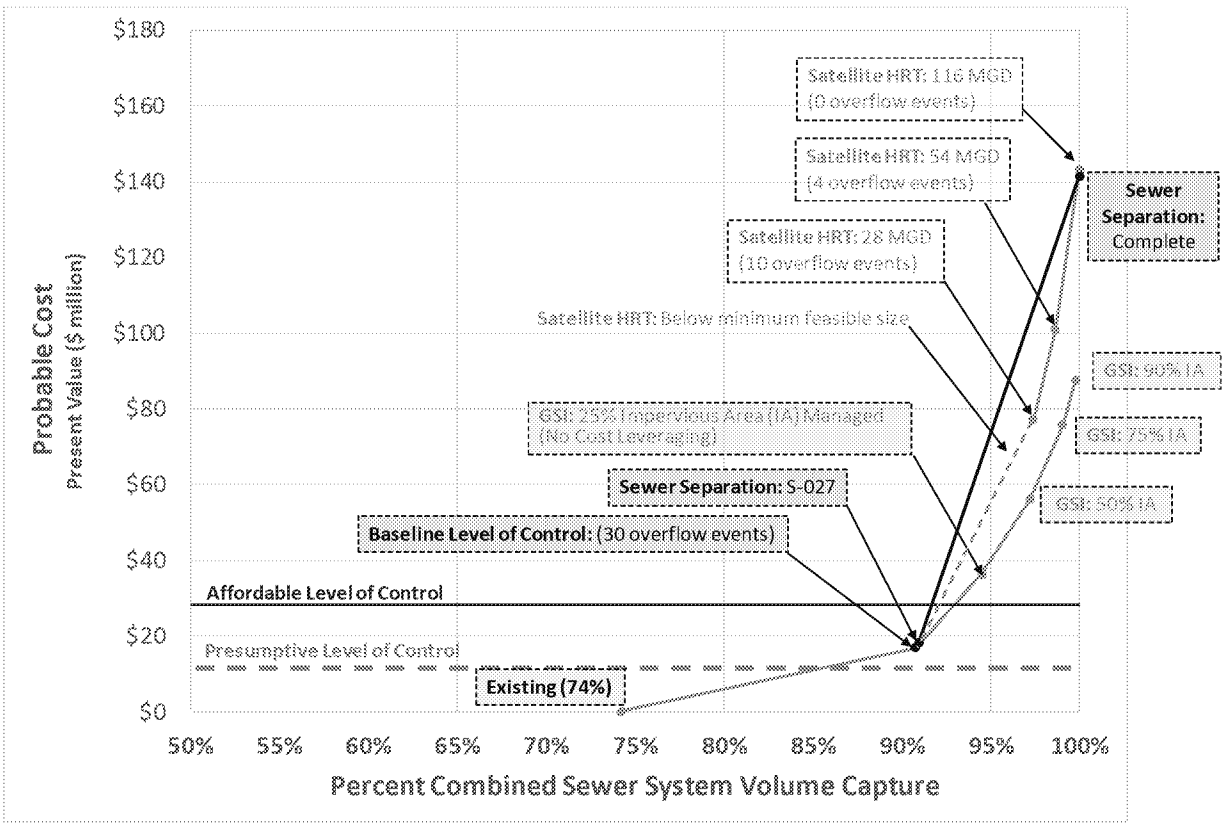

Figure 8.4.7-4: Upper Paxton Creek West - CSO Capture Performance and Opinion of Probable Cost Estimate

Figure 8.4.7-5 presents a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the

decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

- The ***baseline level of control*** captures 91 percent of the combined sewage volume generated within the Upper Paxton Creek West Planning Area during the typical year. Approximately $16.8 million of the cost of CRW's baseline level of control is apportioned to the Upper Paxton Creek West Planning Area, including $281,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved exceeds the ***presumptive level of control (85% combined sewage volume capture)*** for this planning area, further CSO control is considered a low priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control*** is defined as the level of control achieved through expenditures determined to be affordable to CRW's customers. The Financial Capabilities Analysis presented in Section 7 indicates that a capital investment of $28 million can be apportioned to the Upper Paxton Creek West Planning Area, with $16.8 million already allocated to the baseline level of control. Investments within this range should focus on collection system rehabilitation and/or control of unauthorized releases within this Planning Area during the 20-year planning horizon.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address these collection system rehabilitation and/or unauthorized releases. The cost-performance curve indicates that the decentralized control strategy is less costly than the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. The smallest satellite treatment/ storage facility feasible to implement within the Upper Paxton Creek West Planning Area – a 28 MGD satellite HRT – costs three to five times the affordable level of control range for this planning area. Since the Upper Paxton Creek West Planning Area has a low priority for additional CSO control, and this technology is ineffective at control of unauthorized releases, this control strategy is not recommended for this planning area.

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. The cost performance curves clearly show that complete sewer separation is both more costly than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

8.4.7.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving CSO control within the Upper Paxton Creek West Planning Area. An additional investment of $11.5 million is considered affordable for control of unauthorized releases and/or collection system rehabilitation within this planning area. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land

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redevelopment projects. While this planning area will not be prioritized for additional CSO controls, any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

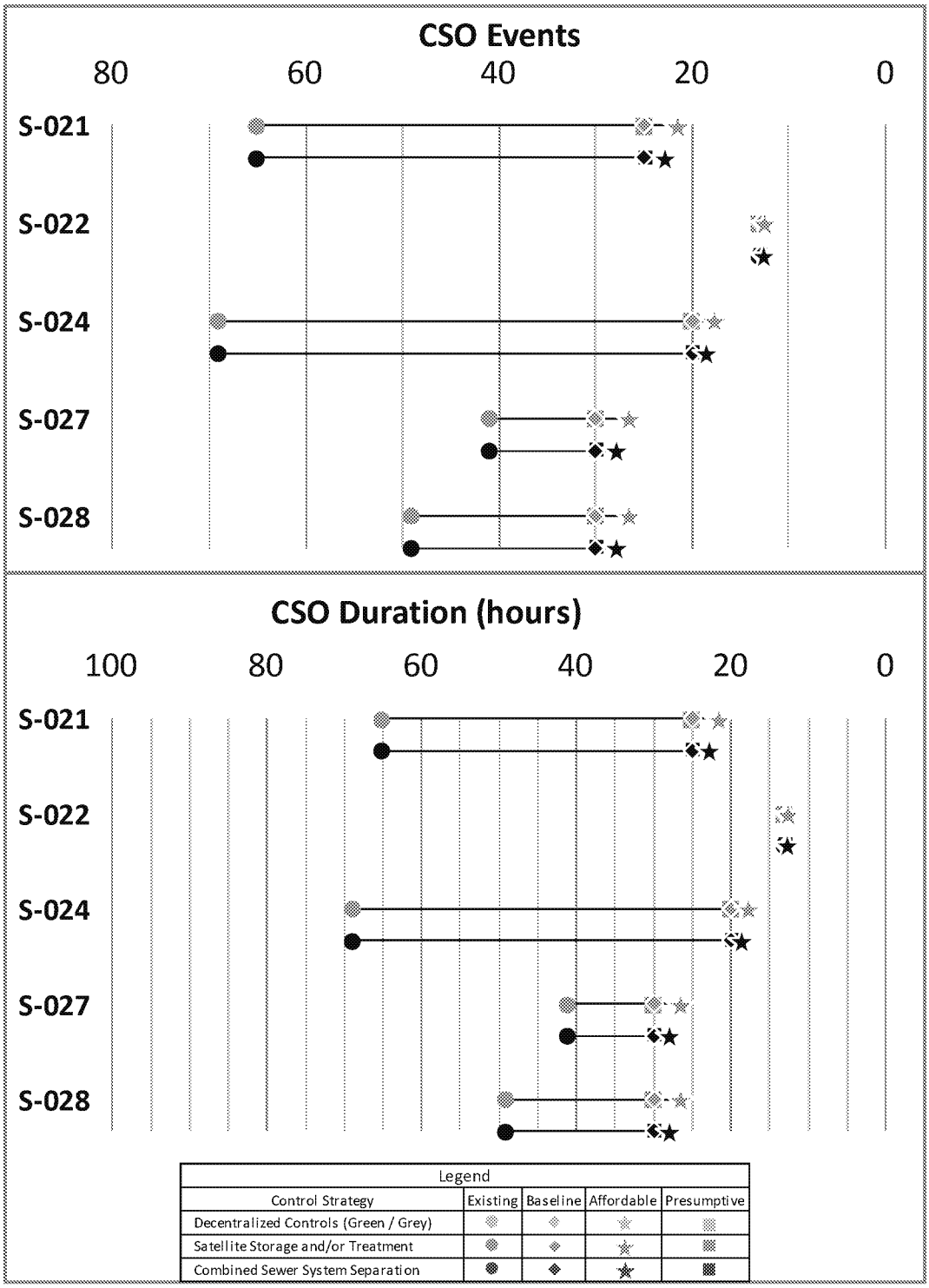

Figure 8.4.7-5: Upper Paxton Creek West - Annual CSO Event Frequency and Duration Performance by Control Strategy

8.4.8 Arsenal Boulevard Planning Area

The Arsenal Boulevard Planning Area, shown on **Figure 8.4.8-1**, encompasses a 374 acre area within the Asylum Run and Paxton Creek Sewershed areas. It includes separate sanitary catchments SS-019 and SS-020, which are part of the Asylum Run Sewershed, and SS-008, which is part of the Paxton Creek Sewershed. Catchment SS-019 follows Arsenal Boulevard and consists of residential/commercial development, including properties within Susquehanna Township. Catchment SS-020 consists of a few properties near the Asylum Run Interceptor connection to Paxton Creek Interceptor. Catchment SS-008 consists of the Farm Show Complex along with a few unmetered State-owned properties in Susquehanna Township. The following existing problems have been identified within the Arsenal Boulevard Planning Area:

- Extensive CCTV inspections revealed significant structural rehabilitation needs for the Arsenal Boulevard trunk sewer.
- H&H modeling conducted for the Separate Sanitary System (SSS) Capacity Assessment Report submitted in April 2017 determined that the Arsenal Boulevard trunk sewer was flowing 30 to 60 percent full during 2- to 10-year design storms, indicating adequate capacity to convey tributary flows to the Asylum Run Interceptor. The H&H model indicates that the Asylum Run Interceptor flows full during the 2-year to 10-year design storms, with HGL elevations more than 8 feet below the rim elevations of most manholes. In the portion of the Asylum Run Interceptor between its connection to the Paxton Creek Relief Interceptor and the Paxton Creek Interceptor, three manholes exhibit peak HGL elevations less than 6 feet below the manhole rim during the 2- to 10-year design storms. However, windshield survey investigations indicated the adjacent commercial/ industrial facilities within the SS-020 sewershed area are built on slab foundations and do not appear to have basements, so sewer backups would not occur. Therefore, there is no evidence of known or predicted SSOs or basement backups associated with the hydraulic capacities of the Asylum Run sewer pipes during a 2- to 10-year design storm.
- The H&H model simulations indicated that the separate sanitary trunk sewers within catchment SS-008, tributary to the upper reaches of the Paxton Creek interceptor, are flowing full during the peak 2- to 10-year design storms. Surcharge elevations are within 4 feet of the manhole rims at 6 manholes during the 2- to 10-year design storms.
- Stormwater discharges regulated under DEP MS4 Permit requirements contribute pollutant loading to Paxton Creek, the Susquehanna River and Chesapeake Bay. A Joint Pollution Reduction Plan (PRP) submitted with CRW's MS4 permit application proposes pollutant controls to be implemented over the next five years, focused primarily on stream restoration projects addressing the Paxton Creek TMDL. No stormwater PRP projects were identified for the Arsenal Boulevard Planning Area.

8.4.8.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable measures to control SSOs and rehabilitate sewer assets. The following Baseline controls are assigned an immediate priority within the Arsenal Boulevard Planning Area:

- **Sewer Rehabilitation.** The *Arsenal Boulevard Trunk Sewer Rehabilitation and Replacement Project* involves the following:

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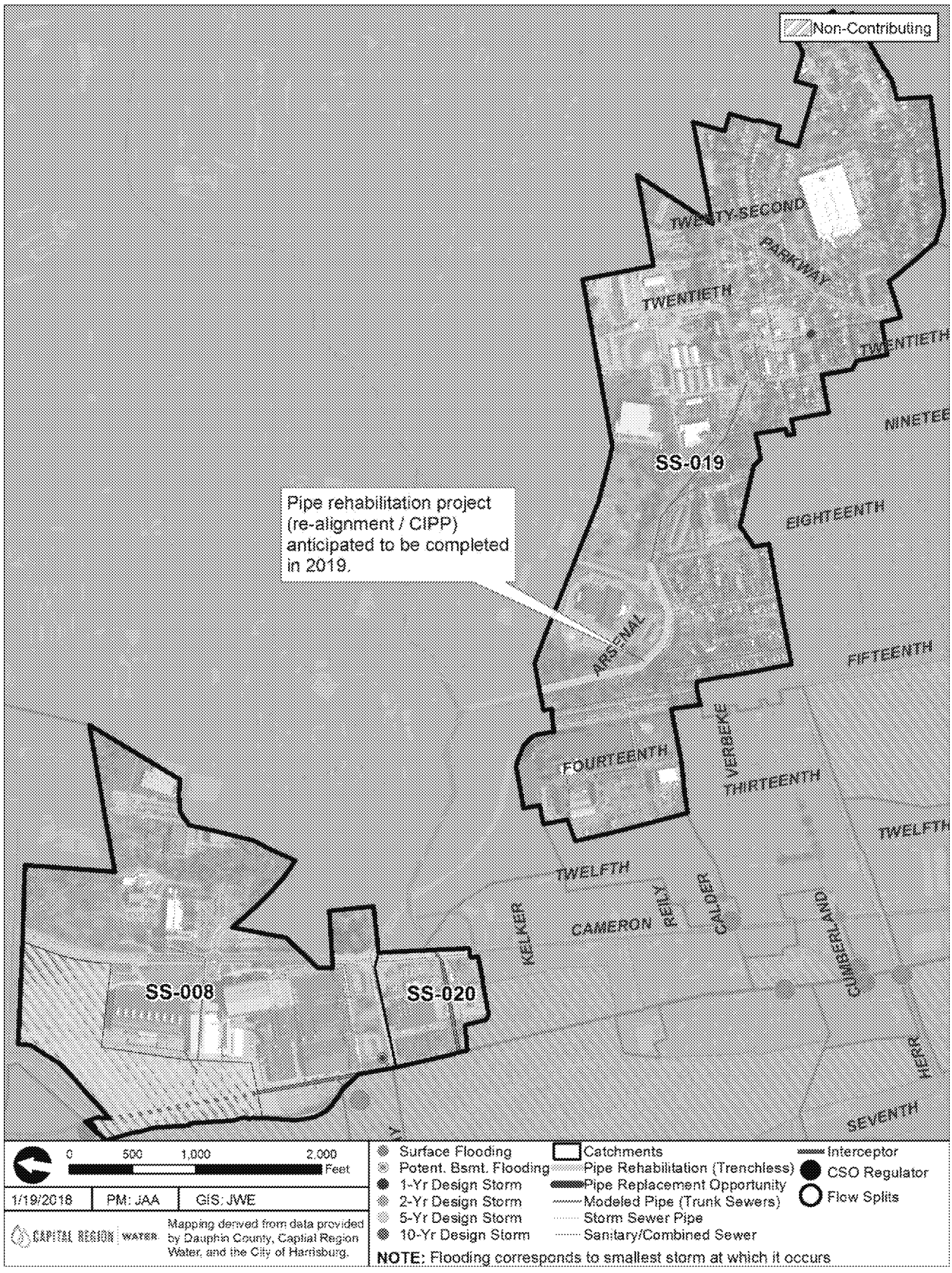

Figure 8.4.8-1: Arsenal Boulevard - Existing Hydraulic and Structural Problems

- Installation of a new 24" gravity sewer with an alternate alignment, totaling approximately 1,150 feet, to facilitate abandonment of the existing 24" gravity sewer located in the stream and/or beneath steep slopes,
- CIPP lining of approximately 2,300 feet of 20"-24" VCP, including stream stabilization in key areas,
- Elimination of one of two stream crossings by re-routing the gravity sewer,
- Replacement of a 10" existing gravity sewer stream crossing, including new manholes, and
- Manhole stabilization and rehabilitation.
- The estimated capital cost of this project is $2.3 million. It is currently being designed.

- **Water in Basement.** H&H modeling conducted in this planning area does not indicate sewer surcharging / flooding levels that present a high risk of water in basement or SSOs.
- **Sewer Redirection.** No sewer redirection is recommended in this planning area.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.8-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.8-1** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.8-1: Arsenal Boulevard - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
SS-008	26.39	4.88	31.27	14.55	16.56	31.11	62.38
SS-019	11.60	1.74	13.34	13.19	5.00	18.19	31.54
SS-020	1.94	0.00	1.95	6.14	3.51	9.65	11.59
Total	**39.94**	**6.62**	**46.56**	**33.88**	**25.06**	**58.95**	**105.51**
of Total Impervious	**33%**	**6%**	**39%**	**28%**	**21%**	**49%**	**88%**

Given sufficient hydraulic capacity for sanitary sewers, and the PRP approach which does not require specific load reductions for this area, the decentralized control (green-grey) strategy is not recommended for the Arsenal Boulevard Planning Area at this time.

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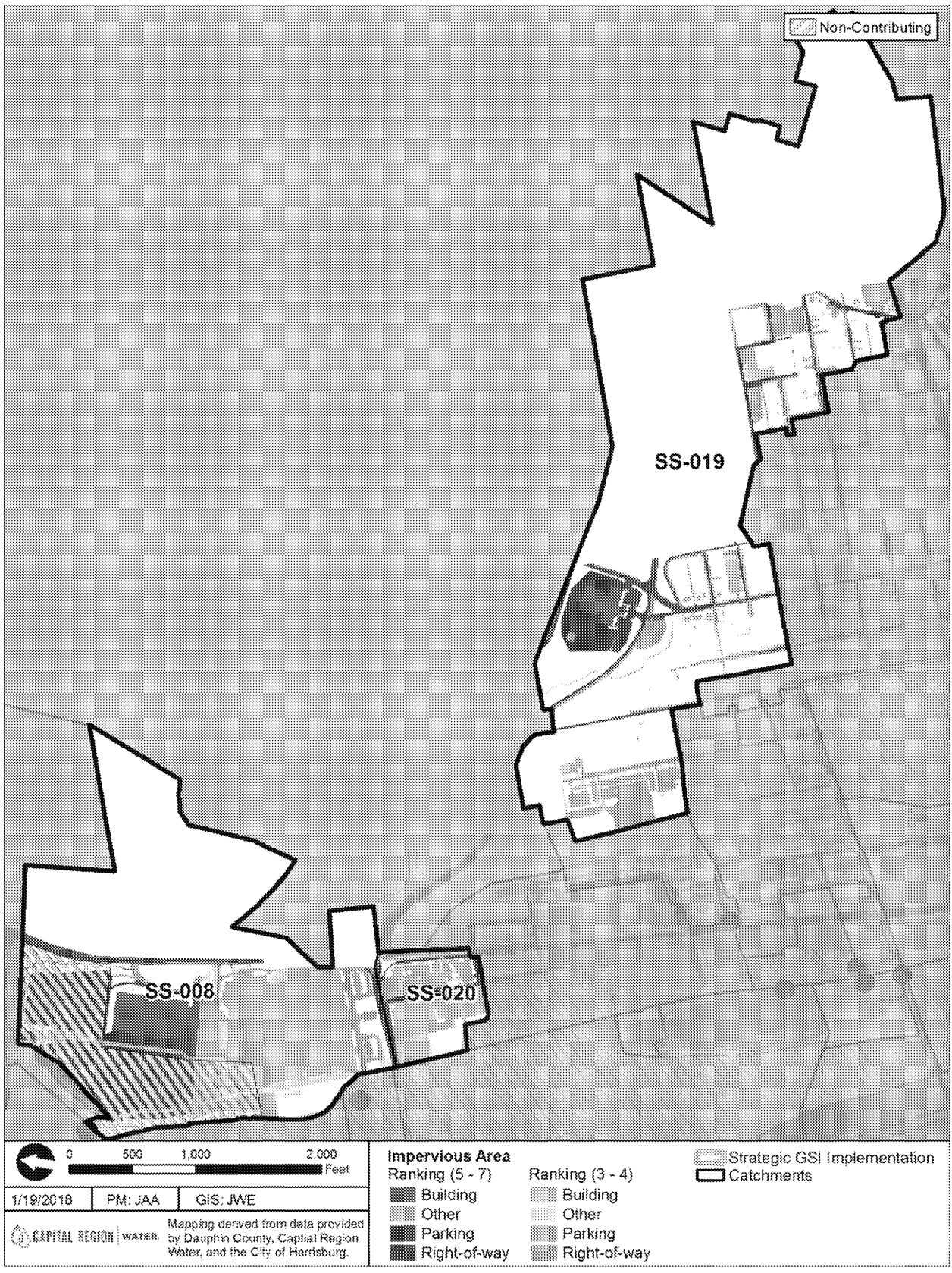

Figure 8.4.8-2: Arsenal Boulevard - Green Stormwater Infrastructure / Sediment Reduction Opportunities

Local Control Strategy 2: Satellite Storage and/or Treatment

The Arsenal Boulevard Planning Area is served by separate storm and sanitary sewers. Flow monitoring and H&H modeling do not indicate levels of sewer surcharging or flooding that present a high risk of SSOs. As such, the satellite storage/treatment control strategy is not applicable to this planning area.

Local Control Strategy 3: Combined Sewer System Separation

The Arsenal Boulevard Planning Area is served by separate storm and sanitary sewers. As such, the sewer separation control strategy is not applicable to this planning area.

8.4.8.2 Cost Performance Evaluation

Cost-performance evaluations are only used to evaluate control strategies for combined sewer overflow control. As such, they are not applicable to this planning area.

8.4.8.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving wet weather control objectives in the Arsenal Boulevard Planning Area.

Recommended controls consist of:

- The *Arsenal Boulevard Trunk Sewer Rehabilitation and Replacement Project* involves: installation of a new gravity sewer, totaling approximately 1,150 feet, CIPP lining of approximately 2,300 feet, including stream stabilization in key areas, elimination of one of two stream crossings by re-routing the gravity sewer, and manhole stabilization and rehabilitation.

- The total estimated opinion of probable cost of these recommended controls is $2.3 million. This planning area does not have any CSO discharges and therefore will not be prioritized for additional stormwater controls, but further wet weather improvements can be achieved with decentralized green-grey controls integrated into private redevelopment and decentralized controls integrated into utility repair and replacement projects to control unauthorized releases within the planning area.

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8.4.9 Upper Paxton Creek East Planning Area

The Upper Paxton Creek East Planning Area encompasses a 130 acre area within the Front Street Interceptor Sewershed. It is roughly bounded by Cameron Street on the west, 12th/15th Street on the east, Herr Street on the south, and Muench Street on the north. The Upper Paxton Creek East Planning Area largely consists of commercial properties along Cameron Street, with residential properties in S-023 and S-026, and an overall impervious area of 40 acres. It encompasses combined sewer catchments S-023, S-025, S-026, and separate sanitary catchment SS-009, delineated on **Figure 8.4.9-1**. All of the catchment areas discharge to the Paxton Creek Interceptor (S-025 and S-026) or Paxton Creek Relief Interceptor (S-023 and SS-009) and/or overflow to Paxton Creek. Figure 8.4.9-1 also identifies locations where capacity/flooding issues, river intrusion, relatively high CSO frequency and low capture, and some identified structural issues exist.

8.4.9.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.9-1** for the Upper Paxton Creek East Planning Area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: High priority gate repairs have been identified for CSOs 025 and 026 to prevent river intrusion at the 1-year flood stage. Low priority gate repairs have been identified for CSO 023 to prevent river intrusion at the 5-year flood stage. No outfall pipe repairs were identified.

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at CSOs 023 and 025. H&H modeling did not find additional weir adjustments to be effective.

- **Adjust Orifice Openings**: Brown and Brown (B&B) orifice control devices (see Figure 3-9) exist at CSO regulator structures 025 and 026; and a fixed orifice control (see Figure 3-10) exists at CSO regulator structure 023. During wet weather, according to H&H modeling, the orifice restrictions at CSO regulator structures 023 and 026 contribute to CSOs. High priority is given to removing these B&Bs and orifice restrictions, replacing them with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

Table 8.4.9-1: Upper Paxton Creek East - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-023	✓	✓	✓		✓	$21,000		$26,000
S-025	✓	✓			✓	$26,000		
S-026	✓		✓		✓	$35,000		
					Total Cost:	**$82,000**		**$26,000**

Priority:	High	Medium	Low	None

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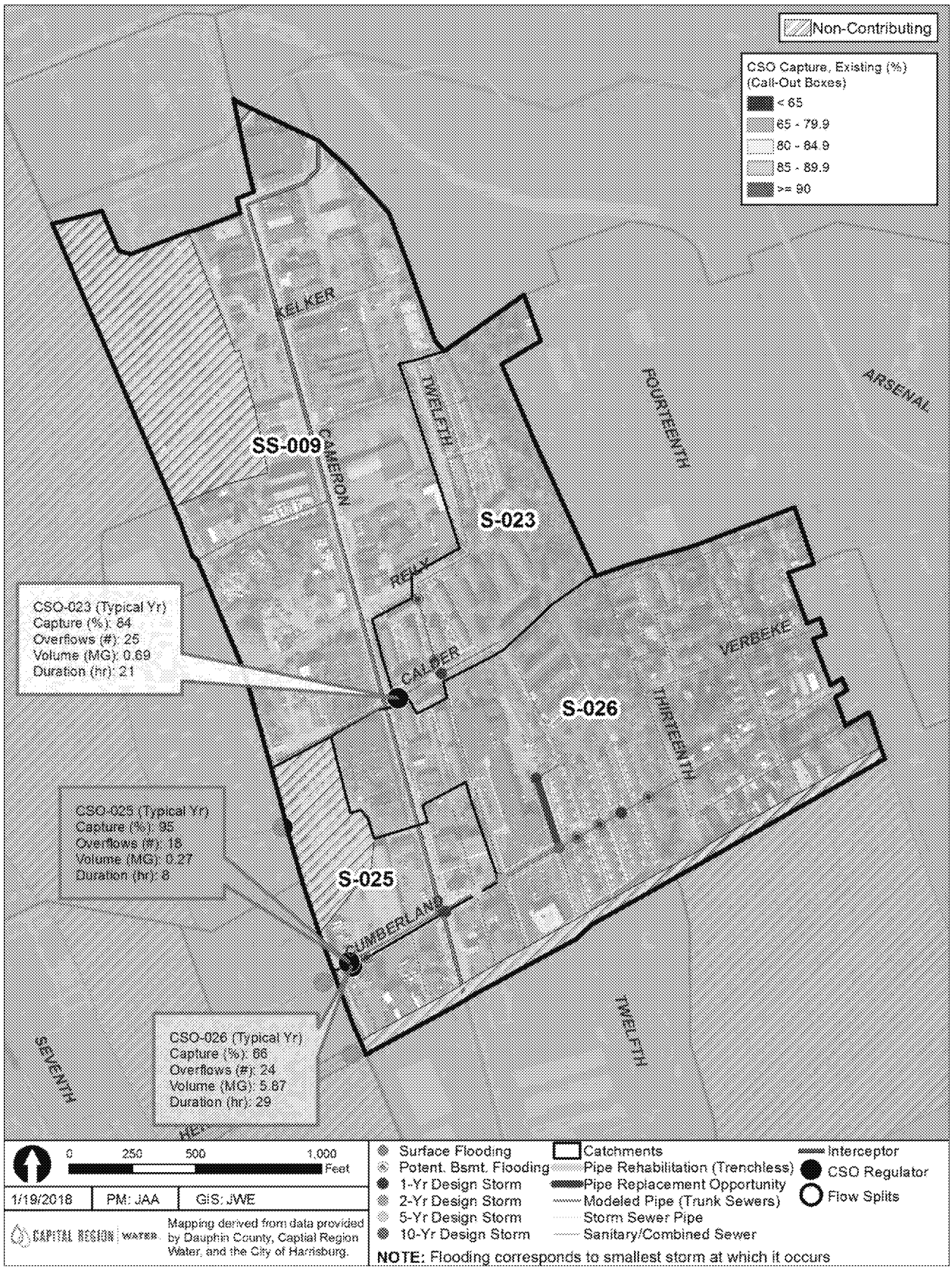

Figure 8.4.9-1: Upper Paxton Creek East - Existing Hydraulic and Structural Problems

- **Expand Connection Pipes:** H&H modeling did not reveal any locations for affordable and cost-effective connection pipe expansion.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Upper Paxton Creek East Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber or metal flap gates) are recommended for CSOs 023 and 025, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSOs 026.

Table 8.4.9-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Upper Paxton Creek East Planning Area:

- Generally, catchments in the Upper Paxton Creek East Planning Area already achieve relatively good CSO performance under existing conditions, exceeding or nearing the 85% capture presumptive level of control at CSOs 023 and 025. So, there is less opportunity for improving these catchments under the baseline controls.

- CSO performance is greatly increased in CSO-026 (+16% capture and a reduction of 9 overflow events).

- CSO-023 also improves performance more modestly (+12% capture and a reduction of 14 overflow events), while minimal performance improvement occurs for CSO-025, which already achieves relatively good performance.

Table 8.4.9-2: Upper Paxton Creek East – Existing/Baseline CSO Performance During Typical Year

	S-023	S-025	S-026	Total
Impervious Drainage Area (acres)	6.3	5.6	28.1	40
CSO Volume Captured (MG)				
▪ Existing Conditions	3.8	5.5	11.2	20.5
▪ Baseline Level of Control	4.3	5.6	13.9	23.8
CSO Volume (MG)				
▪ Existing Conditions	0.7	0.3	5.9	6.8
▪ Baseline Level of Control	0.2	0.1	3.2	3.5
▪ Volume Reduced	0.5	0.1	2.7	3.4
CSO Capture (%)				
▪ Existing Conditions	84%	95%	66%	75%
▪ Baseline Level of Control	96%	98%	81%	87%
CSO Events				Max | Avg.
▪ Existing Conditions	25	18	24	25 22
▪ Baseline Level of Control	11	12	15	15 13
Estimated Implementation Cost				
▪ Per Vol Reduced ($/1000 MG)	$94.00	$260.00	$12.96	$31.76

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- Planning area CSO capture increases from 75% to 87% with these modest changes.
- CSO frequency is reduced from 22 to 13, on average, during the typical year.

Table 8.4.9-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Upper Paxton Creek East Planning Area exceed the presumptive (85% capture) level of control at CSOs 023, 025, and 026. As such, the local control strategy should focus on locations where H&H modeling indicates unauthorized releases occur more often than annually. The following local control strategies will be considered to achieve these objectives.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to Paxton Creek and the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Upper Paxton Creek East Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.9-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.9-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control is achieved for CSOs 023, 025, and 026, and that additional CSO control is not a priority in this Planning Area.
- ***GSI Implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.9-2** indicate impervious areas assigned the highest priority for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a lower priority for control with green/ decentralized infrastructure. **Table 8.4.9-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

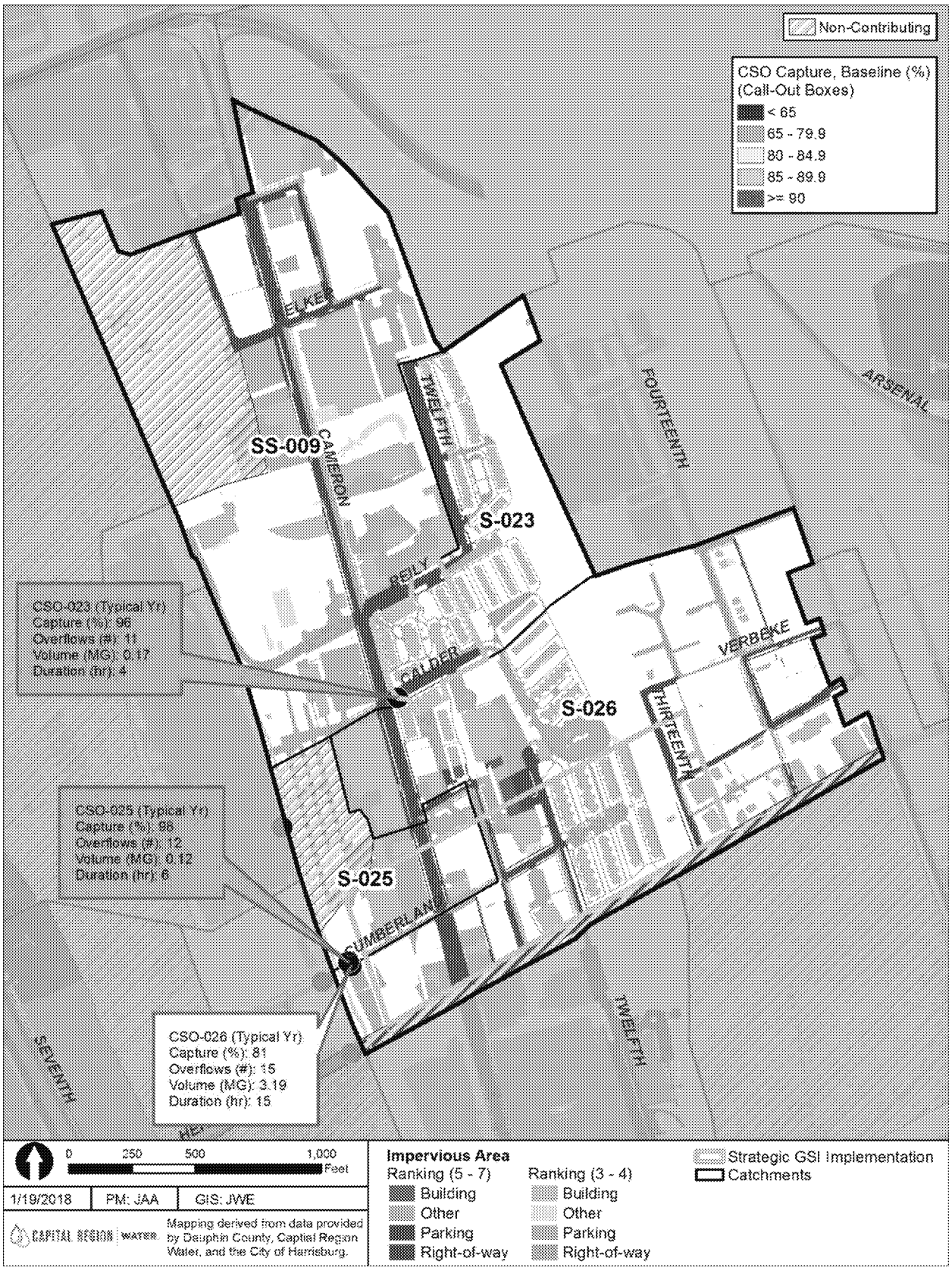

Figure 8.4.9-2: Upper Paxton Creek East - Decentralized Green and Grey Infrastructure Opportunities

Table 8.4.9-3: Upper Paxton Creek East - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-023	0.42	0	0.42	1.21	1.45	2.66	3.08
S-025	0.11	0	0.11	0.61	0.16	0.77	0.88
S-026	3.33	0.33	3.66	7.81	7.09	14.9	18.6
of Total Impervious	**3.9**	**0.33**	**4.2**	**9.6**	**8.7**	**18.3**	**22.5**
Percent of Total	**14%**	**1%**	**15%**	**34%**	**31%**	**64%**	**79%**

Table 8.4.9-3 summarizes green-grey infrastructure opportunities and potential as identified in the Community Greening Plan, and intersected with impervious areas and catchment boundaries within the City Beautiful H_2O Plan, by impervious area type of surface or building sources.

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.9-1.**

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.9-2**, were identified based on these factors. In general, these areas indicate where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits. In the Upper Paxton Creek East Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- Along Calder Street (near Cameron Street, in S-023) where H&H modeling indicates the potential for unauthorized releases on more than an average annual basis.

- Along Cumberland Street where H&H modeling indicates the potential for unauthorized releases on more than an average annual basis.

Note that flooding in this area is exacerbated by backwater from Paxton Creek, where decentralized GSI has limited effectiveness in reducing flood volumes/stages.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.9-3 illustrates the major components of the Satellite Control Strategy within the Upper Paxton Creek East Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to Susquehanna River. This strategy focuses on CSO control and does not address unauthorized releases within the collection system. The satellite control strategy builds upon the technologies identified as part of the Baseline Level of Control and the following technologies described below.

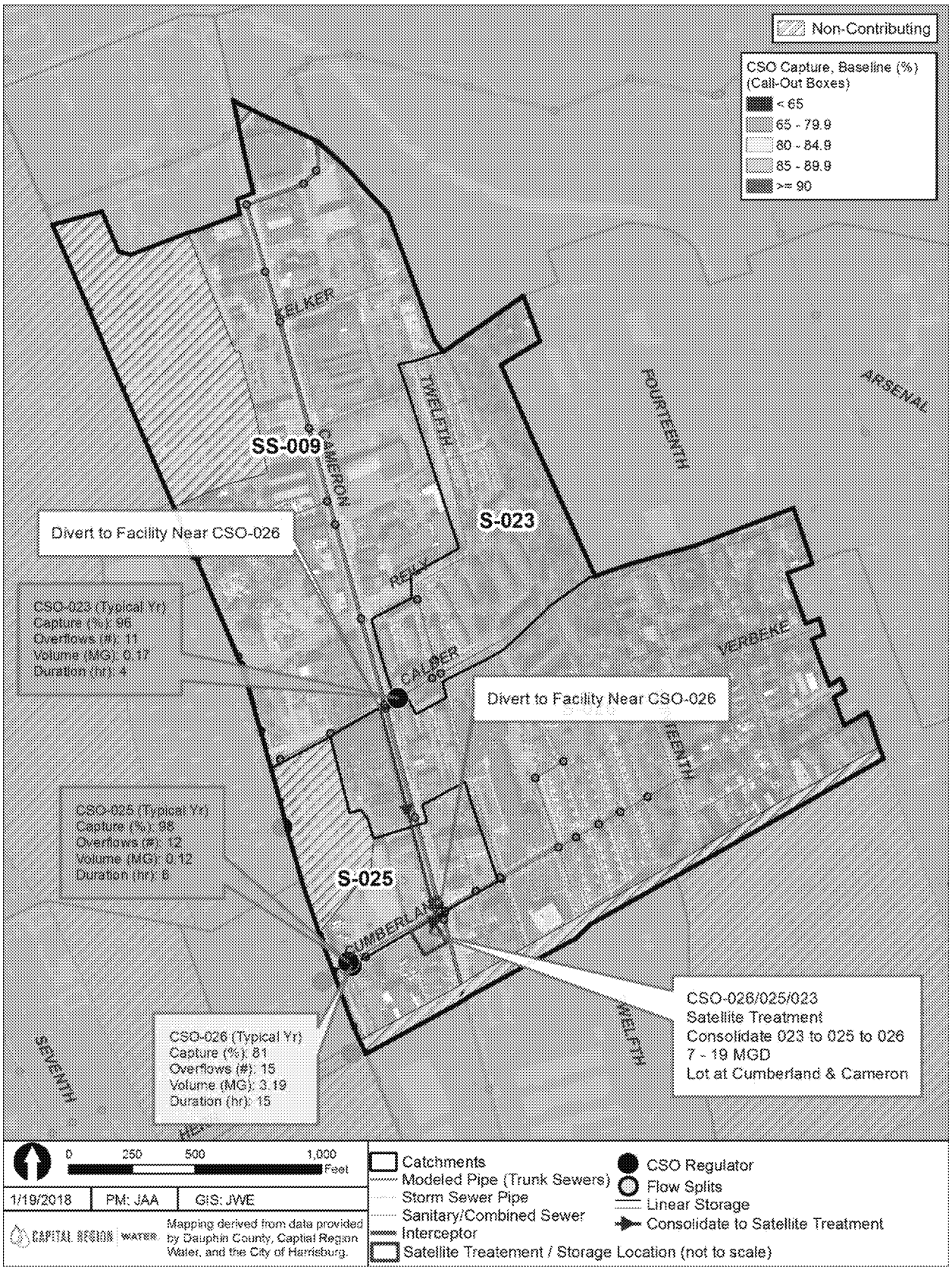

Figure 8.4.9-3: Upper Paxton Creek East - Satellite Treatment / Storage Opportunities

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.
- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.
- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

High potential satellite control sites are located in CSO catchments that do not satisfy an affordable level of control (approximately 80 percent capture) and take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Moderate potential satellite control sites are located in CSO catchments that do not satisfy a presumptive level of control (approximately 85 percent capture) and/or present moderate site constraints.

Moderate Potential Satellite Control Sites: Locate a satellite storage and/or treatment facility near the intersection of Cumberland and Cameron Streets, with 850 feet of consolidation sewer along Front Street to collect overflows from CSOs 023, 025, and 026, sized to treat runoff collected by the consolidation sewer as necessary to achieve levels of control ranging from 7 to 19 MGD.

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.9-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

Table 8.4.9-4: Upper Paxton Creek East – Levels of Control (Local Control Strategy 3)

Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	none	none	none	
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	none	none	none	
Full Separation	S-023, S-025, S-026	28.4	109	$25

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. No opportunities for cost-effective separation of an entire catchment exist in the Upper Paxton Creek East Planning Area.

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. No opportunities for cost-effective partial separation exist in the Upper Paxton Creek East Planning Area.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. No opportunities for cost-effective partial separation exist in the Upper Paxton Creek East Planning Area.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. **Table 8.4.9-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment.

8.4.9.2 Cost Performance Evaluation

Figure 8.4.9-4 presents cost performance curves for each of the local control strategies developed for the Upper Paxton Creek East Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

Figure 8.4.9-5 presents a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

The ***baseline level of control*** captures 87 percent of the combined sewage volume generated within the Upper Paxton Creek East Planning Area during the typical year. Approximately $3 million of the cost of CRW's baseline level of control is apportioned to the Upper Paxton Creek East Planning Area, including $108,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved exceeds the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a low priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control*** is defined as the level of control achieved through expenditures determined to be affordable to CRW's customers. The Financial Capabilities Analysis presented in Section 7 indicates that a capital investment of $5 million, can be apportioned to the Upper Paxton Creek East Planning Area, with $3 million already allocated to the baseline level of control. Investments within this range should focus on collection system rehabilitation and/or control of unauthorized releases within this Planning Area during the 20-year planning horizon.

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- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address these collection system rehabilitation and/or unauthorized releases. The cost-performance curve indicates that the decentralized control strategy is less costly than the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies.

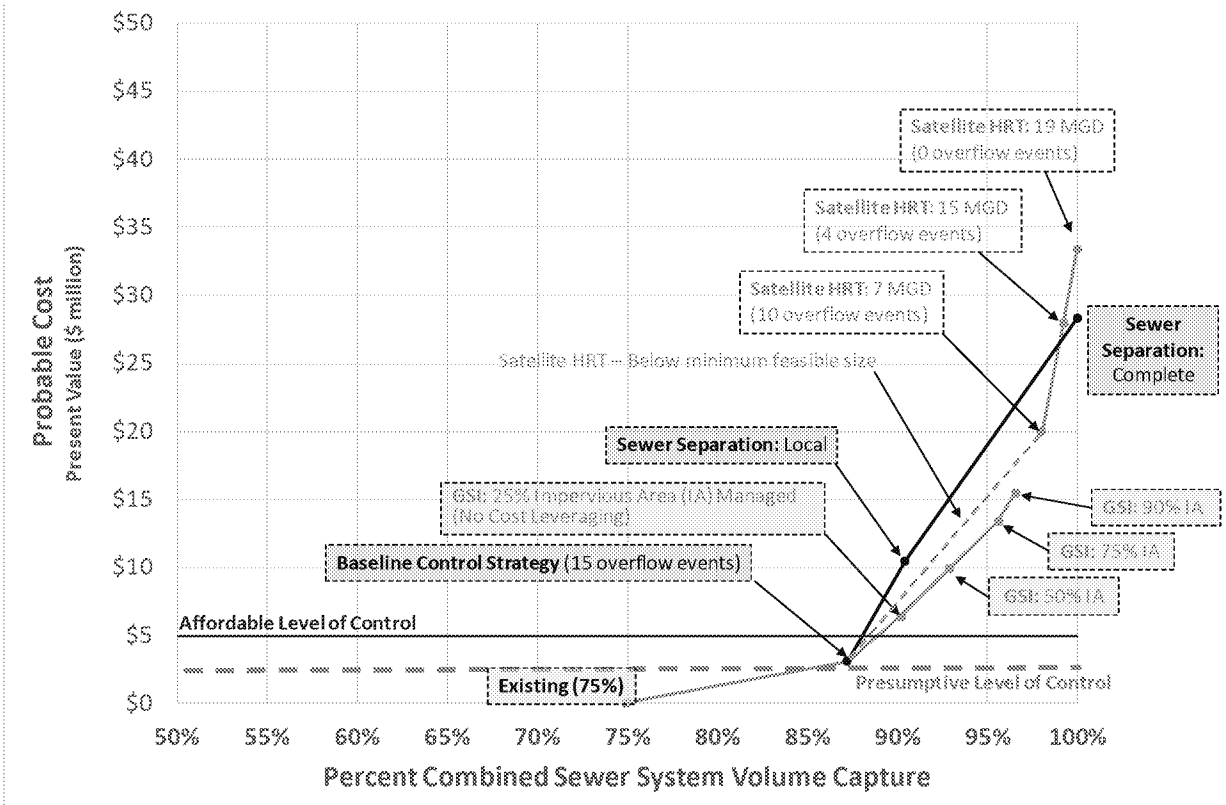

Figure 8.4.9-4: Upper Paxton Creek East - CSO Capture Performance and Opinion of Probable Cost Estimate

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. The smallest satellite treatment/ storage facility feasible to implement within the Upper Paxton Creek East Planning Area – a 7 MGD satellite HRT – costs three to five times the affordable level of control range for this planning area. Since the Upper Paxton Creek East Planning Area has a low priority for additional CSO control, and this technology is ineffective at control of unauthorized releases, this control strategy is not recommended for this planning area.

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. The cost performance curves clearly show that complete sewer separation is both more costly than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

8.4.9.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving CSO control within the Upper Paxton Creek East Planning Area. An additional investment of $2 million is considered affordable for control of unauthorized releases and/or collection system rehabilitation within this planning area. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. While this planning area will not be prioritized for additional CSO controls, any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

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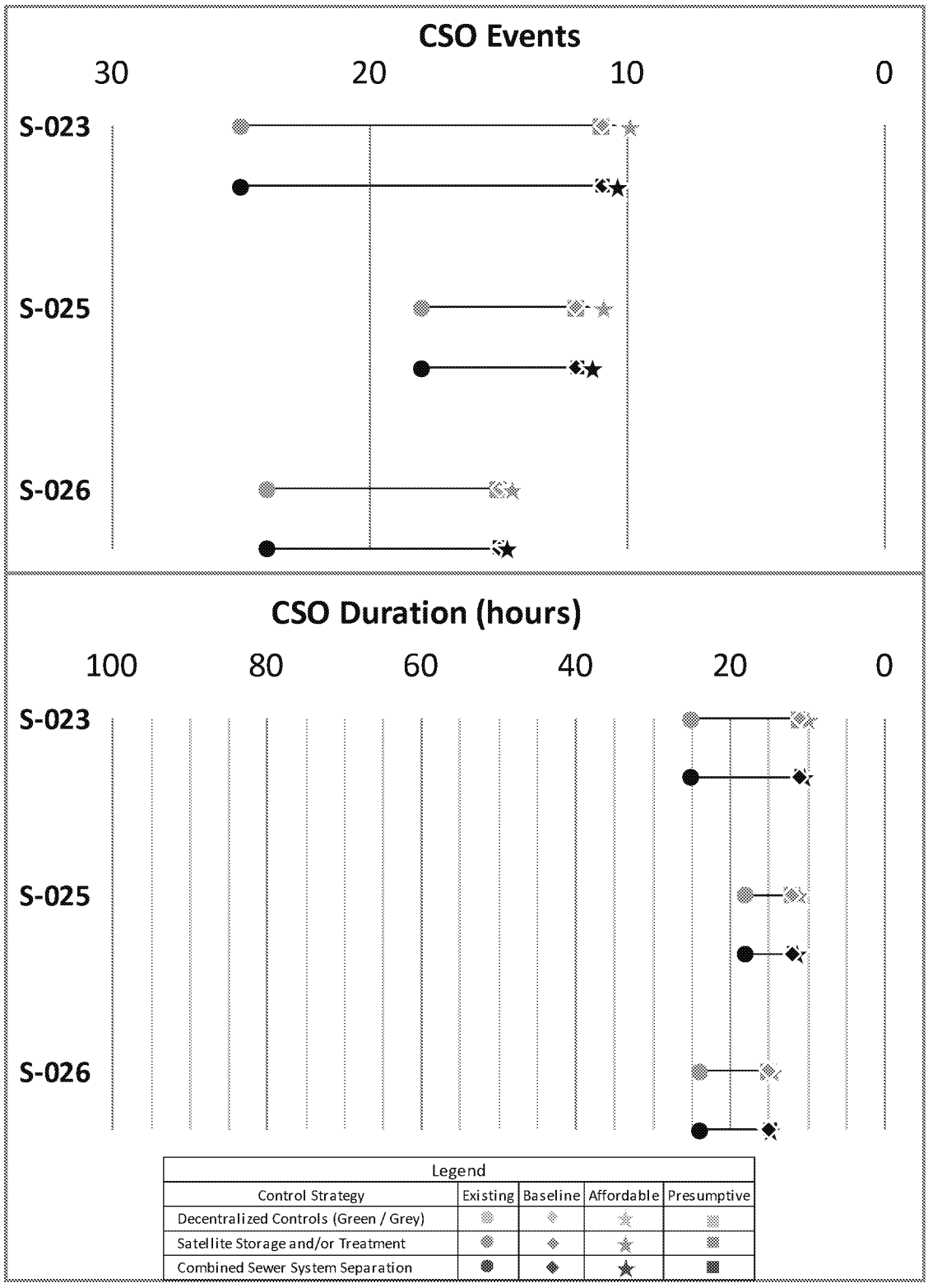

Figure 8.4.9-5: Upper Paxton Creek East - Annual CSO Event Frequency and Duration Performance by Control Strategy

8.4.10 Middle Paxton Creek West Planning Area

The Middle Paxton Creek West Planning Area encompasses a 129 acre area within the Paxton Creek Interceptor Sewershed. It is roughly bounded by the Paxton Creek on the east, Twenty-Fifth Street on the east, Interstate 83 on the south, and the City of Harrisburg boundary/Market Street on the north. The Middle Paxton Creek West Planning Area largely consists of multi-family residential, commercial, and institutional properties on the south and west ends, with an overall impervious area of 97 acres. It encompasses combined sewer catchments S-030, S-032, S-037, S-038, and S-041, all of which discharge to the Paxton Creek interceptor and/or overflow to Paxton Creek. **Figure 8.4.10-1** is a map identifying the extent of this planning area and the existing issues, including capacity/flooding issues, river intrusion, relatively high CSO frequency and low capture, and some identified structural issues.

8.4.10.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.10-1** for the Middle Paxton Creek West Planning area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: High priority gate repairs have been identified for CSOs 032 and 041 to prevent river intrusion at the 1-year flood stage. Medium priority gate repairs have been identified for CSOs 030 and 038 to prevent river intrusion at the 2-year flood stage. Low priority gate repairs have been identified for CSO 037 to prevent river intrusion at the 5-year flood stage. High priority outfall pipe repairs have been identified for CSOs 038 and 041.

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at CSOs 030, 032, 037, and 041.

Table 8.4.10-1: Middle Paxton Creek West - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-030	✓	✓			✓	$11,000	$15,000	
S-032	✓	✓			✓	$26,000		
S-037	✓	✓	✓	✓	✓	$87,000		$26,000
S-038	✓				✓	$36,000		
S-041	✓	✓			✓	$37,000		
					Total Cost:	**$197,000**	**$15,000**	**$26,000**

Priority:	High	Medium	Low	None

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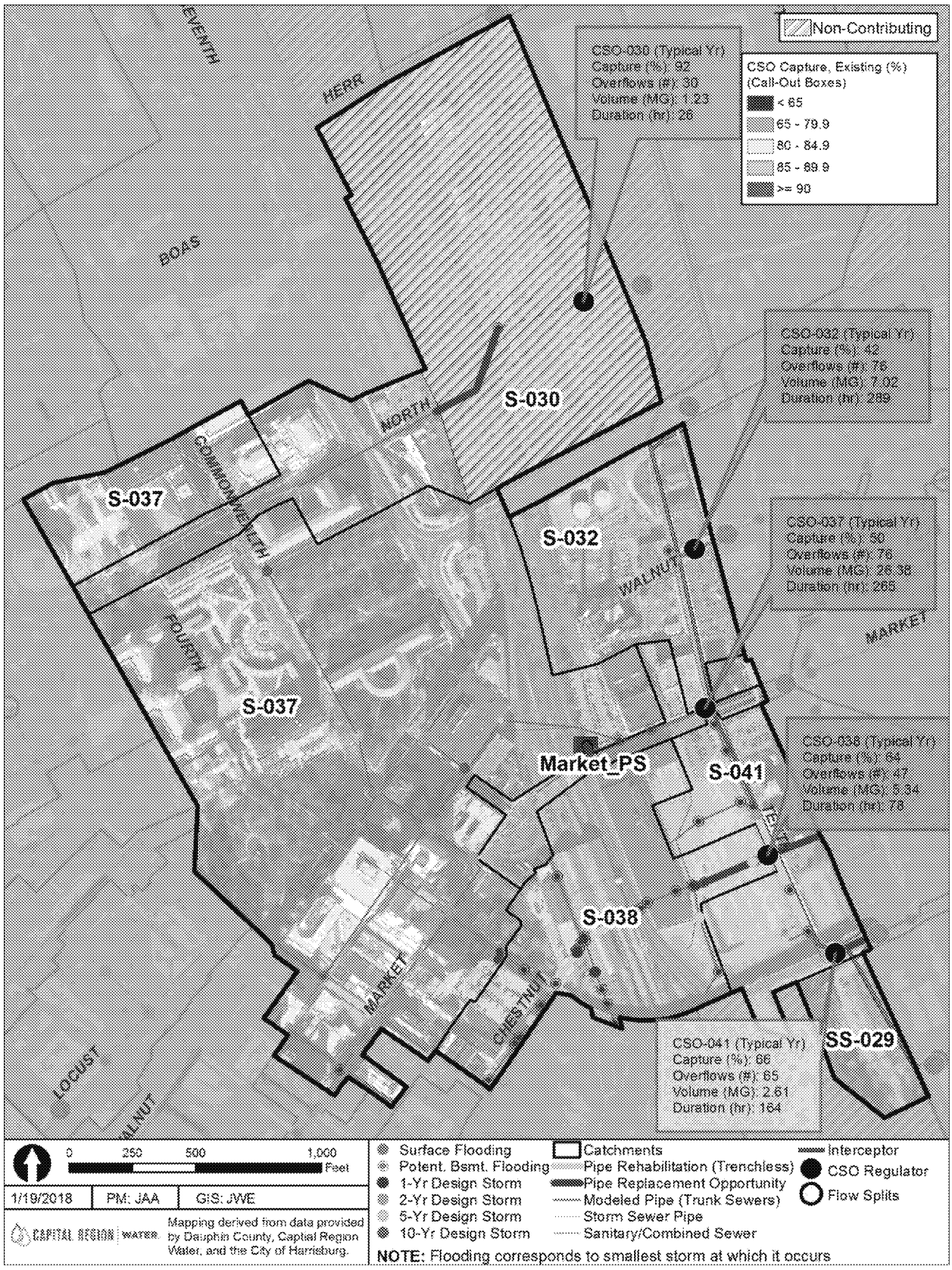

Figure 8.4.10-1: Middle Paxton Creek West - Existing Hydraulic and Structural Problems

- **Adjust Orifice Openings**: Brown and Brown (B&B) orifice control devices (see Figure 3-9) exist at each CSO regulator structure in the Middle Paxton Creek West Planning Area. During wet weather, according to H&H modeling, the orifice restriction at CSO-037 contributes to CSOs. High priority is given to removing this B&B and orifice restriction, replacing it with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

- **Expand Connection Pipes:** H&H modeling revealed that CSO-037 is a location for affordable and cost-effective connection pipe expansion. The remaining existing connector pipes are of sufficient size.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Middle Paxton Creek West Planning Area. Today, CRW's Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber and metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSO 037.

- **Pipe Rehabilitation:** Trunk sewers in S-030 and S-038 have been identified for pipe rehabilitation, repair, or replacement depending on further site investigations.

Table 8.4.10-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Middle Paxton Creek West Planning Area:

- CSO performance is greatly increased in CSOs 032 (+25% capture and a reduction of 19 overflow events), 037 (+40% capture and a reduction of 52 overflow events), 038 (+31% capture and a reduction of 41 overflow events), and 041 (+12% capture and a reduction of 23 overflow events) with weir and regulator connector pipe changes. Other catchments also improve performance.

- Catchment S-030 also improves performance more modestly.

- Planning area CSO capture increases from 60% to 89% with these modest changes.

- CSO frequency is reduced from 59 to 29, on average, during the typical year.

Table 8.4.10-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Middle Paxton Creek West Planning Area exceed the presumptive (85% capture) level of control at CSOs 030, 037, and 038. As such, the local control strategy should focus on the remaining CSOs 032 and 041, as well as locations throughout the planning area where H&H modeling indicates unauthorized releases occur more often than annually. The following local control strategies will be considered to achieve these objectives.

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Table 8.4.10-2: Middle Paxton Creek West – Existing/Baseline CSO Performance During Typical Year

	S-030	S-032	S-037	S-038	S-041	Total
Impervious Drainage Area (acres)	15.9	7.5	53.7	15.6	10.9	104
CSO Volume Captured (MG)						
▪ Existing Conditions	16.7	5.2	26.4	9.5	5.2	62.9
▪ Baseline Level of Control	17.3	8.2	47.8	14.0	6.1	93.4
CSO Volume (MG)						
▪ Existing Conditions	1.2	7.0	26.4	5.3	2.6	42.6
▪ Baseline Level of Control	0.6	3.9	5.0	0.7	1.7	12.0
▪ Volume Reduced	0.7	3.1	21.4	4.6	0.9	30.6
CSO Capture (%)						
▪ Existing Conditions	93%	42%	50%	64%	67%	60%
▪ Baseline Level of Control	96%	68%	91%	95%	78%	89%
CSO Events						Max | Avg.
▪ Existing Conditions	30	76	76	47	65	76 59
▪ Baseline Level of Control	15	57	24	6	42	57 29
Estimated Implementation Cost						
▪ Per Vol Reduced ($1,000/MG)	$37.14	$8.39	$5.28	$7.83	$41.11	$7.78

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to Paxton Creek and the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Middle Paxton Creek West Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.10-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

The call-out boxes on **Figure 8.4.10-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control is achieved within the Middle Paxton Creek West Planning Area at all CSO catchments except S-032 and S-041, where additional CSO control should be considered a near- to mid-term priority for this Planning Area. The most-cost-effective opportunities to deploy GSI take into consideration the following factors:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.10-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control (85 percent capture) is met or exceeded at CSOs 030, 037, and 038. As such, additional CSO control should receive priority within CSOs 032 and 041.

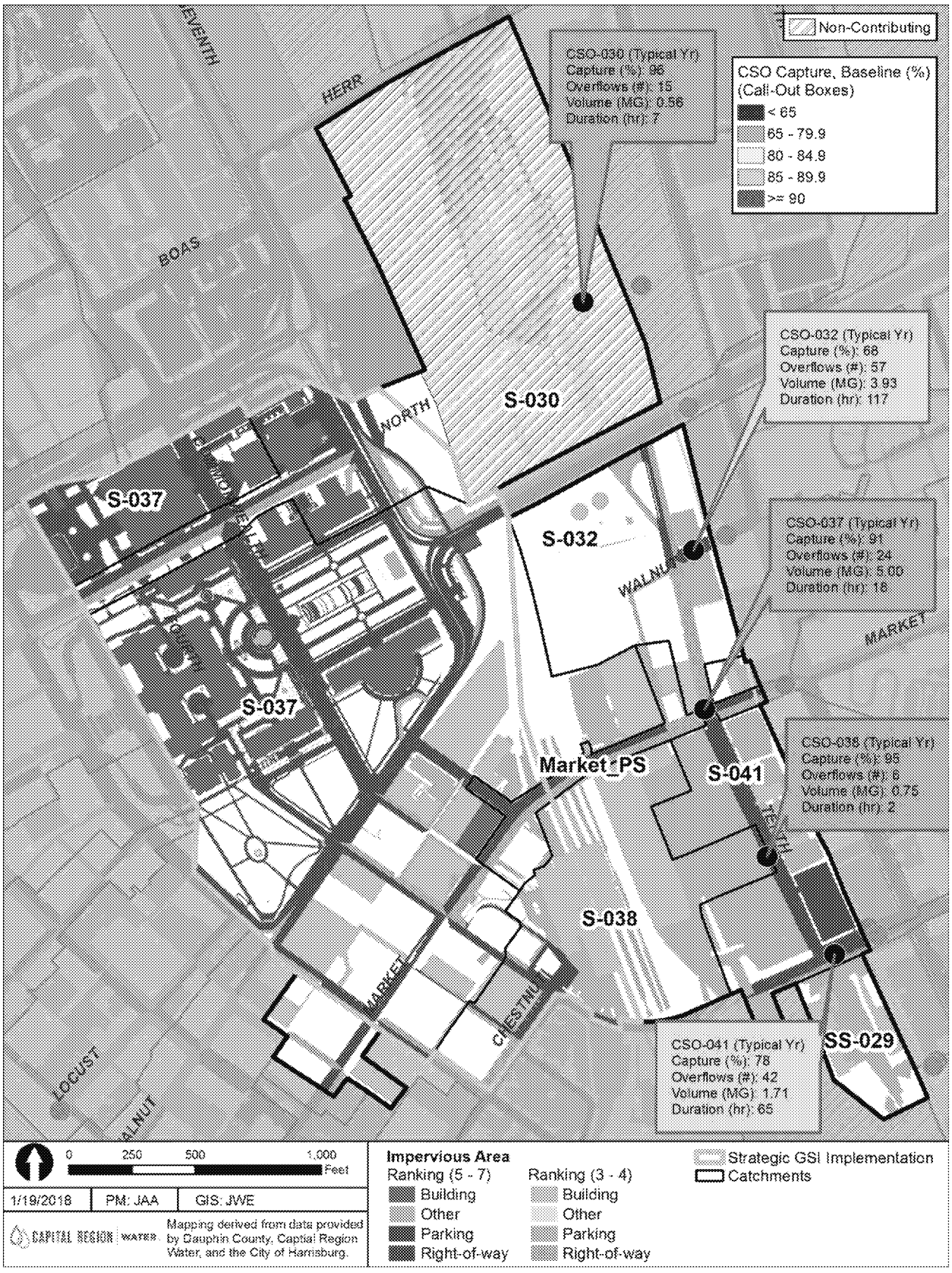

Figure 8.4.10-2: Middle Paxton Creek West - Decentralized Green and Grey Infrastructure Opportunities

- ***GSI implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.10.2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.10-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.10-3: Middle Paxton Creek East - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-029	3.69	1.87	5.56	1.33	0.00	1.33	6.89
S-031	0.48	0.04	0.51	2.38	0.49	2.87	3.39
S-033	20.7	11.3	32.0	4.46	8.54	13.0	45.0
S-034	1.07	0.22	1.29	6.11	6.81	12.9	14.2
S-040	2.59	0.68	3.28	6.83	0.79	7.62	10.9
Total	28.5	14.2	42.7	21.1	16.6	37.7	80.4
of Total Impervious	29%	15%	44%	22%	17%	39%	83%

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.10-1**.

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.10-2**, were identified based on these factors, in general, these areas indicate where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits. In the Middle Paxton Creek West Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- West of the railroad corridor throughout the catchments S-037 and S-038, with highest potential areas on and/or near the Pennsylvania State Capitol building complex.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.10-3 illustrates the major components of the Satellite Control Strategy within the Middle Paxton Creek West Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to Paxton Creek. This strategy focuses on CSO control and does not address unauthorized releases within the collection system. The satellite control strategy builds upon the technologies identified as part of the Baseline Level of Control and the following technologies described below.

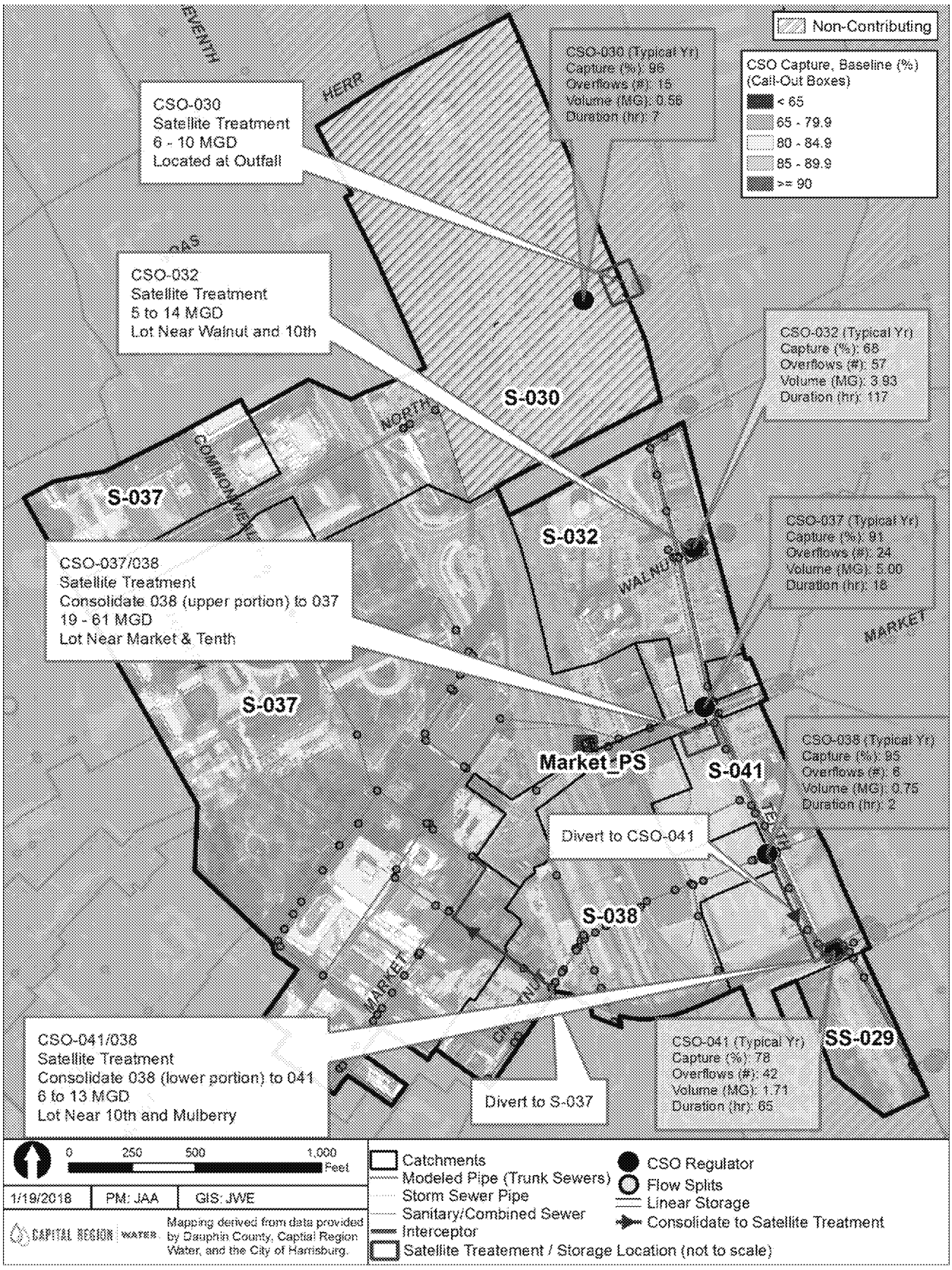

Figure 8.4.10-3: Middle Paxton Creek West - Satellite Treatment / Storage Opportunities

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.
- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.
- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

These facilities would be sited to take advantage of existing regulator structure geography and collection system capacity, subject to site constraints.

In addition to consolidation pipes and facilities, in this planning area the trunk sewer in S-038 is structurally compromised and requires addressing via either diversion of flow to S-037 or reconstruction of the trunk sewer that crosses below the railroad corridor. In this strategy, the repair is assumed to be a diversion to S-037.

The following satellite storage/treatment strategy has been developed for the Middle Paxton Creek West Planning Area:

Moderate Potential Satellite Control Sites: Satellite storage and/or treatment facilities sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control and located near:

- CSOs 037/038 (satellite high rate treatment): south of the intersection of Market and Tenth Streets in an existing parking lot with capacity range of 19 to 61 MGD.
- CSO 030 (satellite high rate treatment): at the outfall of this CSO with capacity range of 6 to 10 MGD.
- CSO 032 (satellite high rate treatment): at a parking lot near 10th and Walnut with capacity range of 10 to 14 MGD.
- CSO 041/038 (satellite high rate treatment): at a parking lot near 10th and Mulberry (north of elevated roadway) with capacity range of 6 to 13 MGD.

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green stormwater infrastructure to treat and attenuate runoff. In the Middle Paxton Creek West Planning Area and other areas with potential partial sewer separation opportunities near waterbodies this green stormwater infrastructure could be constructed by private entities as redevelopment occurs in these locations. This would be a complete separation of runoff in some areas near Paxton Creek, to be implemented as part of redevelopment. As properties are redeveloped over the coming years, they will be able to disconnect from the combined sewer system and connect to the new partially separated system.

Table 8.4.10-4 describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

Table 8.4.10-4: Middle Paxton Creek West – Levels of Control (Local Control Strategy 3)

Type of Separation Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	S-032, S-041	18.4	14	$8
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	S-038	8.6	2	$6.2
Full Separation	S-030, S-032, S-037, S-038, S-041	97.3	117	$69

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. If utility conflicts are minimal, cost-effective opportunities for total separation exist by consolidating into a single connection to the interceptor within catchment pairs S-032 and S-041 and represents 19% of the impervious area in the planning area.

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. Cost-effective opportunities for sanitary flow rerouting exist within 9% of the impervious area in the planning area: 8.6 acres of Catchment S-038.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. Additional cost-effective opportunities for stormwater disconnection exist within 9% of the impervious area in the planning area of combined sewer pipes: 8.6 acres of Catchment S-038.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. **Table 8.4.10-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment.

8.4.10.2 Cost Performance Evaluation

Figure 8.4.10-4 presents cost performance curves for each of the local control strategies developed for the Middle Paxton Creek West Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

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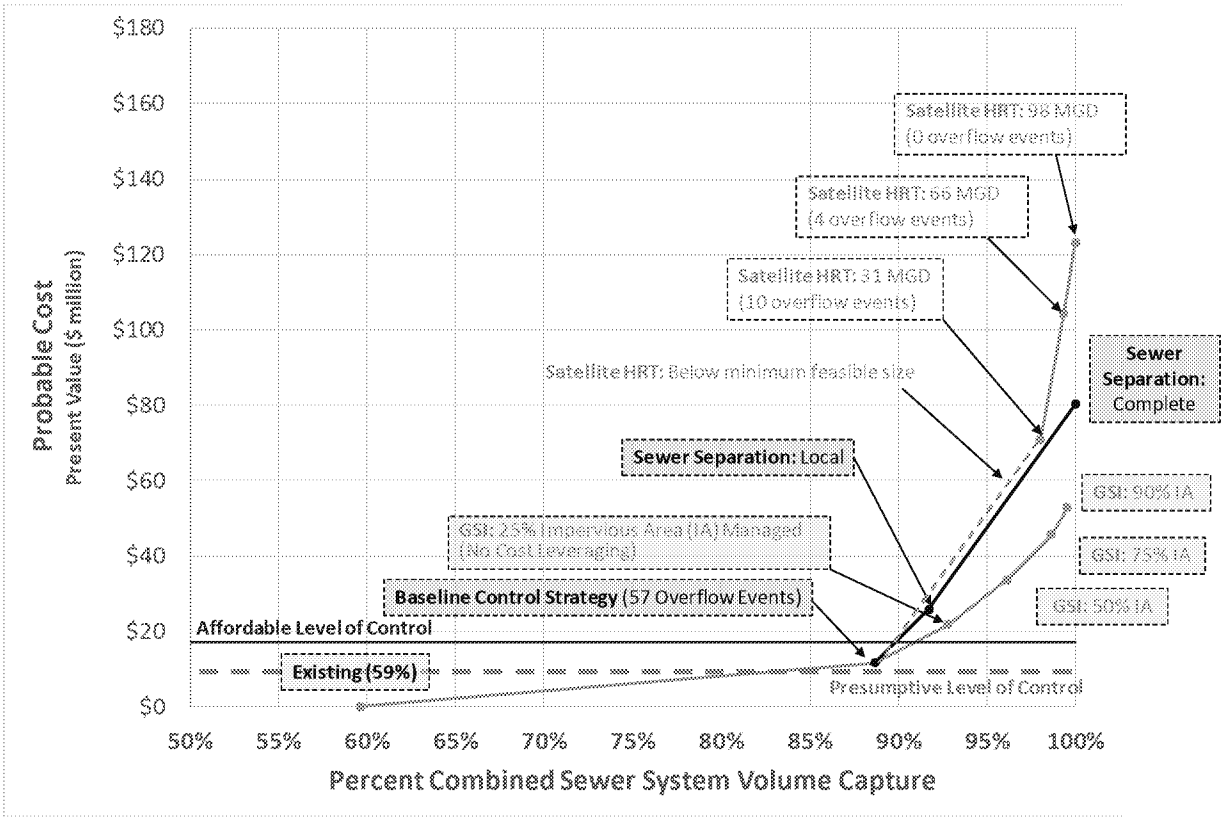

Figure 8.4.10-4: Middle Paxton Creek West - CSO Capture Performance and Opinion of Probable Cost Estimate

Figure 8.4.10-5 presents a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

- The ***baseline level of control*** captures 89 percent of the combined sewage volume generated within the Middle Paxton Creek West Planning Area during the typical year. Approximately $12 million of the cost of CRW's baseline level of control is apportioned to the Middle Paxton Creek West Planning Area, including $238,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved exceeds the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a low priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control***, defined as the level of control achieved through expenditures determined to be affordable to CRW's customers based on the Financial Capabilities Analysis presented in Section 7. The affordable level of control, as apportioned to the Middle Paxton Creek West Planning Area is $17 million, with $12 million already allocated to the baseline level of control. Investments within this range should focus on collection system rehabilitation

and/or control of unauthorized releases within this Planning Area during the 20-year planning horizon.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address these collection system rehabilitation and/or unauthorized releases. The cost-performance curve indicates that the decentralized control strategy is less costly than the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. The smallest satellite treatment/ storage facility feasible to implement within the Middle Paxton Creek West Planning Area – a 31 MGD satellite HRT – costs three to five times the affordable level of control range for this planning area. Since the Middle Paxton Creek West Planning Area has a low priority for additional CSO control, and this technology is ineffective at control of unauthorized releases, this control strategy is not recommended for this planning area.

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. The cost performance curves clearly show that complete sewer separation is both more costly than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

8.4.10.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving CSO control within the Middle Paxton Creek West Planning Area. An additional investment of $5 million is considered affordable for control of unauthorized releases and/or collection system rehabilitation within this planning area. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. While this planning area will not be prioritized for additional CSO controls, any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved. Additionally, priority structural issues within the collection system including a collapsed trunk sewer under the railroad corridor in S-038 may require diversion of the western portion of the catchment to S-037 ($1.5 million) and additional green stormwater infrastructure to reduce stormwater inflows and reduce unauthorized releases in this area. Further, sewer separation of catchments S-041, S-032, and the eastern portion of S-038 may be viable in this Planning Area over the long term with potential redevelopment of this area. This has the potential to reduce the size of diversion pipes and reduce the number of combined sewer overflows along Paxton Creek.

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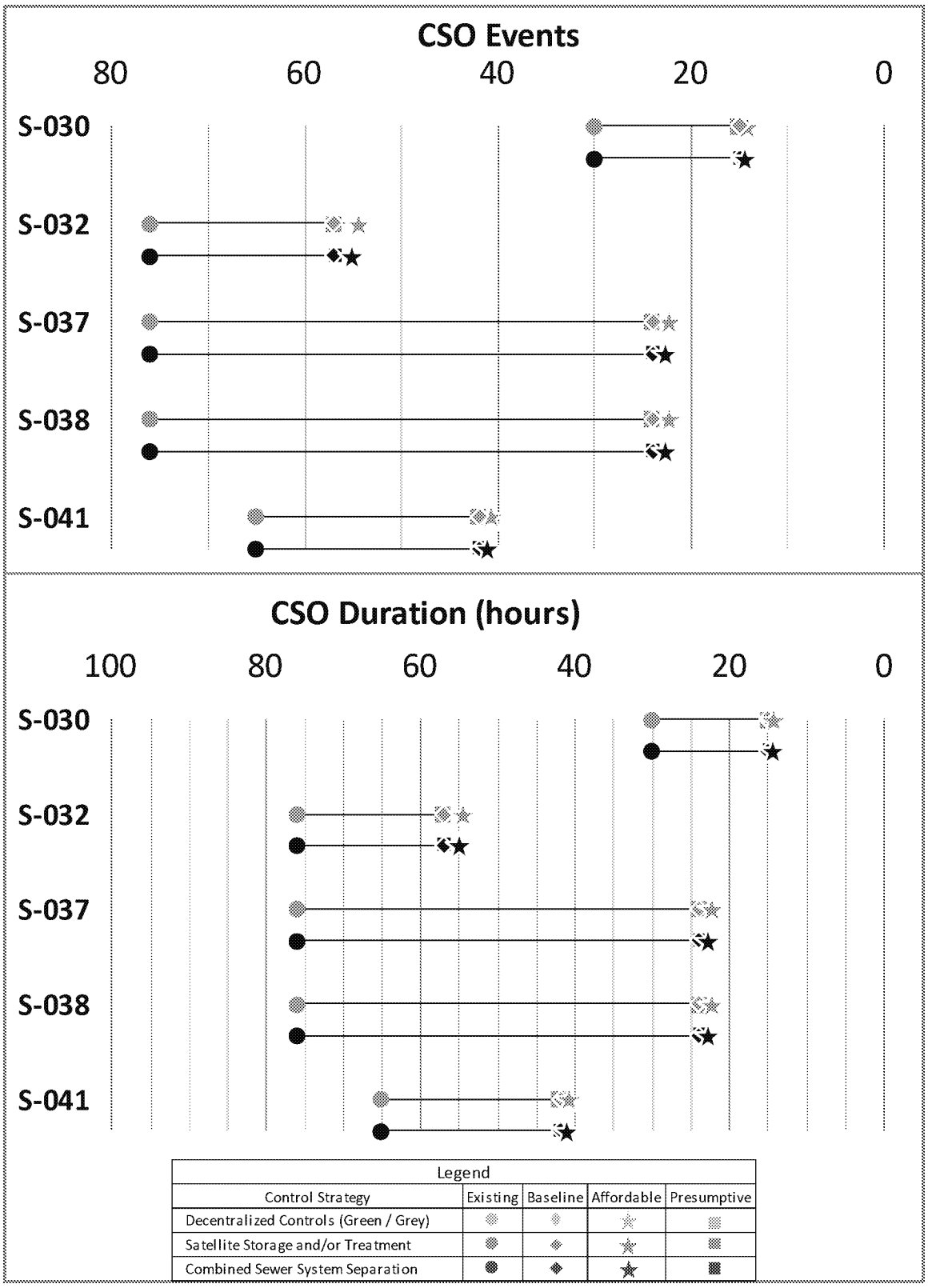

Figure 8.4.10-5: Middle Paxton Creek West - Annual CSO Event Frequency and Duration Performance by Control Strategy

8.4.11 Middle Paxton Creek East Planning Area

The Middle Paxton Creek East Planning Area encompasses a 335 acre area within the Paxton Creek Interceptor Sewershed. It is roughly bounded by Herr Street on the north, Twenty-Third Street on the east, Kittatinny Street on the south, and the Paxton Creek on the west. The Middle Paxton Creek East Planning Area largely consists of residential, commercial, and institutional properties on the south and west ends, with an overall impervious area of 203 acres. It encompasses combined sewer catchments S-029, S-031, S-033, S-034, S-039, and S-040, all of which discharge to the Paxton Creek interceptor and/or overflow to Paxton Creek. **Figure 8.4.11-1** is a map identifying the extent of this planning area and the existing issues, including capacity/flooding issues, river intrusion, relatively high CSO frequency and low capture, and identified structural issues.

8.4.11.1 Definition of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.11-1** for the Middle Paxton Creek East Planning area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: High priority gate repairs have been identified for CSOs 029, 033, 039, and 040 to prevent river intrusion at the 1-year flood stage. Medium priority gate repairs have been identified for CSO 034 to prevent river intrusion at the 2-year flood stage. Low priority gate repairs have been identified for CSO 031 to prevent river intrusion at the 5-year flood stage. High priority outfall pipe repairs have been identified for CSOs 029 and 034, while lower priority outfall pipe repairs have been identified for CSOs 033 and 039.

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at CSOs 029, 031, and 039. H&H modeling did not find additional weir adjustments to be effective.

- **Adjust Orifice Openings**: Brown and Brown (B&B) orifice control devices (see Figure 3-9) exist at each CSO regulator structure in the Middle Paxton Creek East Planning Area. During wet weather, according to H&H modeling, orifice restrictions at all Middle Paxton Creek East CSO regulators contribute to CSOs. High priority is given to removing these B&Bs and orifice restrictions, replacing them with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

- **Expand Connection Pipes:** H&H modeling revealed that CSO-031 is a location for affordable and cost-effective connection pipe expansion. The remaining existing connector pipes are of sufficient size.

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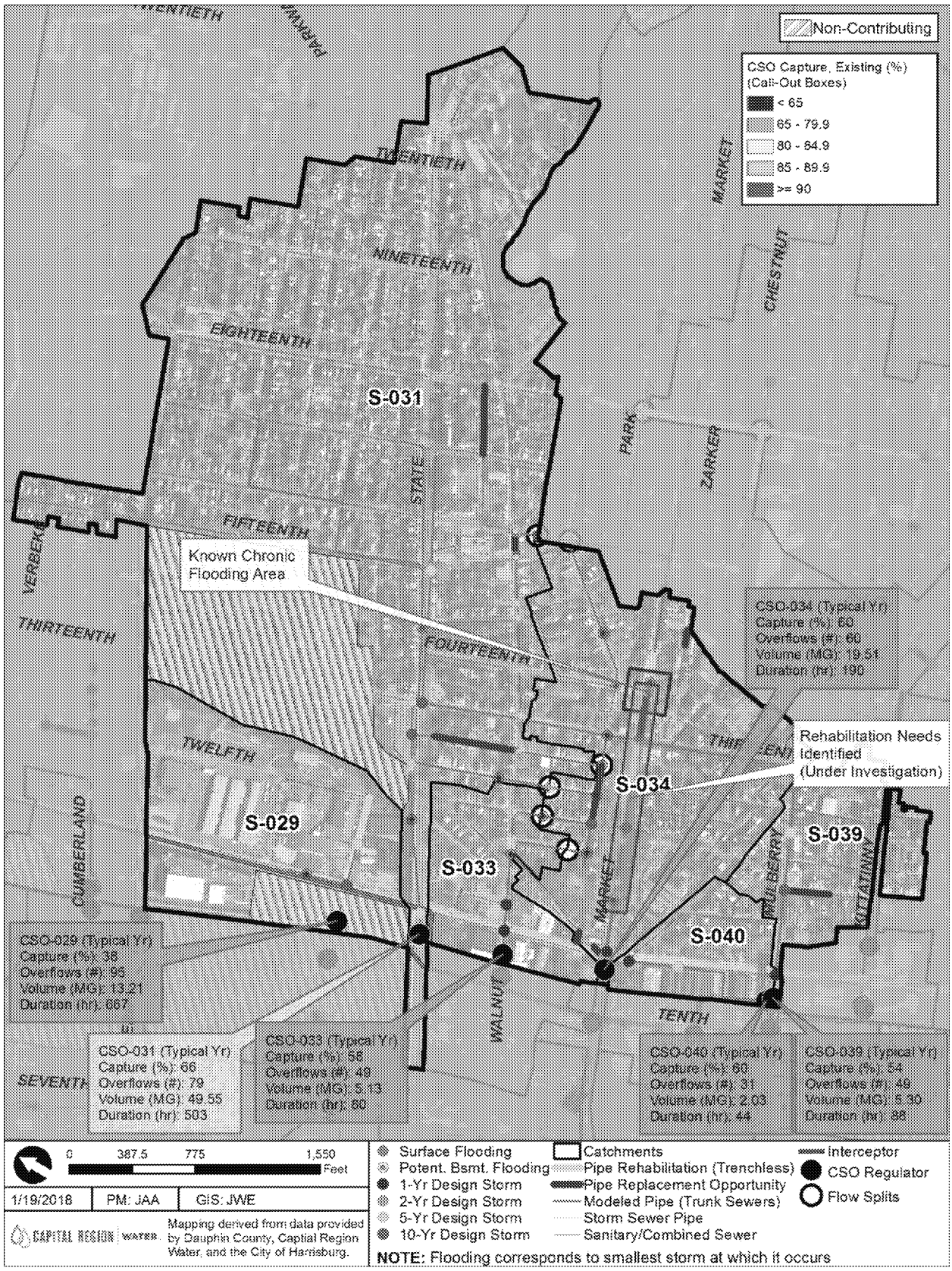

Figure 8.4.11-1: Middle Paxton Creek East - Existing Hydraulic and Structural Problems

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Middle Paxton Creek East Planning Area. Today, CRW's Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber and metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSO 031.

Table 8.4.11-1: Middle Paxton Creek East - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-029	✓	✓	✓		✓	$47,000		
S-031	✓	✓	✓	✓	✓	$145,000		$26,000
S-033	✓		✓		✓	$46,000		
S-034	✓		✓		✓	$46,000		
S-039	✓	✓	✓		✓	$47,000		
S-040	✓		✓		✓	$35,000		
					Total Cost:	**$366,000**		**$26,000**

Priority:	High	Medium	Low	None

In addition, the following additional baseline controls within the collection system have been identified:

- To alleviate flooding potential and reduce CSO discharges, divert the branch sewer in Bailey Street in CSO-034 to Linden Street and CSO-031.
- To alleviate flooding potential and reduce CSO discharges, divert the branch sewer in South 15th Street from CSO-034 to CSO-059.
- To eliminate a significant hydraulic bottleneck and alleviate flooding potential, replace trunk sewer in S-034 along Market Street from Cameron Street to the regulator. Also propose rebuilding regulator for CSO and flooding benefit.

Table 8.4.11-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Middle Paxton Creek East Planning Area:

- CSO performance is greatly increased in CSO-031 with weir and regulator connector pipe changes. Other catchments also improve performance.
- Planning area CSO capture increases from 61% to 85% with these modest changes.
- CSO frequency is reduced from 61 to 29, on average, during the typical year.

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Table 8.4.11-2: Middle Paxton Creek East – Existing/Baseline CSO Performance During Typical Year

	S-029	S-031	S-033	S-034	S-040	S-039	Total
Impervious Drainage Area	23.2	107.4	13.0	36.3	8.6	14.3	203
CSO Volume Captured (MG)							
▪ Existing Conditions	8.3	95.0	7.1	29.7	3.1	6.2	149
▪ Baseline Level of Control	18.1	134.0	9.8	36.1	3.4	5.7	207
CSO Volume (MG)							
▪ Existing Conditions	13.2	49.5	5.1	19.5	2.0	5.3	94.7
▪ Baseline Level of Control	3.4	10.6	2.5	13.1	1.7	5.8	36.9
▪ Volume Reduced	9.9	39.0	2.7	6.5	0.4	-0.5	57.8
CSO Capture (%)							
▪ Existing Conditions	38%	66%	58%	60%	60%	54%	61%
▪ Baseline Level of Control	84%	93%	80%	73%	67%	49%	85%
CSO Events							Max | Avg.
▪ Existing Conditions	95	79	49	60	31	49	95 61
▪ Baseline Level of Control	27	23	16	41	24	40	41 29
Estimated Implementation Cost							
▪ Per Vol Reduced ($/1000	$4.75	$4.38	$17.04	$7.08	$87.50	($94.00)	$6.78

Table 8.4.11-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Middle Paxton Creek East Planning Area exceed the presumptive (85% capture) level of control at CSOs 029 and 031. As such, the local control strategy should focus on CSOs 033, 034, 040, and 039, as well as locations throughout the planning area where H&H modeling indicates unauthorized releases occur more often than annually. The following local control strategies will be considered to achieve these objectives.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to Paxton Creek and the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Middle Paxton Creek East Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.11-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.11-2** define the level of control achieved under the Baseline Level of Control, indicating that a

presumptive level of control is achieved for CSOs 029 and 031. As such, additional CSO control should receive priority within CSOs 033, 034, 040, and 039.

- ***GSI implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.11-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.11-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.11-3: Middle Paxton Creek East - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-029	6.07	1.27	7.34	7.88	6.85	14.73	22.07
S-031	24.07	0.97	25.04	27.15	6.31	33.45	58.49
S-033	2.18	0.05	2.23	3.99	2.37	6.36	8.59
S-034	4.38	0.16	4.54	12.88	2.28	15.16	19.70
S-039	3.23	0.10	3.32	3.39	3.74	7.13	10.45
S-040	2.70	0.03	2.73	2.06	2.31	4.38	7.11
Total	**42.62**	**2.58**	**45.20**	**57.35**	**23.86**	**81.21**	**126.41**
of Total Impervious	**21%**	**1%**	**22%**	**28%**	**12%**	**40%**	**62%**

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.11-1.**

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.11-2**, were identified based on these factors. In general, these Areas indicate where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits. In the Middle Paxton Creek East Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- Along Market Street, and at several intersections along Walnut and Mulberry Streets.
- Along Regina Street, which may help alleviate chronic street flooding at Market and 14th Streets.
- Derry Street cul-de-sac (near Cameron Street).
- Intersection at Goodwill and Cameron Streets.
- Summit Terrace was identified as an Early Action Project in the Community Greening Plan.

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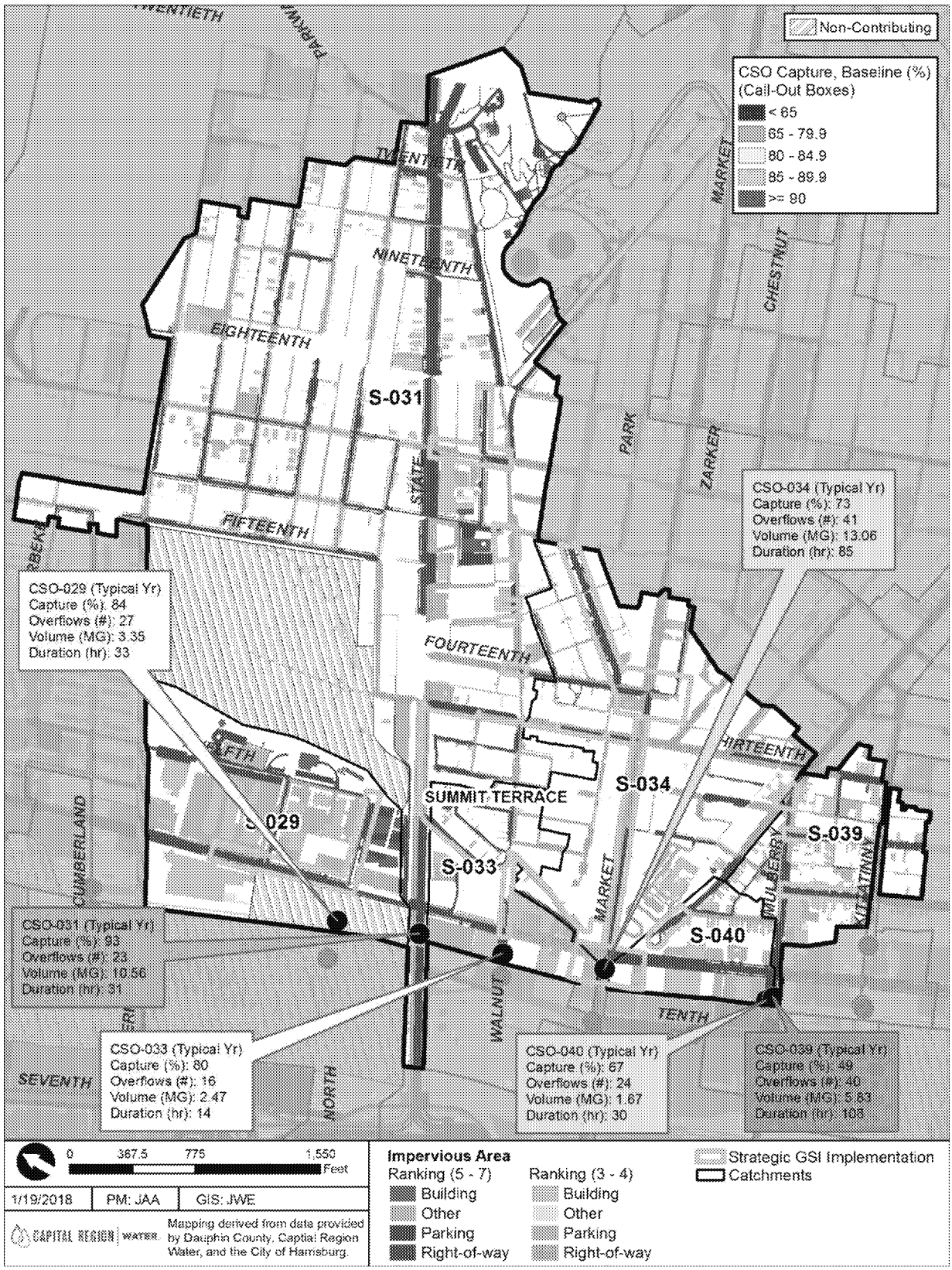

Figure 8.4.11-2: Middle Paxton Creek East - Decentralized Green and Grey Infrastructure Opportunities

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.11-3 illustrates the major components of the Satellite Control Strategy within the Middle Paxton Creek East Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a treatment facility using new consolidation sewers, treated, disinfected, and discharged to the creek. This strategy focuses on CSO control and generally does not address unauthorized releases within the collection system. The satellite control strategy builds upon the technologies identified as part of the Baseline Level of Control and the following technologies described below.

- Satellite treatment and/or storage facilities and associated infrastructure. These facilities would be sited to take advantage of existing regulator structure geography and collection system capacity, subject to site constraints.
- New conveyance conduits to transmit more flow to the treatment/storage facilities.

High potential satellite control sites are located in CSO catchments that do not satisfy an affordable level of control (approximately 80 percent capture) and take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Moderate potential satellite control sites are located in CSO catchments that do not satisfy a presumptive level of control (approximately 85 percent capture) and/or present moderate site constraints.

Moderate Potential Satellite Control Sites: Add consolidation sewers and satellite treatment facilities to achieve a presumptive level of control.

- 400 feet of consolidation sewer along Paxton Creek to collect overflows from CSOs 029 and 031 and convey them to a 22 to 81 MGD treatment facility at an open lot at Cameron Street and State Street.
- 1,000 feet of consolidation sewer along Cameron Street to collect overflows from CSOs 033 and 034 and convey them to a 5 to 60 MGD treatment facility at Walnut Street (between Cameron Street and Paxton Creek).
- A satellite treatment or storage facility (4 to 29 MGD treatment or 0.1 to 0.4 MG storage) at Mulberry Street (between Cameron Street and Paxton Creek) to consolidate flow from CSOs 039 and 040.

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.11-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

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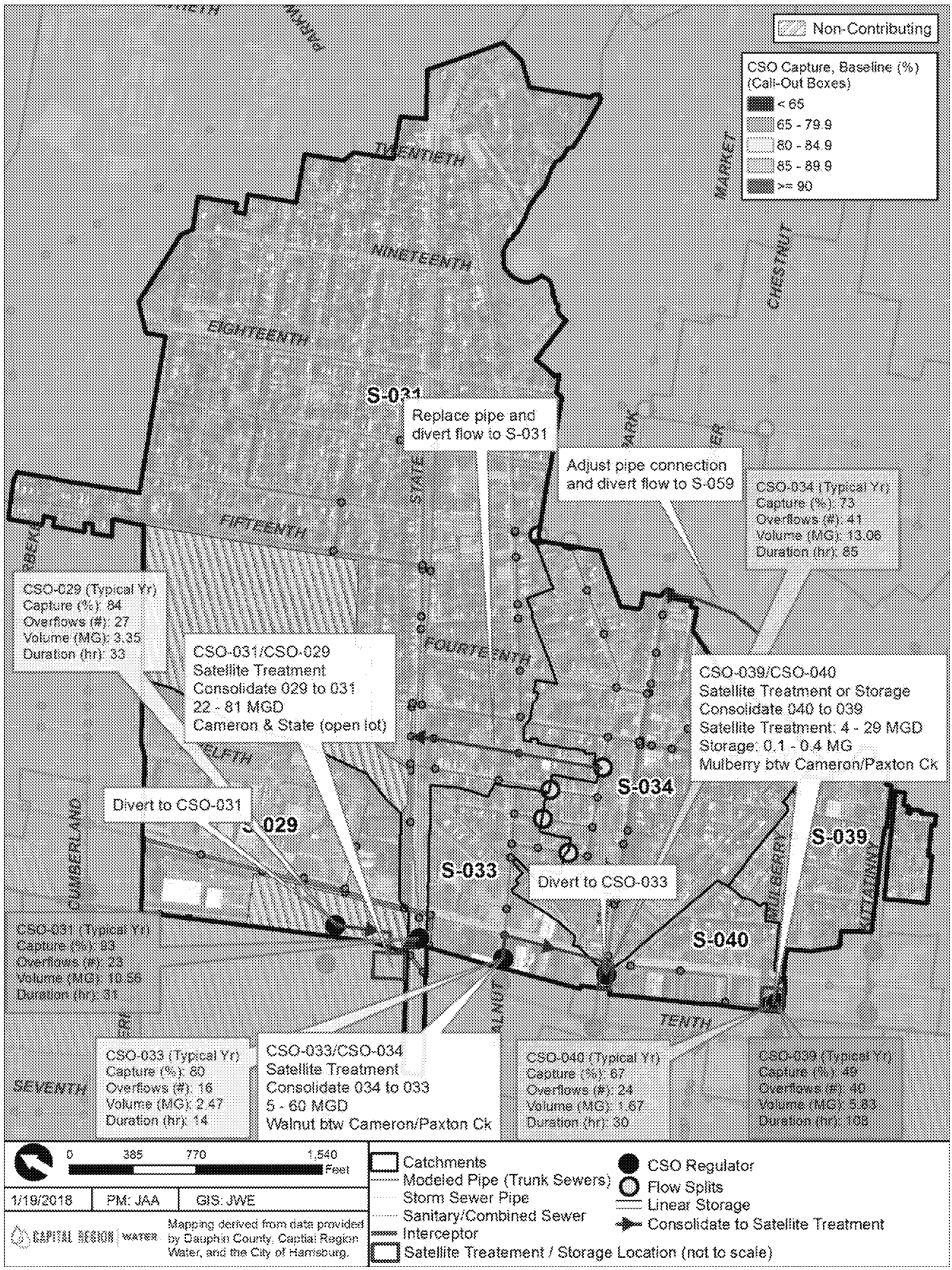

Figure 8.4.11-3: Middle Paxton Creek East - Satellite Treatment / Storage Opportunities

Table 8.4.11-4: Middle Paxton Creek East – Levels of Control (Local Control Strategy 3)

Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	S-029	24.6	16	$10.8
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	S-029, S-040	6.4	16	$3.9
Full Separation	S-029, S-031, S-033, S-034, S-040, S-039	68	169	$171

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number of sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. Cost-effective opportunities for total separation exist within catchment S-029.

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. Cost-effective opportunities for sanitary flow rerouting exist within 3.6% of the impervious area in the planning area: 3.9 acres of Catchment S-029 and 2.8 acres of Catchment S-040.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. Cost-effective opportunities for stormwater disconnection exist within 3.6% of the impervious area in the planning area: 3.9 acres of Catchment S-029 and 2.8 acres of Catchment S-040.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. In the Middle Paxton Creek East Planning Area, **Table 8-11.4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment.

8.4.11.2 Cost Performance Evaluation

Figure 8.4.11-4 presents cost performance curves for each of the local control strategies developed for the Middle Paxton Creek East Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

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Figure 8.4.11-5 presents a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

- The ***baseline level of control*** captures 85 percent of the combined sewage volume generated within the Middle Paxton Creek East Planning Area during the typical year. Approximately $22 million of the cost of CRW's baseline level of control is apportioned to the Middle Paxton Creek East Planning Area, including $392,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved exceeds the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a low priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control***, defined as the level of control achieved through expenditures determined to be affordable to CRW's customers based on the Financial Capabilities Analysis presented in Section 7. The affordable level of control, as apportioned to the Middle Paxton Creek East Planning Area is $35 million, with $22 million already allocated to the baseline level of control. Investments within this range should focus on collection system rehabilitation and/or control of unauthorized releases within this Planning Area during the 20-year planning horizon.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address these collection system rehabilitation and/or unauthorized releases. The cost-performance curve indicates that the decentralized control strategy is less costly than the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. The smallest satellite treatment/ storage facility feasible to implement within the Middle Paxton Creek East Planning Area – a 11 MGD satellite HRT – costs up to two times the affordable level of control range for this planning area. Since the Middle Paxton Creek East Planning Area has a low priority for additional CSO control, and this technology is ineffective at control of unauthorized releases, this control strategy is not recommended for this planning area.

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. The cost performance curves clearly show that complete sewer separation is both more costly than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

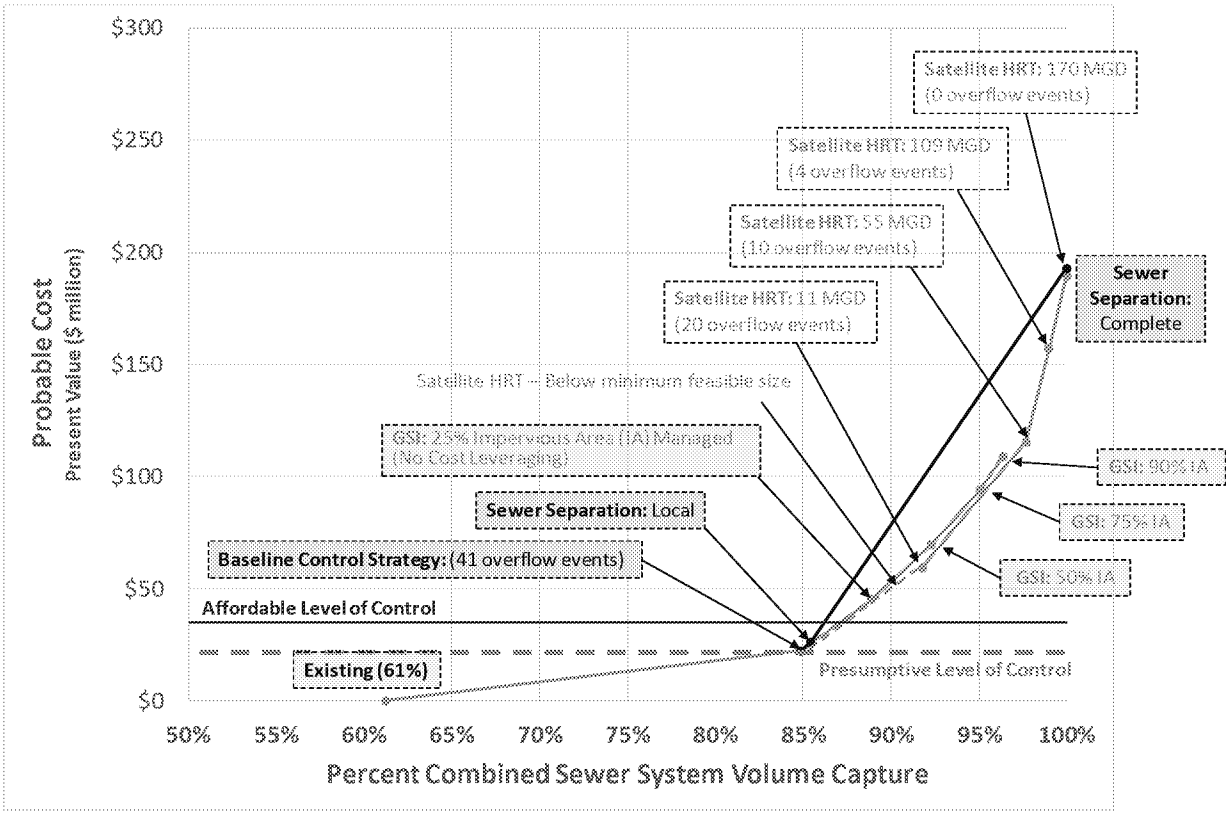

Figure 8.4.11-4: Middle Paxton Creek East - CSO Capture Performance and Opinion of Probable Cost Estimate

8.4.11.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving CSO control within the Middle Paxton Creek East Planning Area. An additional investment of $13 million is considered affordable for control of unauthorized releases and/or collection system rehabilitation within this planning area. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. While this planning area will not be prioritized for additional CSO controls, any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

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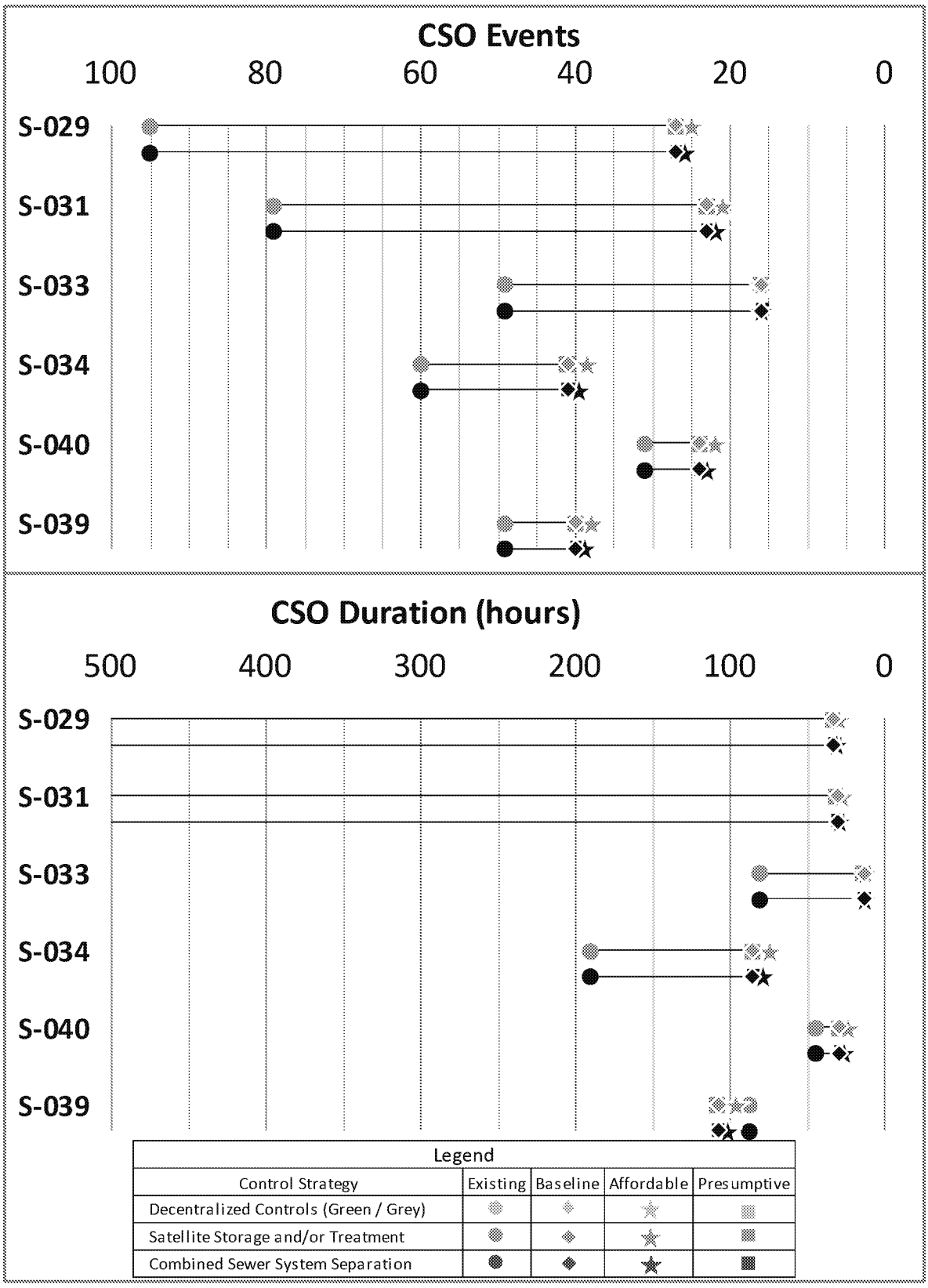

Figure 8.4.11-5: Middle Paxton Creek East - Annual CSO Event Frequency and Duration Performance by Control Strategy

8.4.12 Lower Paxton Creek Planning Area

The Lower Paxton Creek Planning Area encompasses a 948 acre area within the Paxton Creek Interceptor Sewershed. It is roughly bounded by the Paxton Creek on the west, Twenty-Fifth Street on the east, Interstate 83 on the south, and the City of Harrisburg boundary/Market Street on the north. The Lower Paxton Creek Planning Area largely consists of single-family residential development on the north and east ends, with commercial and institutional properties on the south and west ends and an overall impervious area of 464 acres. It encompasses seven combined sewer catchments and separate sanitary/stormwater catchments SS-011, SS-012, and SS-013, delineated on **Figure 8.4.12-1**. All of the catchment areas discharge to the Paxton Creek interceptor and/or overflow to Paxton Creek. Figure 8.4.12-1 is a map identifying the extent of this planning area and the existing issues, including capacity/flooding issues, river intrusion, relatively high CSO frequency and low capture, and some identified structural issues.

8.4.12.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.12-1** for the Lower Paxton Creek Planning Area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: High priority gate repairs have been identified for CSO 043 to prevent river intrusion at the 1-year flood stage. Medium priority gate repairs have been identified for CSOs 042, 044, 045, 046 and 048 to prevent river intrusion at the 2-year flood stage. Low priority outfall pipe repairs have been identified for CSO 043.

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at all CSOs within the Lower Paxton Creek Planning Area.

Table 8.4.12-1: Lower Paxton Creek - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-042	✓	✓	✓		✓	$21,000	$15,000	
S-043	✓	✓	✓		✓	$47,000		
S-044	✓	✓				$1,000	$15,000	
S-045	✓	✓			✓	$11,000	$15,000	
S-046	✓	✓			✓	$11,000	$15,000	
S-048	✓	✓	✓		✓	$21,000	$15,000	
S-059		✓	✓			$11,000		
					Total Cost:	**$123,000**	**$75,000**	

Priority:	High	Medium	Low	None

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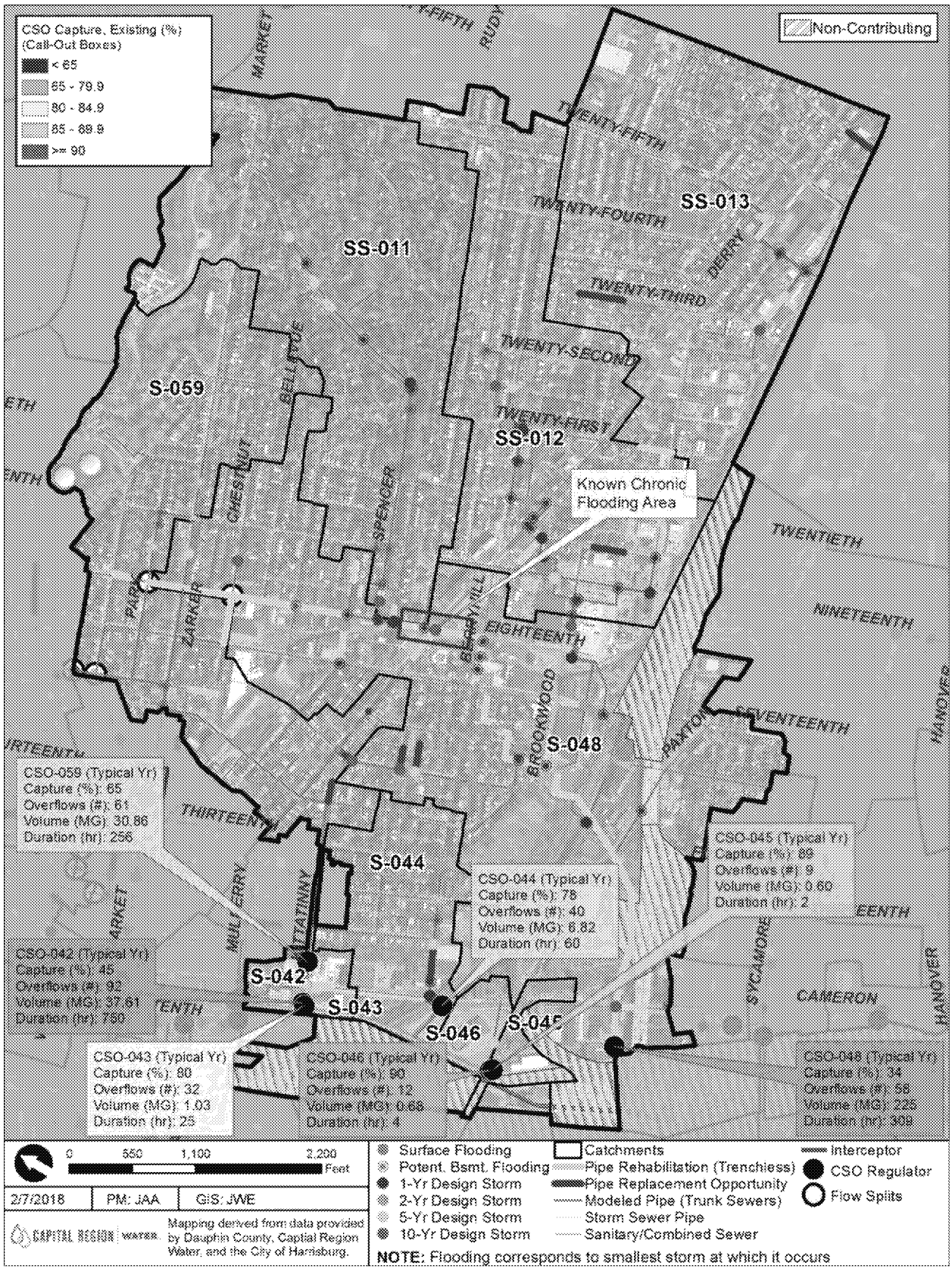

Figure 8.4.12-1: Lower Paxton Creek - Existing Hydraulic and Structural Problems

- **Adjust Orifice Openings**: Brown and Brown (B&B) orifice control devices (see Figure 3-9) exist at CSO regulator structures 042, 043, and 048; and a fixed orifice control (see Figure 3-10) exists at CSO regulator structures 044, 045, 046, and 059. During wet weather, according to H&H modeling, orifice restrictions at CSOs 042, 043, 048, and 059 contribute to CSOs. High priority is given to removing these B&Bs and orifice restrictions, replacing them with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

- **Expand Connection Pipes:** H&H modeling did not reveal any locations for affordable and cost-effective connection pipe expansion. The existing connector pipes are of sufficient size.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Lower Paxton Creek Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g. rubber and metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSOs 042/059, 044, and 048.

Table 8.4.12-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Lower Paxton Creek Planning Area:

- CSO performance is greatly increased in CSOs 042 (+30% capture and a reduction of 72 overflow events), 059 (see CSO-042), and 048 (+27% capture and a reduction of 3 overflow events) with weir and regulator connector pipe changes.

- Catchments S-043, S-044, and S-045 also improve performance more modestly.

- Catchment S-046 decreases performance slightly from existing conditions, due to changes in interceptor hydraulic grade lines.

- Planning area CSO capture increases from 38% to 66% with these modest changes.

- CSO frequency is reduced from 43 to 25, on average, during the typical year.

Table 8.4.12-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Lower Paxton Creek Planning Area exceed the presumptive level of control (85 percent capture) at CSOs 043, 044, 045 and 046. As such, the local control strategy should focus on the remaining CSOs 042/059 and 048, as well as locations throughout the planning area where H&H modeling indicates unauthorized releases occur more often than annually. The following local control strategies will be considered to achieve these objectives.

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Table 8.4.12-2: Lower Paxton Creek – Existing/Baseline CSO Performance During Typical Year

	S-042	S-043	S-044	S-045	S-046	S-048	S-059	Total
Impervious Drainage Area (acres)	4.5	4.2	30.5	8.2	7.3	170	82.8	308
CSO Volume Captured (MG)								
▪ Existing Conditions	31.3	4.0	23.5	4.5	5.9	117	See 042	186
▪ Baseline Level of Control	75.7	3.8	25.4	4.3	5.8	209	See 042	324
CSO Volume (MG)								
▪ Existing Conditions	37.6	1.0	6.8	0.6	0.7	225	30.9	302
▪ Baseline Level of Control	1.4	0.8	4.9	0.6	1.1	133	22.7	164
▪ Volume Reduced	36.2	0.2	2.0	0.0	-0.4	92.0	8.1	138
CSO Capture (%)								
▪ Existing Conditions	45%	80%	78%	88%	90%	34%	See 042	38%
▪ Baseline Level of Control	76%	84%	84%	89%	83%	61%	See 042	66%
CSO Events								Max | Avg.
▪ Existing Conditions	92	32	40	9	12	58	61	92 43
▪ Baseline Level of Control	20	19	34	8	22	55	20	55 25
Estimated Implementation								
▪ Per Vol Reduced ($/1000 MG)	$0.99	$235.00	$8.00	#DIV/0!	($65.00)	$0.39	$1.36	$1.43

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to Paxton Creek and the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Lower Paxton Creek Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.12-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

The call-out boxes on **Figure 8.4.12-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control is achieved within the Lower Paxton Creek Planning Area at all CSO catchments except S-042/S-059 and S-048, where additional CSO control should be considered a near- to mid-term priority for this Planning Area. The most-cost-effective opportunities to deploy GSI, and maximize other triple bottom line benefits, take into consideration the following factors.

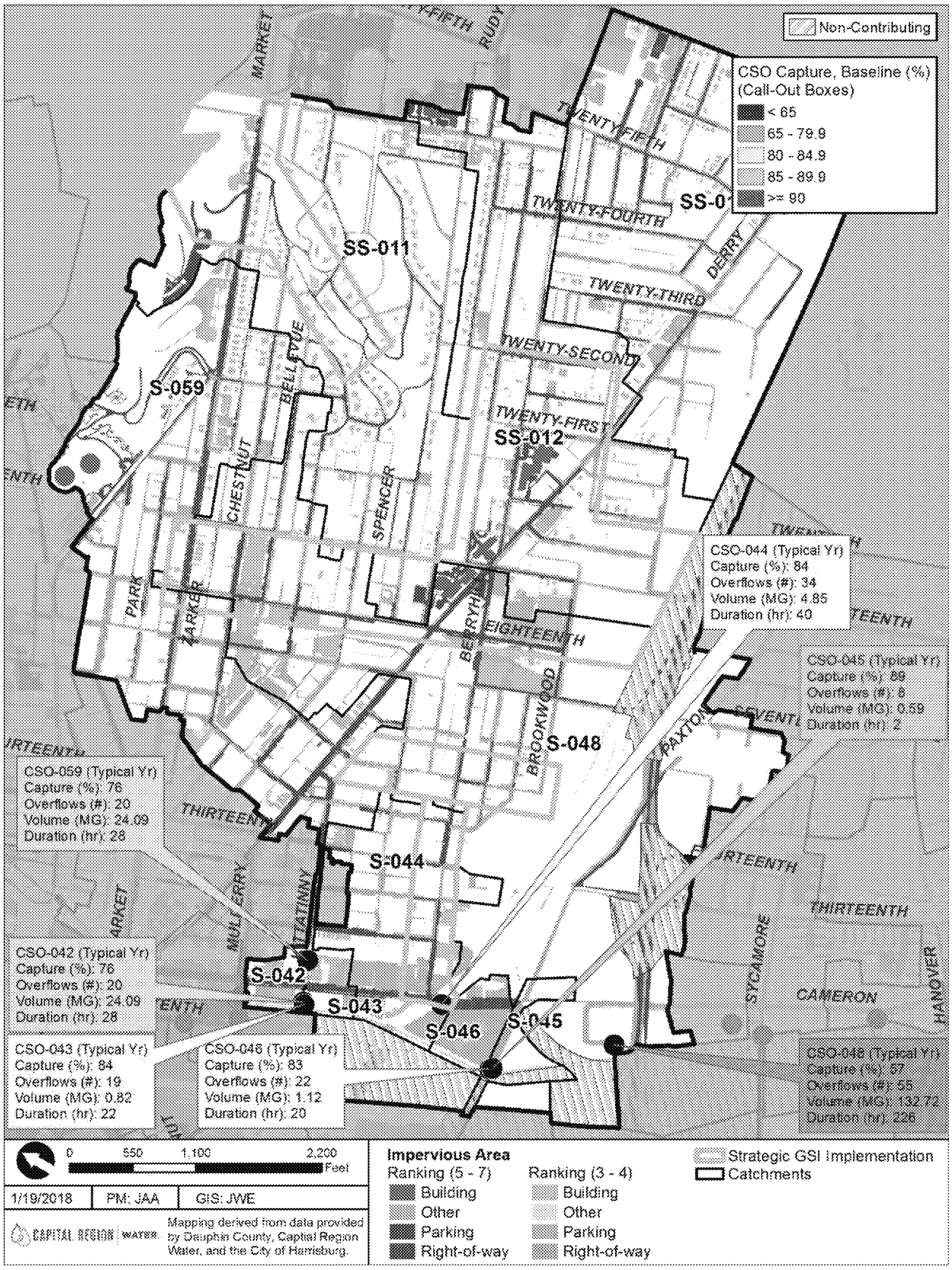

Figure 8.4.12-2: Lower Paxton Creek - Decentralized Green and Grey Infrastructure Opportunities

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- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.12-2** define the level of control achieved under the Baseline Level of Control, indicating that the baseline level of control is less than the presumptive level of control within CSOs 042/059 and 048, and that additional CSO control should receive priority within these three catchments.

- In the Lower Paxton Creek Planning Area, baseline controls fail to achieve all CSO control objectives at CSOs 042/059 and 048, achieve the affordable level of control at CSO-044, and nearly meet or exceed the presumptive level of control for the Susquehanna River at CSOs 043, 045, and 046. As such, near- and mid-term controls should focus on the CSOs 042/059 and 048, with long-term control priority assigned to the other CSOs.

- ***GSI implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.12-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.12-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.12-3: Lower Paxton Creek - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-042	0.84	0.01	0.86	0.71	1.53	2.25	3.10
S-043	0.75	0.02	0.77	0.93	1.18	2.11	2.88
S-044	4.23	0.24	4.47	10.6	3.27	13.9	18.4
S-045	0.05	0.00	0.05	1.95	0.13	2.08	2.12
S-046	1.15	0.01	1.16	4.57	1.45	6.02	7.18
S-048	57.3	6.25	63.5	95.7	38.1	134	197
S-059	7.39	0.18	7.56	11.4	3.26	14.6	22.2
Total	**71.7**	**6.72**	**78.4**	**126**	**48.9**	**175**	**253**
of Total Impervious	**14%**	**1%**	**15%**	**25%**	**10%**	**34%**	**50%**

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.12-1**.

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.12-2**, were identified based on these factors. In general, these Areas indicate where decentralized controls

can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits. In the Lower Paxton Creek Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- At or near the point where the separate storm sewers serving catchments SS-011, SS-012, and SS-013 discharge into the combined sewers serving catchment S-048, generally located along the Eighteenth Street Corridor and the area bounded by 18th Street, 22nd Street, Kensington Street, and Brookwood Street. This area includes the known chronic flooding area at 18th Street and Derry Street, a natural topographic depression. In this area, separate storm sewers could be connected to surface detention basins to provide peak flow control and/or pollutant removal, where topography is favorable.

- Along or adjacent to the ditch running along the Norfolk Southern Railroad, which currently receives discharges from CRW's separate storm sewers and conveys then to an inlet to the combined sewer system located near Paxton Street between the intersections with 13th Street and the I-83 overpass.

- Retrofit into the existing Bellevue Park ponds within SS-011.

- Along streets where H&H modeling indicates the potential for unauthorized releases on more than an average annual basis (e.g., 15th Street between Brookwood Street and Derry Street, Berryhill Street between Cameron Street and 15th Street).

- The Market Street corridor within catchment S-059, including uncontrolled separate stormwater drainage from Reservoir Park.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.12-3 illustrates the major components of the Satellite Control Strategy within the Lower Paxton Creek Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to Paxton Creek. This strategy focuses on CSO control and does not address unauthorized releases within the collection system. The satellite control strategy builds upon the technologies identified as part of the Baseline Level of Control and the following technologies described below.

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.

- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.

- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

These facilities would be sited to take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. The following satellite storage/treatment strategies have been developed for the Lower Paxton Creek Planning Area:

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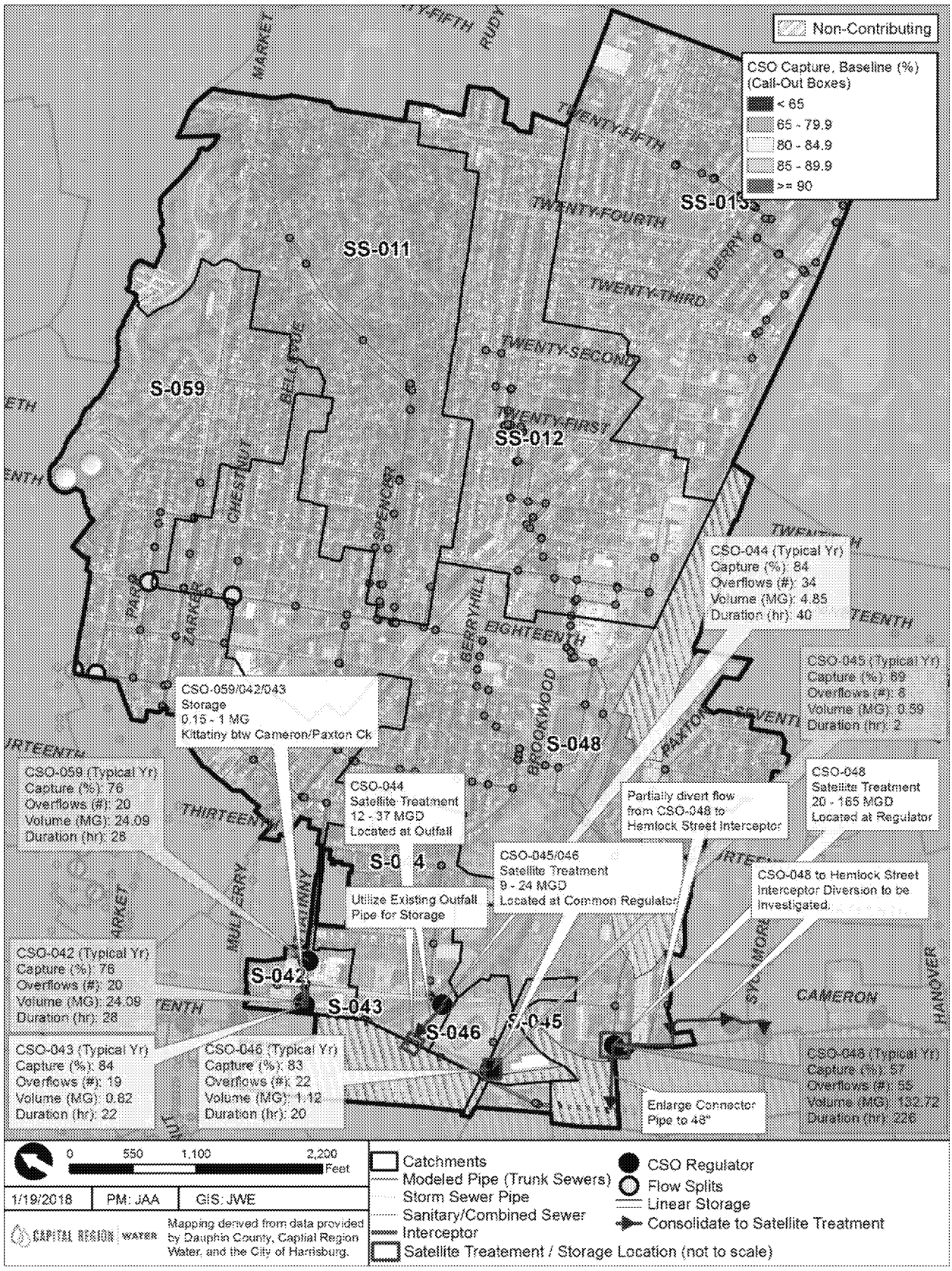

Figure 8.4.12-3: Lower Paxton Creek - Satellite Treatment / Storage Opportunities

High Potential Satellite Control Sites: Satellite storage and/or treatment facilities sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control and located near:

- CSOs 042, 043, 059 (storage and/or treatment facilities): west of the intersection of Kittatinny and Cameron Streets with a volume of 0.15 to 1 MG for storage and then a satellite treatment facility with a capacity range of 25 to 88 to achieve higher levels of CSO control.
- CSO 048 (satellite high rate treatment): southeast of the intersection 10th and Shannon Streets with a capacity range of 20 to 165 MGD.

Moderate Potential Satellite Control Sites: Satellite storage and/or treatment facilities sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control and located near:

- CSO 044 (satellite high rate treatment): southwest of the intersection Cameron and Berryhill Streets along outfall pipe with a capacity range of 12 to 37 MGD.
- CSOs 045, 046 (satellite high rate treatment): Paxton Street at Paxton Creek with a capacity range of 9 to 24 MGD.

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.12-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

Table 8.4.12-4: Lower Paxton Creek – Levels of Control (Local Control Strategy 3)

Type of separation Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	S-042/S-043, S-045/S-046	24.5	18	$11
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	S-044, S-048	9.8	34	$8
Cost-Effective Sanitary Rerouting and/or Stormwater Disconnection	S-044, S-048	250+	34+	$28* - $146**
Full Separation	S-042, S-043, S-044, S-045, S-046, S-048	30.5	2,320	$277

*New stormwater piping as represented in Figure 8.4.12-4 with Option 1 changes

** Includes new stormwater pipe and stormwater treatment for entire contributing area

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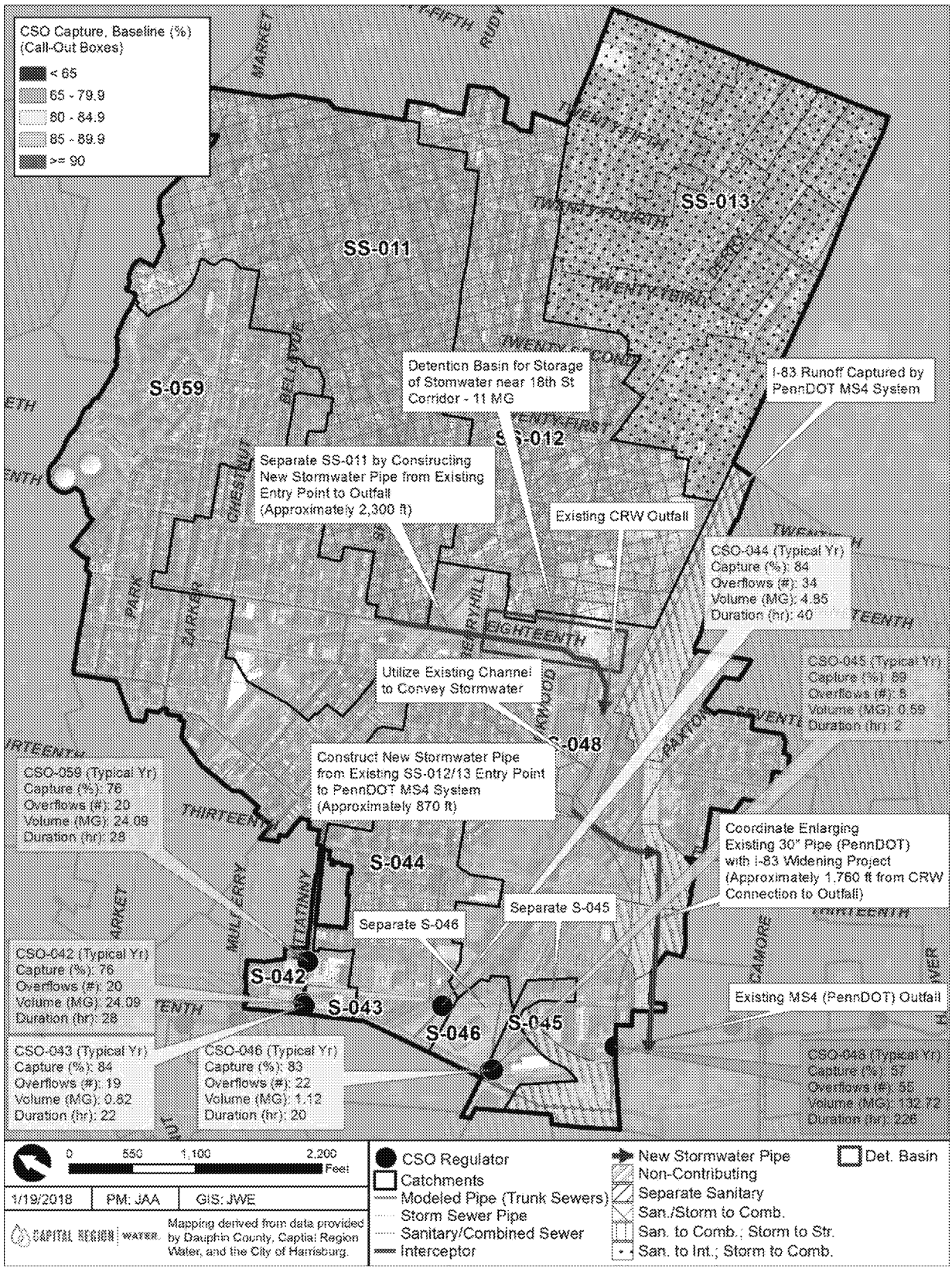

Figure 8.4.12-4: Lower Paxton Creek - Stormwater Disconnection and Full Catchment Separation

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. If utility conflicts are minimal, cost-effective opportunities for total separation exist by consolidating into a single connection to the interceptor within catchment pairs S-042/S-043 and S-045/S-046. These catchment pairs have trunk sewers located in the same street.

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. Cost-effective opportunities for sanitary flow rerouting exist within 2% of the impervious area in the planning area: 3.7 acres of Catchment S-044 and 6.1 acres of Catchment S-048.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. **Figure 8.4.12-4** illustrates an opportunity to re-route 59% of the impervious area, located in separate stormwater sewered areas to directly discharge to Paxton Creek and/or be diverted to a storage and detention facility located in acquired parcel(s) near 18th Street between Berryhill and Interstate 83. Additional cost-effective opportunities for stormwater disconnection exist within 2% of the impervious area in the planning area of combined sewer pipes: 3.7 acres of Catchment S-044 and 6.1 acres of Catchment S-048.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. **Table 8.4.12-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment.

8.4.12.2 Cost Performance Evaluation

Figure 8.4.12-5 presents cost performance curves for each of the local control strategies developed for the Lower Paxton Creek Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

Figures 8.4.12-6 and **8.4.12-7** present a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the decentralized green-gray control strategy reduces CSO event frequency and CSO duration at nearly all CSO locations in the Uptown Planning Area at an affordable level of control. Instances where CSO frequency or duration increases from the existing condition are likely caused by the increased utilization of the interceptor capacity, thereby reducing acceptance capacity from connector pipes sensitive to higher interceptor

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flow depths. The satellite storage/treatment control strategy reduces CSO event frequencies and durations more uniformly and at more locations due to the consolidation of overflow volumes into a few consolidated locations. The partial sewer separation control strategy shows similar performance to the decentralized green-gray control strategy at the presumptive level of control, but as indicated in **Figure 8.4.12-5** the cost is much greater for that performance.

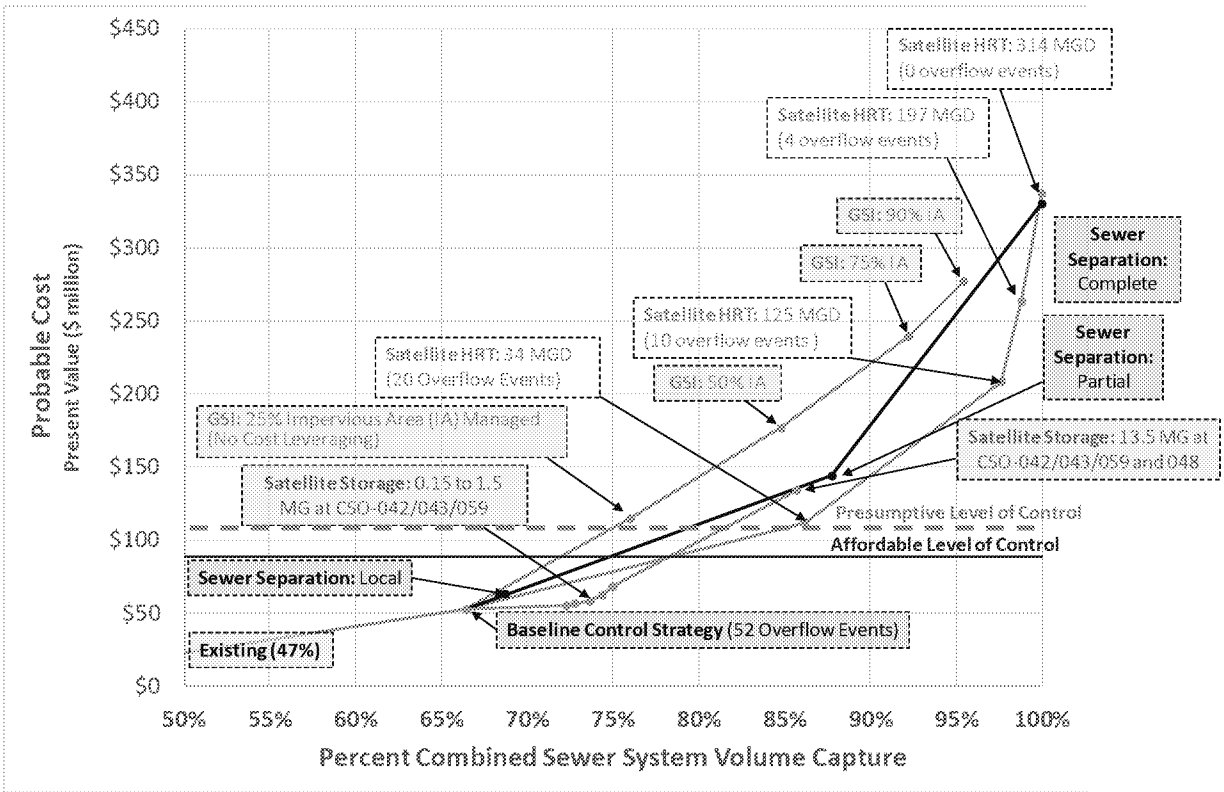

Figure 8.4.12-5: Lower Paxton Creek - CSO Capture Performance and Opinion of Probable Cost Estimate

- The ***baseline level of control*** captures 66 percent of the combined sewage volume generated within the Lower Paxton Creek Planning Area during the typical year. Approximately $52 million of the cost of CRW's baseline level of control is apportioned to the Lower Paxton Creek Planning Area, including $198,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved is less than the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a high priority during the 20-year planning horizon for this planning area.

- The ***affordable level of control***, defined as the level of control achieved through expenditures determined to be affordable to CRW's customers based on the Financial Capabilities Analysis presented in Section 7. The affordable level of control, as apportioned to the Lower Paxton Creek Planning Area is $89 million, with $52 million already allocated to the baseline level of control.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address both CSO control and unauthorized releases, and can be implemented independently or as part of a larger

project (e.g., collection system/utility rehabilitation, land redevelopment). **Figure 8.4.12-5** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Percent of Impervious Area Controlled with GSI		Cost
		CSO Control	Unauthorized Release Control	
Baseline	66%	None	None	$52M
Affordable (high)	72%	15%	Included	$89M
Presumptive	85%	50%	Included	$177M

The cost-performance curve indicates that the decentralized green-grey control strategy is cost-comparative with the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies. It is also best suited to achieve control of both CSOs and unauthorized releases.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. **Figure 8.4.12-5** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Storage/Treatment Capacity	Cost
Baseline	68%	None	$16.7M
Affordable (high)	78%	5 MG	$89M
Presumptive	85%	12.5 MG	$130M

An estimated 5 MG satellite storage facility within the Lower Paxton Creek Planning Area is projected to cost near the affordable level of control, with a 12.5 MG of satellite storage projected to approach the presumptive level of control. A satellite treatment/storage strategy is ineffective at control of unauthorized releases

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. **Figure 8.4.12-5** provides the cost and performance of this control strategy, summarized as follows:

Level of Control	CSO Capture Achieved	Percent Separation Required	Cost
Baseline	68%	None	$16.7M
Affordable (high)	81%	24%	$89M
Presumptive	85%	49%	$130M

The cost performance curves clearly show that complete sewer separation is cost-comparative with the other two control strategies within the affordable level of control range. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

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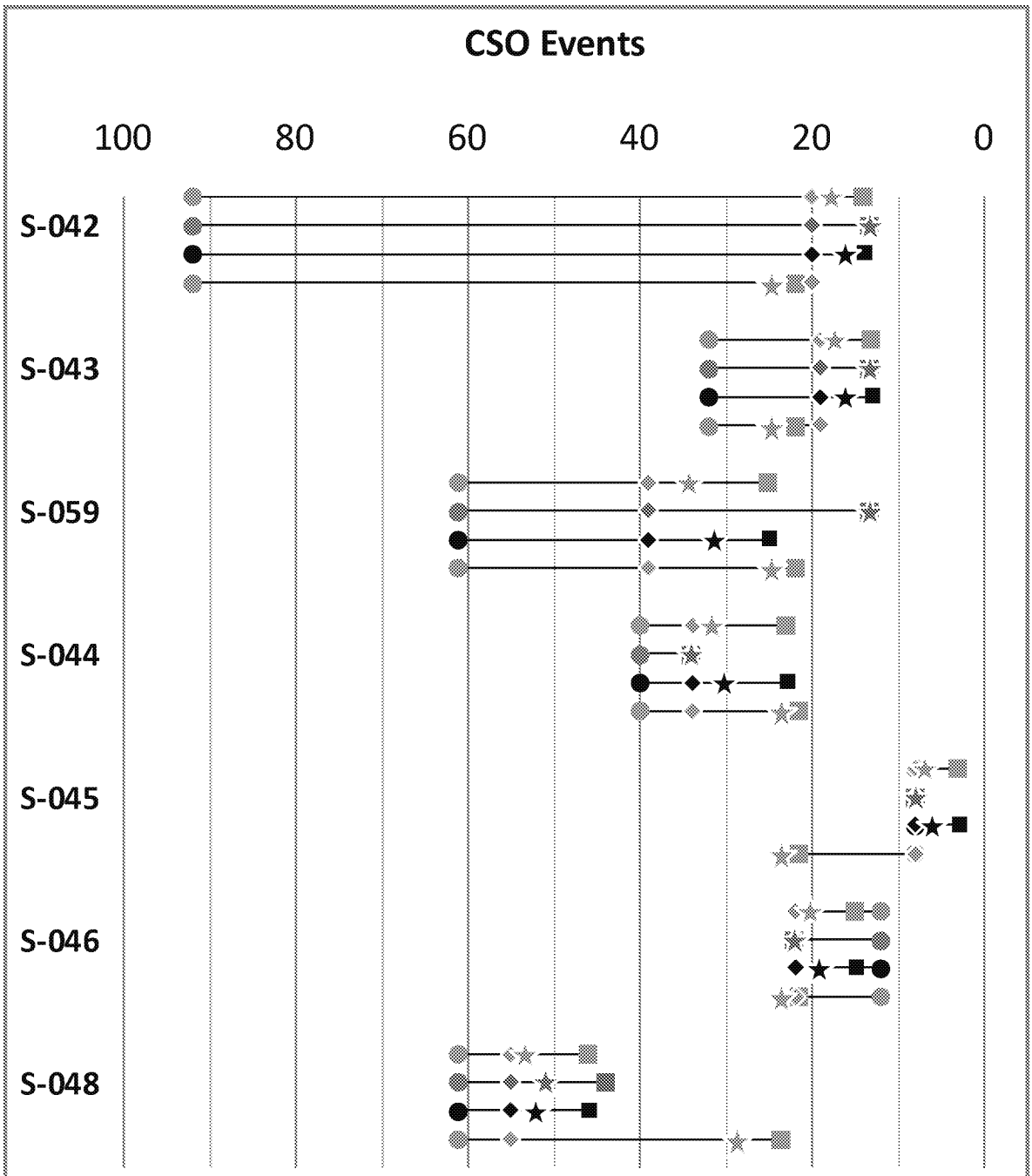
8.4.12.3 Local Control Strategy Findings

Based on this evaluation the Baseline Level of Control improves wet weather performance, increasing the volume of combined sewage captured during the typical year from 48 percent to 68 percent. The cost-performance evaluation presented in this section indicates that CRW has financial capacity to achieve additional wet weather control within this planning area. The cost-performance evaluation also indicates that all three strategies provide options for additional control for the cost within the affordable level of control range. Therefore, pursuing a Hybrid Control Strategy to supplement the Baseline Level of Control provides CRW with an affordable, flexible approach to increased CSO control within the Lower Paxton Creek Planning Area.

About $89 million of CRW's remaining financial capacity is apportioned to the Lower Paxton Creek Planning area for control of CSOs, unauthorized releases and/or collection system rehabilitation within this planning area. Additional controls may be affordable if the remaining financial capability apportioned to other, lower priority planning areas is re-apportioned to the Lower Paxton Creek Planning Area over the 20-year planning horizon. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. This planning area is prioritized for additional CSO controls, and any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

CRW will prioritize the Lower Paxton Creek Planning Area for additional controls beyond the Baseline Level of Control at a cost of up to $21 million (managing the runoff from a total of 9% of the impervious area), while integrating additional decentralized controls into private redevelopment and utility repair and replacement projects to control unauthorized releases within the planning area.



Legend				
Control Strategy	Existing	Baseline	Affordable	Presumptive
Decentralized Controls (Green / Grey)	●	◆	★	■
Satellite Storage	●	◆	★	■
Combined Sewer System Separation	●	◆	★	■
Satellite Treatment	●	◆	★	■

Figure 8.4.12-6: Lower Paxton Creek - Annual CSO Event Frequency Performance by Control Strategy

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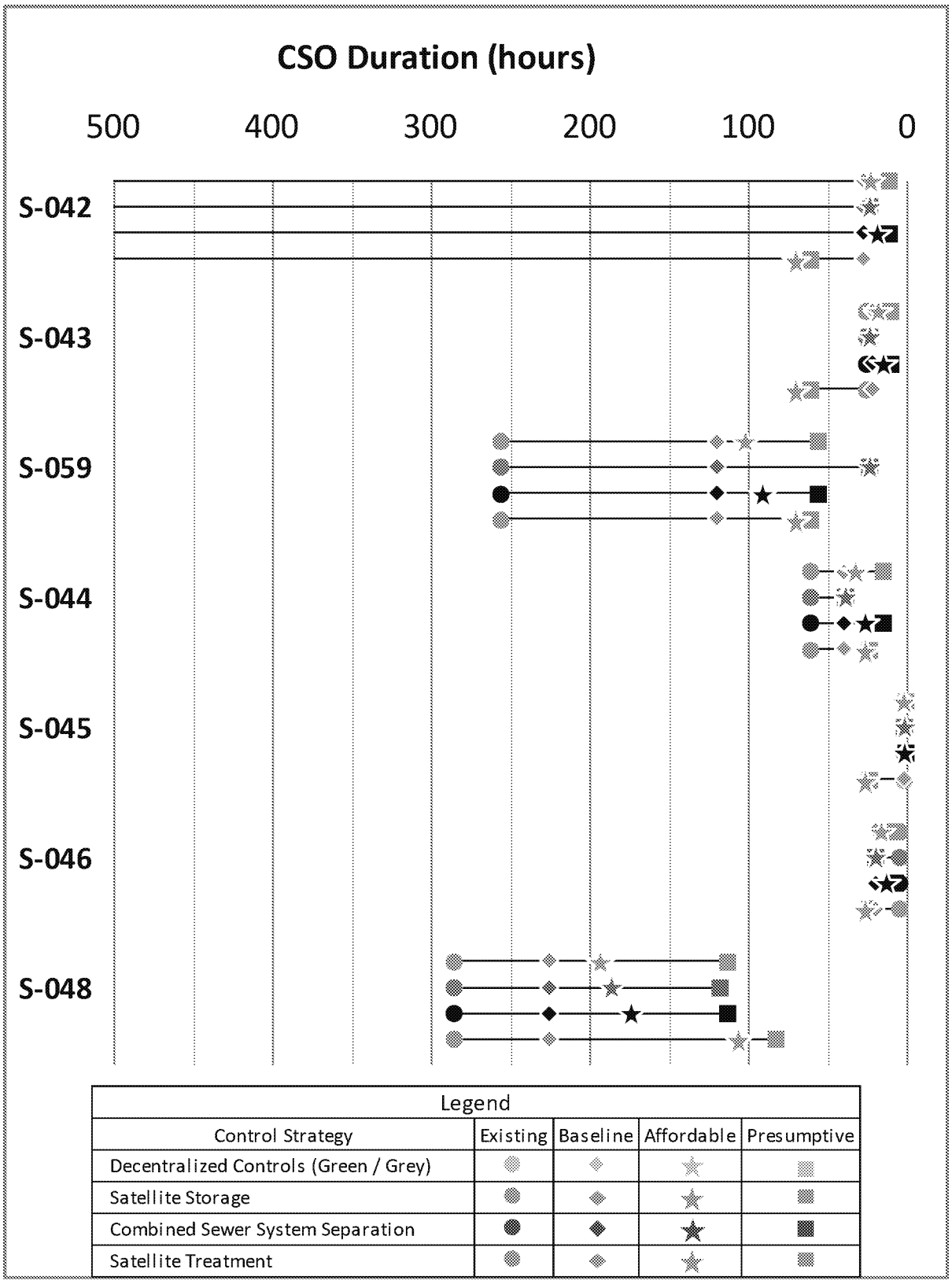

Figure 8.4.12-7: Lower Paxton Creek - Annual CSO Duration Performance by Control Strategy

8.4.13 Hemlock Street Planning Area

The Hemlock Street Planning Area encompasses a 129 acre area within the Paxton Creek Interceptor Sewershed. It is roughly bounded by Paxton Creek on the west, 15th Street on the east, Magnolia, Hanover, and 13th Streets on the south, and I-83 on the north. The Hemlock Street Planning Area largely consists of commercial/institutional properties along Cameron Street, with most of the residential properties located in the eastern two thirds of the area, and an overall impervious area of 97 acres. It encompasses combined sewer catchments S-060, S-061, S-062, S-063, and S-064, delineated on **Figure 8.4.13-1**. All of the catchment areas discharge to the Hemlock Street Interceptor and/or overflow to Paxton Creek. Figure 8.4.13-1 is a map identifying the extent of this planning area and the existing issues, including capacity/flooding issues, river intrusion, relatively high CSO frequency and low capture, and some identified structural issues.

8.4.13.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable and cost-effective measures to control CSOs, prevent river intrusion, and rehabilitate sewer assets through flap gate repairs, raising weirs, increasing the size of connector pipes, and optimizing flow splits. Baseline controls were presented in Section 8.2 and are summarized in **Table 8.4.13-1** for the Hemlock Street Planning Area, and are prioritized for implementation as follows:

- **Outfall/Gate Repairs**: Medium priority gate repairs have been identified for all CSO structures in the Hemlock Street Planning Area to prevent river intrusion at the 2-year flood stage. High priority outfall pipe repairs have been identified for CSO 062, while low priority outfall pipe repairs have been identified for CSO 060.

- **Raise Weir Elevations**: H&H modeling reveals that raising weirs up to 12 inches contributes to CSO reductions, with high priority assigned to raising weirs at all CSO structures.

- **Adjust Orifice Openings**: Fixed orifice control (see Figure 3-10) exist at all CSO regulator structures. During wet weather, according to H&H modeling, the orifice restrictions at CSO regulator structures 061, 062, 063, and 064 contribute to CSOs. High priority is given to removing these orifice restrictions, replacing them with vertical slotted openings that increase wet weather conveyance and provide the equivalent capacity of the existing connection pipes between the regulator and the interceptor.

Table 8.4.13-1: Hemlock Street - Baseline Level of Control Improvements

Catchment	Repair Outfall/ Gates	Raise Weir	Remove Orifice	Expand Connector Pipe	Interceptor Backflow Prevention	Estimated Repair Cost		
						High Priority	Medium Priority	Low Priority
S-060	✓	✓			✓	$11,000	$26,000	
S-061	✓	✓	✓		✓	$21,000	$15,000	
S-062	✓	✓	✓		✓	$47,000		
S-063	✓	✓	✓	✓	✓	$77,000	$15,000	
S-064	✓	✓	✓		✓	$21,000	$15,000	
					Total Cost:	**$177,000**	**$71,000**	

Priority:	High	Medium	Low	None

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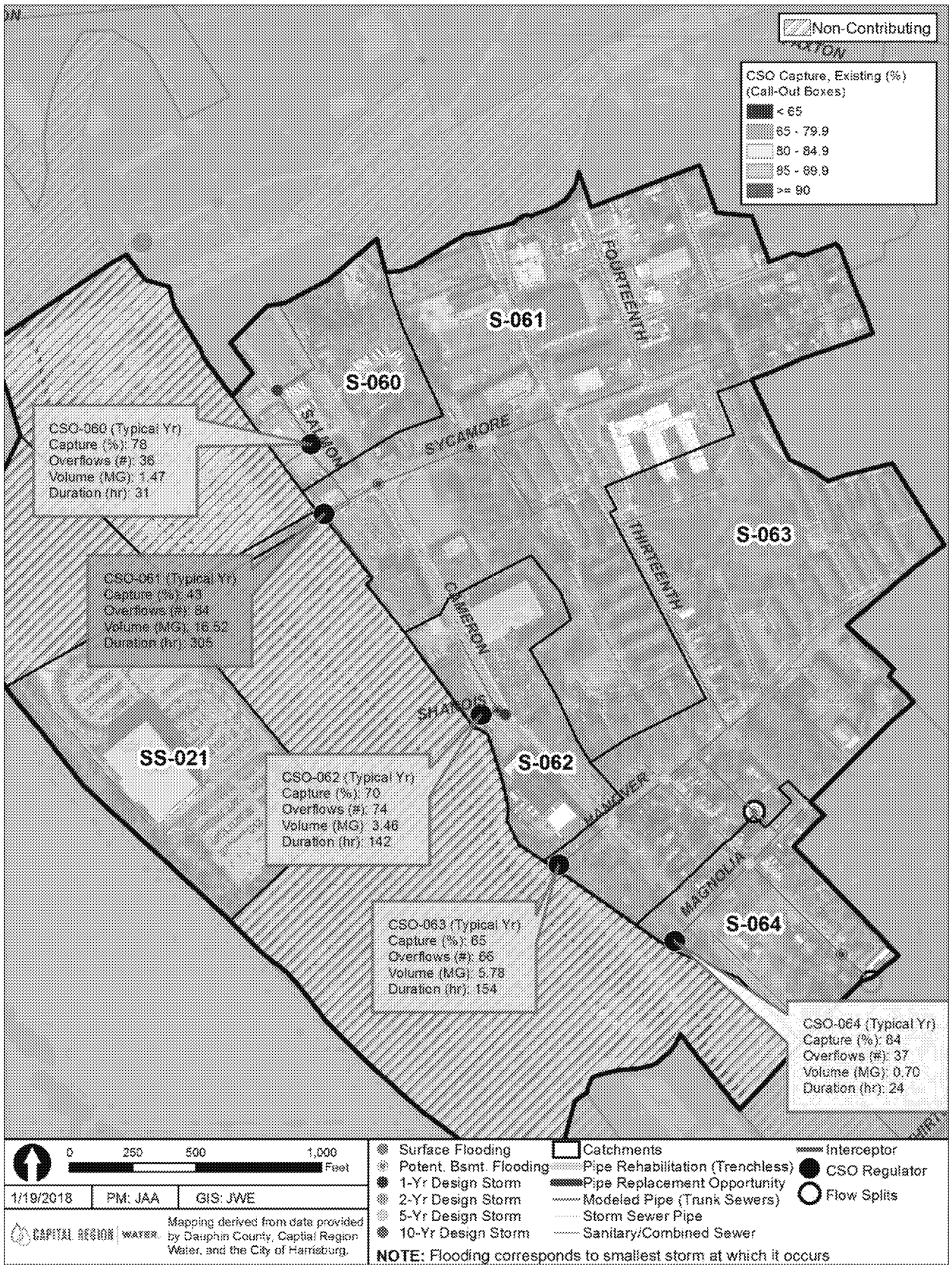

Figure 8.4.13-1: Hemlock Street - Existing Hydraulic and Structural Problems

- **Expand Connection Pipes:** H&H modeling revealed that CSO-063 is a location for affordable and cost-effective connection pipe expansion. The remaining existing connector pipes are of sufficient size.

- **Interceptor Backflow Prevention:** Interceptor surcharging has the potential to back up in most regulators within the Hemlock Street Planning Area. Today, CRW's aging Brown and Brown regulators largely prevent this surcharging from contributing to CSOs. In the future, it is recommended that the B&B regulators be replaced with new regulators. Simple backflow preventions devices (e.g., rubber or metal flap gates) are recommended for smaller catchments, while more advanced regulating gates and dams that may be integrated into real-time control strategies are recommended for larger catchments, such as CSO 061.

Table 8.4.13-2 summarizes the CSO capture performance of the Baseline Level of Control within each combined catchment that makes up the Hemlock Street Planning Area:

- CSO performance is greatly increased in CSO-061 (+44% capture and a reduction of 62 overflow events), CSO-062 (+16% capture and a reduction of 49 overflow events) and CSO-063 (+21% capture and a reduction of 41 overflow events).

- CSO performance improves more modestly at CSO-064 (+12% capture and a reduction of 25 overflow events).

- CSO capture decreases slightly at CSO-060, but the number of overflow events is reduced from 36 to 34 events.

- Planning area CSO capture increases from 59% to 86% with these modest changes.

- CSO frequency is reduced from of 59 to 24, on average, during typical year precipitation.

Table 8.4.13-2 also summarizes the CSO volume reduction performance and unitized capital cost estimates for the Baseline Level of Control. Determining CSO volume reduction weighted costs (represented in units of $ per 1000 gallons CSO reduced) allows comparison of the effectiveness of baseline improvements between catchments. In summary, baseline controls within the Hemlock Street Planning Area exceed the presumptive (85% capture) level of control at all CSOs except CSO-060. As such, the local control strategy should focus on CSO-060, as well as locations throughout the planning area where H&H modeling indicates unauthorized releases may occur more often than annually. The following local control strategies will be considered to achieve these objectives.

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Table 8.4.13-2: Hemlock Street – Existing/Baseline CSO Performance During Typical Year

	S-060	S-061	S-062	S-063	S-064	Total
Impervious Drainage Area (acres)	6.9	33.5	8.3	13.8	4.4	67
CSO Volume Captured (MG)						
▪ Existing Conditions	5.3	12.2	8.1	10.7	3.7	40
▪ Baseline Level of Control	5.0	25.0	9.9	14.2	4.2	58
CSO Volume (MG)						
▪ Existing Conditions	1.5	16.5	3.5	5.8	0.7	28
▪ Baseline Level of Control	1.7	3.8	1.7	2.3	0.2	10
▪ Volume Reduced	-0.3	12.8	1.8	3.5	0.5	18
CSO Capture (%)						
▪ Existing Conditions	78%	43%	70%	65%	84%	59%
▪ Baseline Level of Control	74%	87%	86%	86%	96%	85%
CSO Events						Max | Avg.
▪ Existing Conditions	36	84	74	66	37	84 59
▪ Baseline Level of Control	34	22	25	25	12	34 24
Estimated Implementation Cost						
▪ Per Vol Reduced ($/1000 MG)	($123.33)	$2.81	$26.11	$26.29	$72.00	$13.78

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

This alternative control strategy uses decentralized green and/or grey stormwater management controls to reduce CSOs to Paxton Creek and the Susquehanna River, and unauthorized releases within the collection system. This strategy builds upon the Baseline Level of Control, progressively increasing the amount of runoff from directly-connected impervious areas managed by small-scale, decentralized technologies implemented on both public and private land. Example technologies include street trees, sidewalk planters, rain gardens, surface/subsurface storage, and porous pavement. As described in Section 6, these techniques are designed to reduce effective impervious area and/or reduce runoff reaching the sewer system by restoring a more natural hydrologic cycle.

Decentralized green-grey infrastructure can be placed at many locations within the Hemlock Street Planning Area to achieve effective CSO control. Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.13-2**, were delineated based on the following four factors, indicating where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits:

- ***CSO Control Effectiveness of Baseline Level of Control.*** The call-out boxes on **Figure 8.4.13-2** define the level of control achieved under the Baseline Level of Control, indicating that a presumptive level of control is achieved for CSOs 061, 062, 063, and 064. As such, additional CSO control should receive priority within CSO-060.

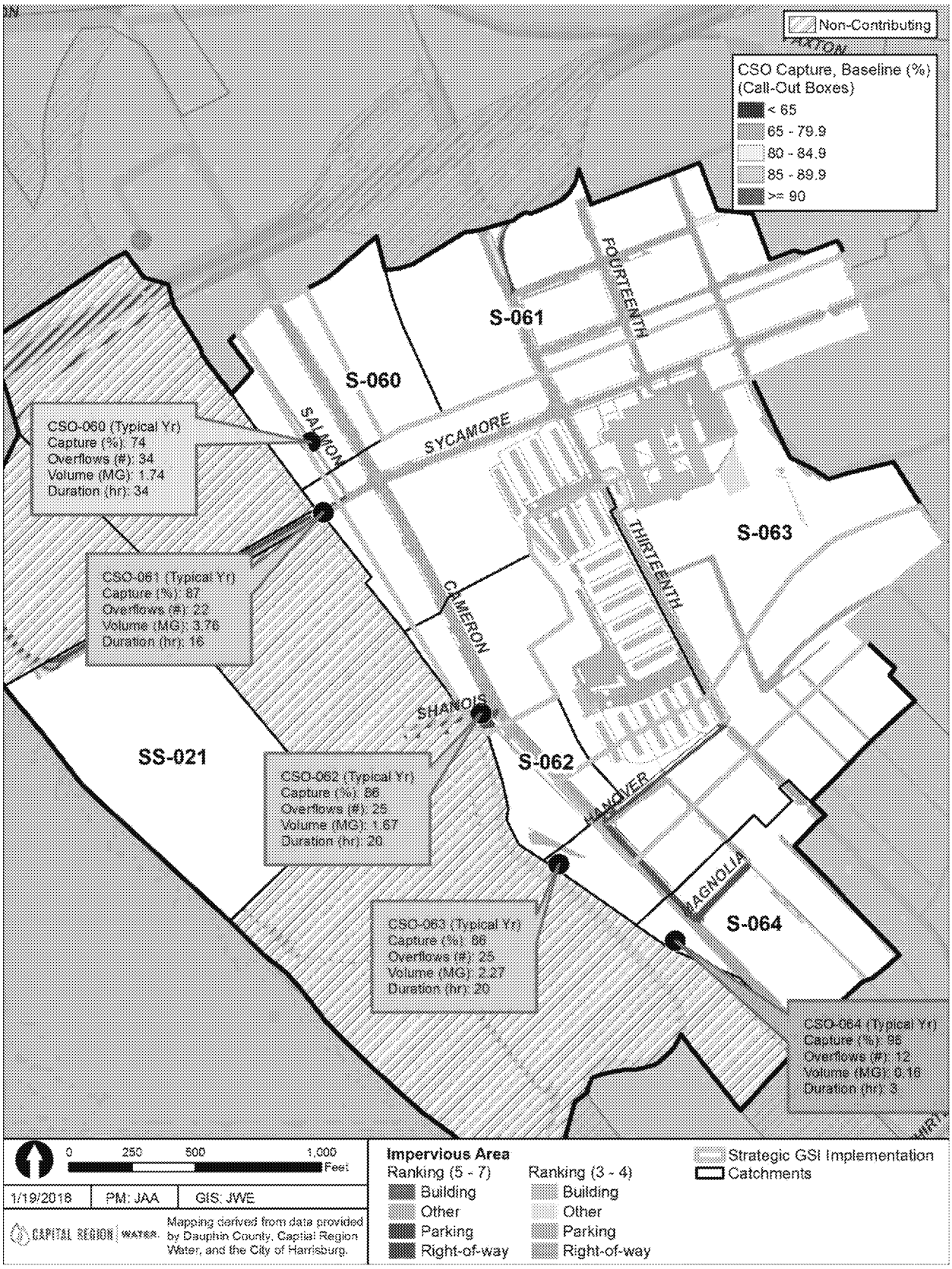

Figure 8.4.13-2: Hemlock Street - Decentralized Green and Grey Infrastructure Opportunities

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- ***GSI implementation Potential.*** CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.13-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.13-3** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Table 8.4.13-3: Hemlock Street - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
S-060	0.00	0.44	0.44	1.21	0.48	1.69	2.13
S-061	0.34	0.09	0.42	10.9	3.69	14.6	15.0
S-062	0.10	0.01	0.11	1.43	0.09	1.51	1.62
S-063	0.53	0.00	0.53	3.91	1.24	5.15	5.68
S-064	0.29	0.00	0.29	1.53	0.02	1.54	1.84
Total	**1.3**	**0.5**	**1.8**	**19.0**	**5.5**	**24.5**	**26.3**
Percent of Total	**1%**	**0%**	**1%**	**12%**	**3%**	**15%**	**16%**

- ***H&H Model Projections of Frequent Unauthorized Releases.*** Priority opportunities for GSI implementation exist where H&H modeling indicates unauthorized releases from the combined collection system to occur during the 1-year design storm, as depicted on **Figure 8.4.13-1.**

- ***Related Near-Term Projects.*** Locations of near-term projects conducive to early implementation of decentralized stormwater controls (e.g., roadway reconstruction projects, development projects, sewer rehabilitation projects, early-action GSI projects).

Strategic GSI Implementation Areas, delineated by the aqua-colored polygons on **Figure 8.4.13-2**, were identified based on these factors. In general, these Areas indicate where decentralized controls can be deployed to mutually achieve enhanced CSO control, control of frequent unauthorized releases, and other triple bottom line benefits. In the Hemlock Street Planning Area, the following locations are designated Strategic GSI Implementation Areas:

- Along Cameron, Hanover, and Sycamore Streets where H&H modeling indicates the potential for unauthorized releases on more than an average annual basis.

Local Control Strategy 2: Satellite Storage and/or Treatment

Figure 8.4.13-3 illustrates the major components of the Satellite Control Strategy within the Hemlock Street Planning Area. This Strategy seeks to reduce CSO volume, frequency, and duration using satellite storage and/or treatment facilities. Combined sewage is conveyed to a treatment facility using new consolidation sewers, where it is either stored for later release into the interceptor or treated, disinfected, and discharged to Paxton Creek. This strategy focuses on CSO control and does

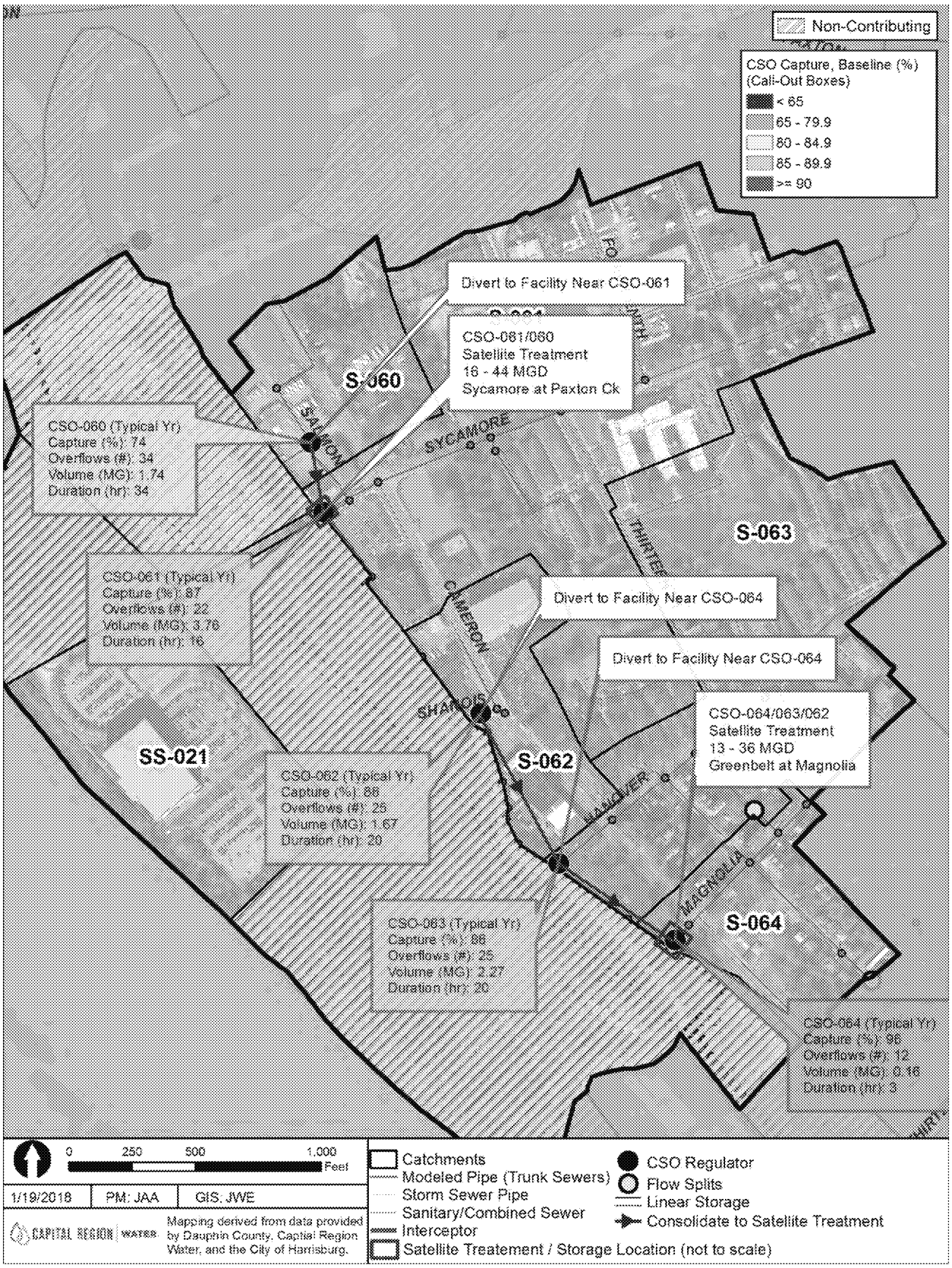

Figure 8.4.13-3: Hemlock Street - Satellite Treatment / Storage Opportunities

not address unauthorized releases within the collection system. The satellite control strategy builds upon the technologies identified as part of the Baseline Level of Control and the following technologies described below.

- Satellite treatment facilities that capture combined sewage and provide primary treatment (e.g., vortex separators, high-rate clarifiers, sedimentation tanks) and disinfection before receiving water discharge.
- Satellite storage facilities of various configurations (e.g., sub-surface tanks, linear storage-conveyance conduits) that capture and detain combined sewage, releasing it to the interceptor after wet weather flows subside.
- New conveyance conduits that capture combined sewage and transmit it to the treatment/storage facilities.

High potential satellite control sites are located in CSO catchments that do not satisfy an affordable level of control and take advantage of existing regulator structure geography and collection system capacity, subject to site constraints. Moderate potential satellite control sites are located in CSO catchments that do not satisfy a presumptive level of control (approximately 85 percent capture) and/or present moderate site constraints.

Moderate Potential Satellite Control Sites: Add consolidation sewers and satellite treatment facilities to achieve a presumptive level of control.

- A satellite storage and/or treatment facility located near Sycamore Street and Paxton Creek, with 500 feet of consolidation sewer along Salmon Street to collect overflows from CSOs 060 and 060, sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control ranging from 16 to 44 MGD.
- A satellite treatment facility located near Magnolia Street and Paxton Creek, with 1,000 feet of consolidation sewer along Paxton Creek to collect overflows from CSOs 062, 063, and 064, sized to treat runoff collected by the consolidation sewer as necessary to achieve various levels of control ranging from 13 to 36 MGD.

Local Control Strategy 3: Combined Sewer System Separation

Sewer separation includes new sanitary sewer infrastructure; conversion of existing combined sewers to a municipal separate storm sewer system (MS4) where possible; disconnection, separation of combined sanitary and storm laterals on private property, and reconnection to the new system; and restoration of streets and sidewalks to their existing condition. Additionally, it includes green infrastructure to treat and attenuate stormwater. **Table 8.4.13-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve the following levels of separation:

- ***Cost-effective Separation of an Entire Catchment.*** Opportunities to cost-effectively separate entire catchment areas exist where a limited number sanitary connections exist within an entire catchment that can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and the CSO regulator to be eliminated. No opportunities for cost-effective full catchment separation exist in the Hemlock Street Planning Area.

Table 8.4.13-4: Hemlock Street – Levels of Control (Local Control Strategy 3)

Level of Control	Catchment ID	Impervious Area to Re-route or Separate (acres)	Approximate Lateral Connections	Cost to Separate/Treat Stormwater ($ million)
Cost-Effective Full Separation	none	None	None	None
Cost-Effective Partial Sanitary Rerouting and/or Stormwater Disconnection	none	None	None	None
Full Separation	S-060, S-061, S-062, S-063, S-064	68	169	$54

- ***Cost-effective Sanitary Flow Rerouting of a Subcatchment.*** Opportunities to cost-effectively re-route sanitary flow from a portion of a catchment may also exist where a limited number of sanitary connections can be directed to a relatively short length of new separate sanitary sewer, allowing the existing combined sewer to be converted to a separate storm sewer and directed away from the CSO regulator. No opportunities for cost-effective partial separation exist in the Hemlock Street Planning Area.

- ***Cost-effective Stormwater Disconnection of a Subcatchment.*** Opportunities to cost-effectively re-route a portion of a catchment may also exist where stormwater inlets and connections can be directed to a relatively short length of new storm sewer, allowing the existing combined sewer to more effectively collect sanitary sewer volumes during wet weather. No opportunities for cost-effective partial separation exist in the Hemlock Street Planning Area.

- ***Full Separation of an Entire Catchment.*** The PCD requires CRW to examine full separation of its collection system. **Table 8.4.13-4** describes the area, length of new sanitary sewer and/or storm sewer, and approximate number of lateral connections needed to achieve complete separation within each catchment.

8.4.13.2 Cost Performance Evaluation

Figure 8.4.13-4 presents cost performance curves for each of the local control strategies developed for the Hemlock Street Planning Area. As required under CRW's partial Consent Decree, each curve defines the cost to achieve a range of CSO volume/frequency reductions. Each cost opinion is developed with a class and accuracy appropriate for long term planning use and as such, has an uncertainty of +50%/-30% with actual costs expected to fall within that range. The curves also indicate the approximate cost to achieve each alternative level of control objective evaluated by the Plan.

Figure 8.4.13-5 presents a summary of annual CSO event frequency and CSO duration performance for each local control strategy. The figure indicates that the affordable level of control for the decentralized green-gray control and the partial sewer separation control strategies exceed the presumptive level of control. The satellite storage/treatment control strategy is not feasible at the affordable and presumptive levels of control due to siting and technology feasibility.

- The ***baseline level of control*** captures 86 percent of the combined sewage volume generated within the Hemlock Street Planning Area during the typical year. Approximately $2.5 million of the cost of CRW's baseline level of control is apportioned to the Hemlock Street Planning Area,

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including $248,000 of improvements to the regulators and outfalls within the planning area. Since the projected CSO volume control achieved exceeds the ***presumptive level of control (85 percent combined sewage volume capture)*** for this planning area, further CSO control is considered a low priority during the 20-year planning horizon for this planning area.

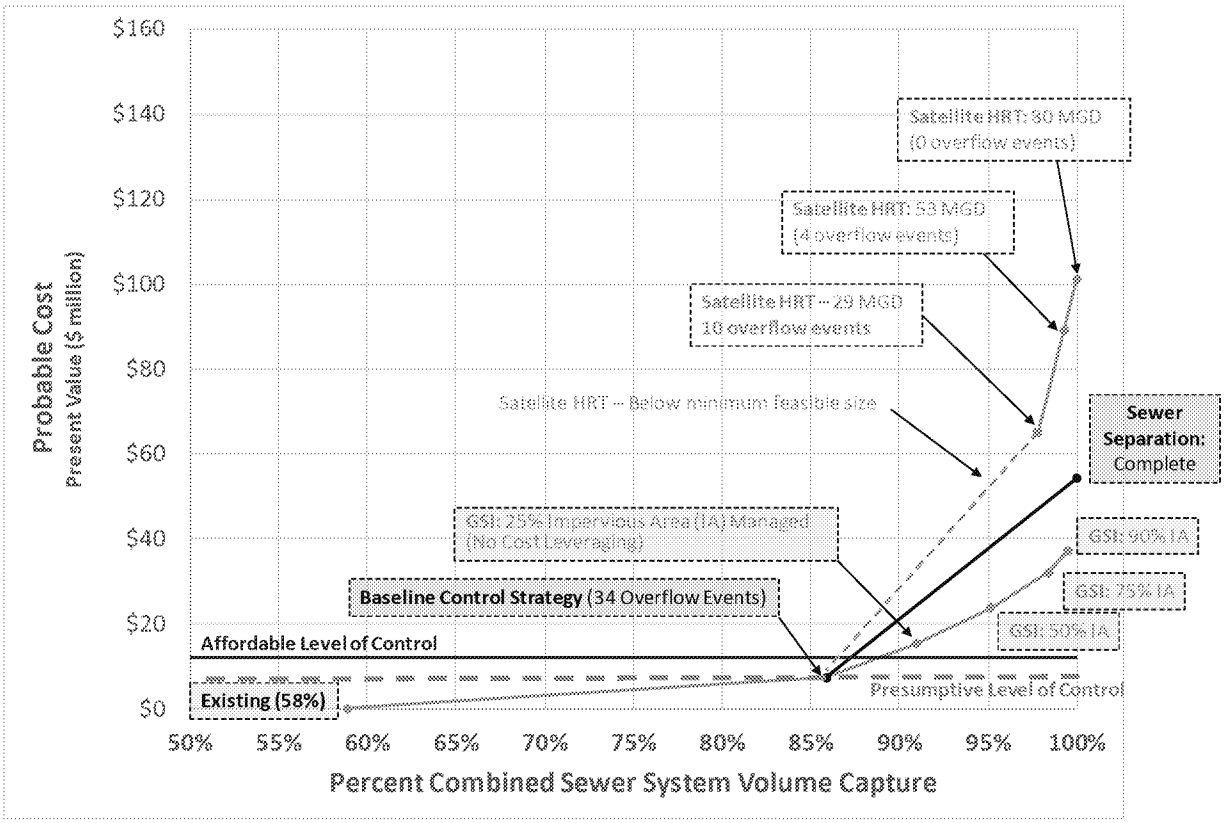

Figure 8.4.13-4: Hemlock Street - CSO Capture Performance and Opinion of Probable Cost Estimate

- The ***affordable level of control***, defined as the level of control achieved through expenditures determined to be affordable to CRW's customers. The Financial Capabilities Analysis presented in Section 7 indicates that a capital investment of $12 million, can be apportioned to the Hemlock Street Planning Area, with $7.2 million already allocated to the baseline level of control. Investments within this range should focus on collection system rehabilitation and/or control of unauthorized releases within this Planning Area during the 20-year planning horizon.

- ***Local Control Strategy 1: Decentralized Controls (Green / Grey)*** is able to address these collection system rehabilitation and/or unauthorized releases. The cost-performance curve indicates that the decentralize control strategy is less costly than the other two control strategies within the affordable level of control range, and provides opportunities to garner other sources of funding unavailable to the other control strategies.

- ***Local Control Strategy 2: Satellite Storage and/or Treatment*** employs storage/treatment facilities to achieve each control level for long-term control. The smallest satellite treatment/ storage facility feasible to implement within the Hemlock Street Planning Area – a 29 MGD satellite HRT – costs at least four times the affordable level of control range for this planning area. Since the Hemlock Street Planning Area has a low priority for additional CSO control, and

this technology is ineffective at control of unauthorized releases, this control strategy is not recommended for this planning area.

- ***Local Control Strategy 3: Combined Sewer System Separation*** requires the highest cost to achieve the three alternative control strategies among the three control strategies. The cost performance curves clearly show that complete sewer separation is both costlier than the decentralized control strategy and far exceeds CRW's financial capabilities. CRW will evaluate whether site-specific sewer separation is a viable component of a project to address collection system rehabilitation, unauthorized releases, and/or land redevelopment, in conjunction with decentralized controls to treat discharges from newly separated storm sewers.

8.4.13.3 Local Control Strategy Findings

Based on this evaluation, the Baseline Level of Control provides CRW with an affordable, flexible approach to achieving CSO control within the Hemlock Street Planning Area. An additional investment of $4.5 million is considered affordable for control of unauthorized releases and/or collection system rehabilitation within this planning area. Decentralized controls (green/grey) and site-specific sewer separation should be considered as part of collection system renewal and/or land redevelopment projects. While this planning area will not be prioritized for additional CSO controls, any decentralized green-grey controls integrated into private redevelopment and/or utility repair and replacement projects will be tracked and evaluated to determine the level of CSO control achieved.

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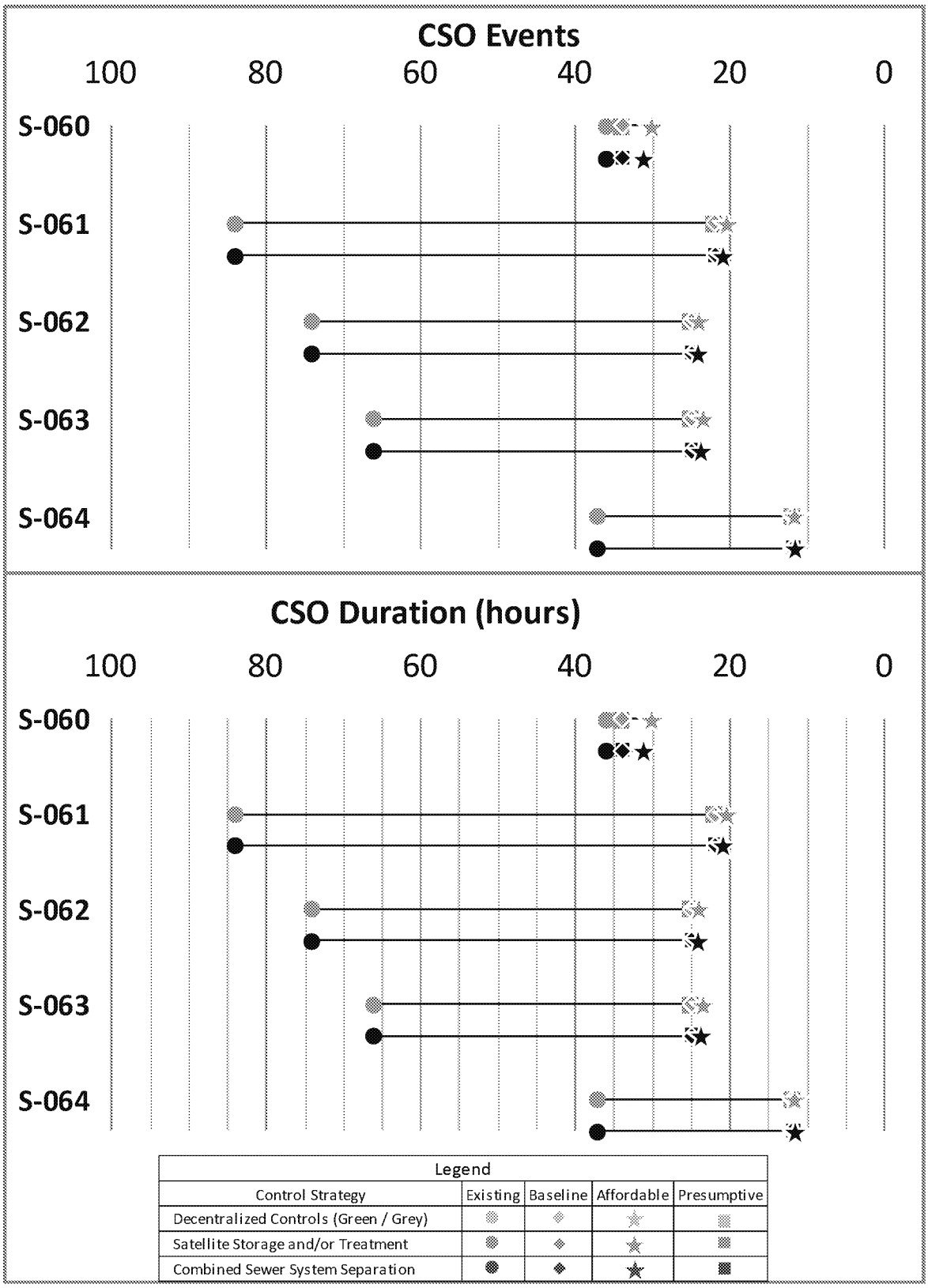

Figure 8.4.13-5: Hemlock Street - Annual CSO Event Frequency and Duration Performance by Control Strategy

8.4.14 East Harrisburg Planning Area

The East Harrisburg Planning Area encompasses a 124 acre area within the Spring Creek Sewershed. It is roughly bounded by Hale Avenue on the west, the City boundary on the east and north, and Rudy Road on the South. The East Harrisburg Planning Area consists of residential development east of 25th Street along with the Harrisburg High School campus and Kline Plaza shopping center. It consists of a single separate sanitary catchment, SS-010, shown on **Figure 8.4.14-1**, which discharges to Penbrook and Paxtang Borough sewers before ultimately reaching the Spring Creek Interceptor. There are no known high priority structural issues (lower priority structural issues are presumed, however), and there are no known SSOs or other hydraulic capacity issues in this area.

8.4.14.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable measures to control SSOs and rehabilitate sewer assets.

- **Sewer Rehabilitation.** No priority sewer rehabilitation needs have been identified in this planning area at this time. Future CCTV inspections will support a more detailed condition assessment and establish sewer rehabilitation priorities and costs.
- **Water in Basement.** H&H modeling conducted in this planning area does not indicate sewer surcharging / flooding levels that present a high risk of water in basement or SSOs.
- **Sewer Redirection.** No sewer redirection is recommended in this planning area.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

Stormwater discharges regulated under PA Department of Environmental Protection (PA-DEP) municipal separate storm sewer system (MS4) Permit requirements contribute pollutant loading to the Susquehanna River and Chesapeake Bay. A Joint Pollution Reduction Plan (PRP) submitted with CRW's MS4 permit application proposes pollutant controls to be implemented over the next five years, focused primarily on stream restoration projects addressing the Paxton Creek total maximum daily loads (TMDL).

The Joint Plan includes proposed best management practices (BMPs) for this planning area. BMP-12 is a stream restoration project (1,800 linear feet) for the stream located north of SS-010 along the Capital Area Greenbelt. BMP-14 includes potential GSI implementation at the Harrisburg High School and surrounding area, as well as a detention facility to manage runoff from the Wilson Parkway and Wyatt Road neighborhoods.

CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.14-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.14-1** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

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Table 8.4.14-1: East Harrisburg - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
SS-010	15.55	6.23	21.77	25.87	12.51	38.38	60.15
of Total Impervious	**24%**	**10%**	**34%**	**41%**	**20%**	**60%**	**94%**

Local Control Strategy 2: Satellite Storage and/or Treatment

The East Harrisburg Planning Area is served by separate storm and sanitary sewers. Flow monitoring and H&H modeling do not indicate levels of sewer surcharging or flooding that present a high risk of SSOs. As such, the satellite storage/treatment control strategy is not applicable to this planning area.

Local Control Strategy 3: Combined Sewer System Separation

The East Harrisburg Planning Area is served by separate storm and sanitary sewers. As such, the sewer separation control strategy is not applicable to this planning area.

8.4.14.2 Cost Performance Evaluation

Cost-performance evaluations are only used to evaluate control strategies for combined sewer overflow control. As such, they are not applicable to this planning area.

8.4.14.3 Local Control Strategy Findings

Based on this evaluation, the sanitary sewer has sufficient hydraulic capacity therefore multiple alternatives for the East Harrisburg Planning Area were not evaluated. The Baseline Level of Control does include stream restoration to achieve the goals of the Pollutant Reduction Plan in the East Harrisburg Planning Area at a total estimated opinion of probable of $857,000. Since this planning area does not have any CSO discharges, it will not be prioritized for additional stormwater controls, but further wet weather improvements can be achieved with decentralized green-grey controls integrated into private redevelopment and decentralized controls integrated into utility repair and replacement projects to control unauthorized releases within the planning area.

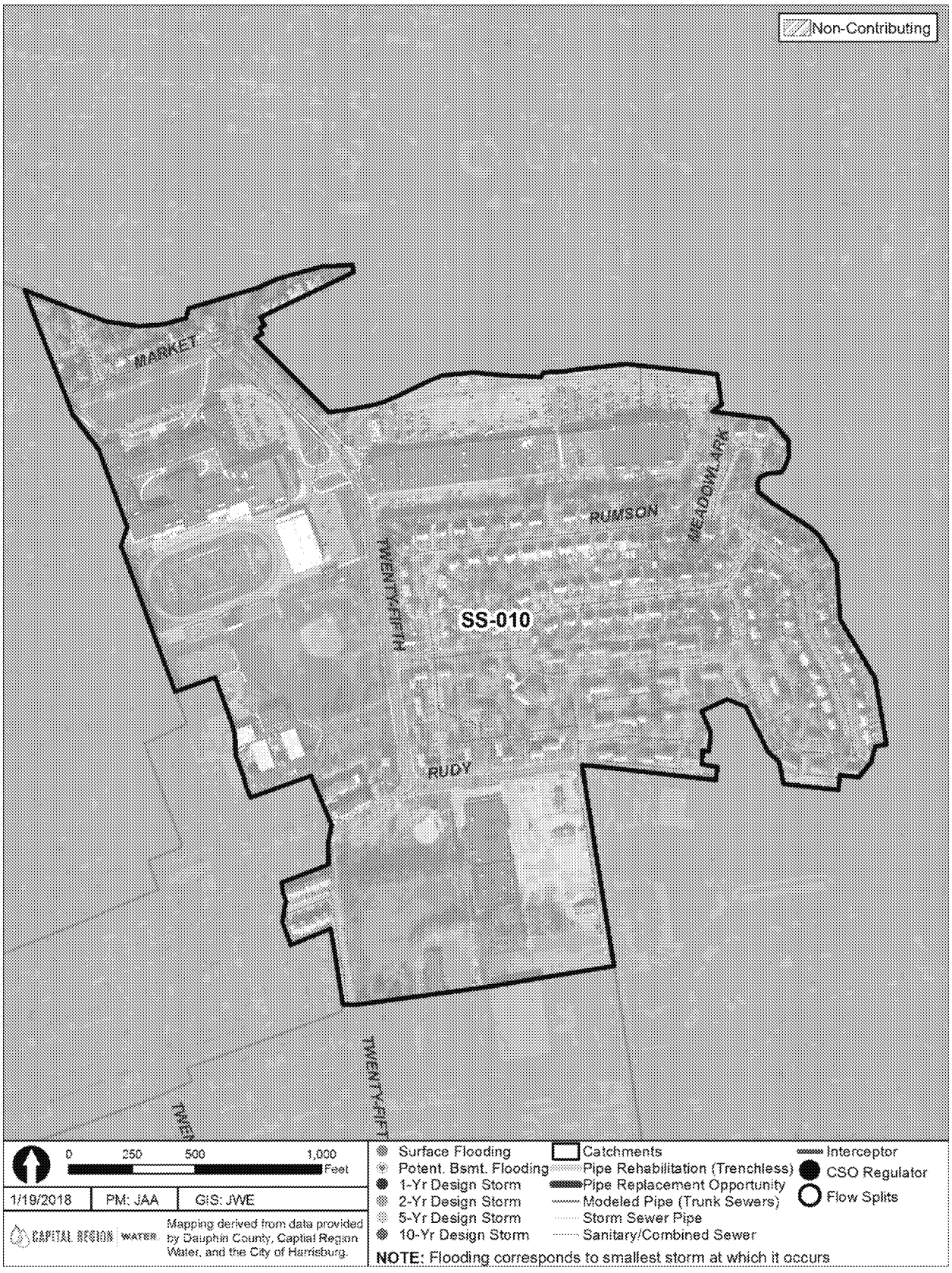

Figure 8.4.14-1: East Harrisburg - Existing Hydraulic and Structural Problems

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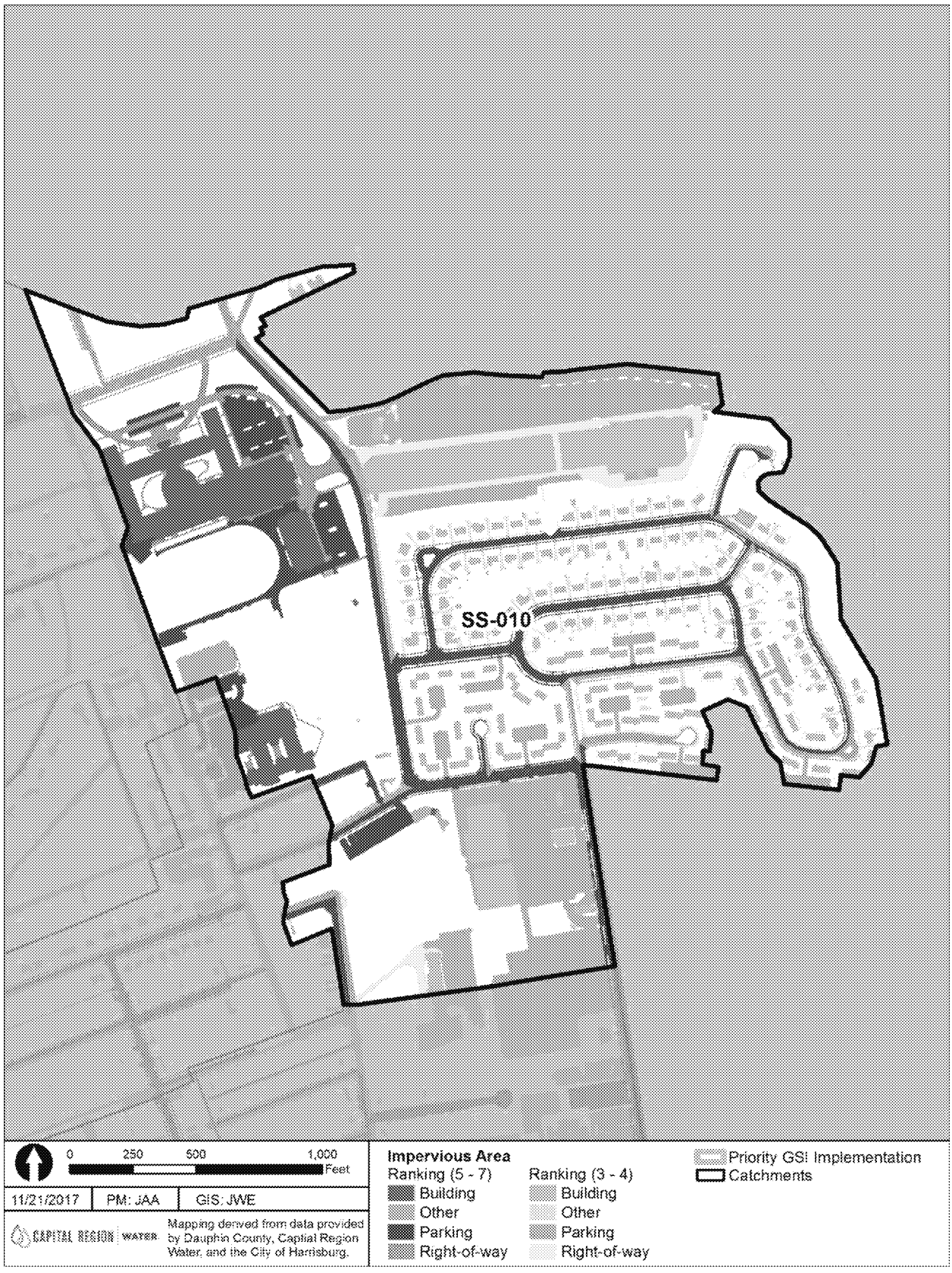

Figure 8.4.14-2: East Harrisburg - Green Stormwater Infrastructure / Sediment Reduction Opportunities

8.4.15 Spring Creek Planning Area

The Spring Creek Planning Area encompasses a 248 acre area within the Spring Creek Interceptor Sewershed, as shown on **Figure 8.4.15-1**. It is roughly bounded by the City boundary to the southeast, capturing the area adjacent to Spring Creek between 20th and Cameron Streets. Development is primarily residential properties. It includes separate sanitary catchments SS-013, SS-014, SS-015, SS-016, SS-017, SS-018, SS-024, and SS-025, shown on Figure 8.4.15-1. Note that sanitary sewage flow from SS-013 (Lower Paxton Creek Planning Area) also discharges to the Spring Creek Interceptor, but stormwater is conveyed to CSO-048.

CRW owns and operates the Spring Creek Interceptor from approximately the location of flow metering site M32 to the Spring Creek Pump Station. The majority of the Spring Creek interceptor and the remaining sewers discharging to the Spring Creek interceptor are owned and operated by other jurisdictions. Approximately 94 percent of the tributary area and over 90 percent of the dry and wet weather wastewater flow to the Spring Creek interceptor originates outside the CRW service area. These flows are contributed by Paxtang and Penbrook Boroughs, and Lower Paxton and Swatara Townships. Thus, hydraulic conditions within the Spring Creek interceptor and pump station are interjurisdictional in nature and cannot be resolved by CRW alone. Existing problems include interjurisdictional capacity/flooding issues and some identified structural issues. The following existing problems have been identified within the Spring Creek Planning Area:

- Pole-camera inspections identified a pair of parallel separate sanitary sewers along Thirteenth Street exhibiting high priority structural rehabilitation needs.
- H&H modeling conducted for the Separate Sanitary System (SSS) Capacity Assessment Report submitted in April 2017 reached the following conclusions:
  - ***Spring Creek Pump Station.*** The H&H model indicated that peak flows during the 2-year design storm exceeds the hydraulic capacity of the Spring Creek Pump Station. The Spring Creek Pump Station also is scheduled for a major rehabilitation.
  - ***Spring Creek Interceptor.*** The portion of the Spring Creek interceptor owned and operated by CRW is surcharged throughout its entire length during peak flow conditions of the 2-year design storm. Five manholes exhibit hydraulic grade line profiles above the manhole rims during the 2-year and 5-year design storms, increasing to six manholes during the 10-year design storm. CRW has sealed many of the manholes along its section of the Spring Creek Interceptor to contain the pressure flow conditions and reduce the risk of SSOs. While evidence of SSOs along Spring Creek was observed in the past, none have been observed by field staff since "problem lids" were bolted down, believed to be in 2009. In addition, there are no adjacent buildings near these manholes, located along a deep valley, so no basement backup would occur. Windshield surveys of commercial buildings along Amity Street, adjacent to two of the surcharging manholes, indicated they likely did not have basements.
  - ***Catchment SS-014.*** There was one manhole along Nineteenth Street where modeled surcharge depths rose to less than four feet from the rim of the manhole during the 2-year design storm, increasing to two manholes during the 5-year design storm. Windshield surveys confirmed the adjacent homes had basements. Homes along the uphill side of the street are high enough to avoid basement flooding. However, there are six homes along the downhill side of the street that potentially could be subjected to basement backups during the 5-year design storm, with one additional home subject to basement backups during the

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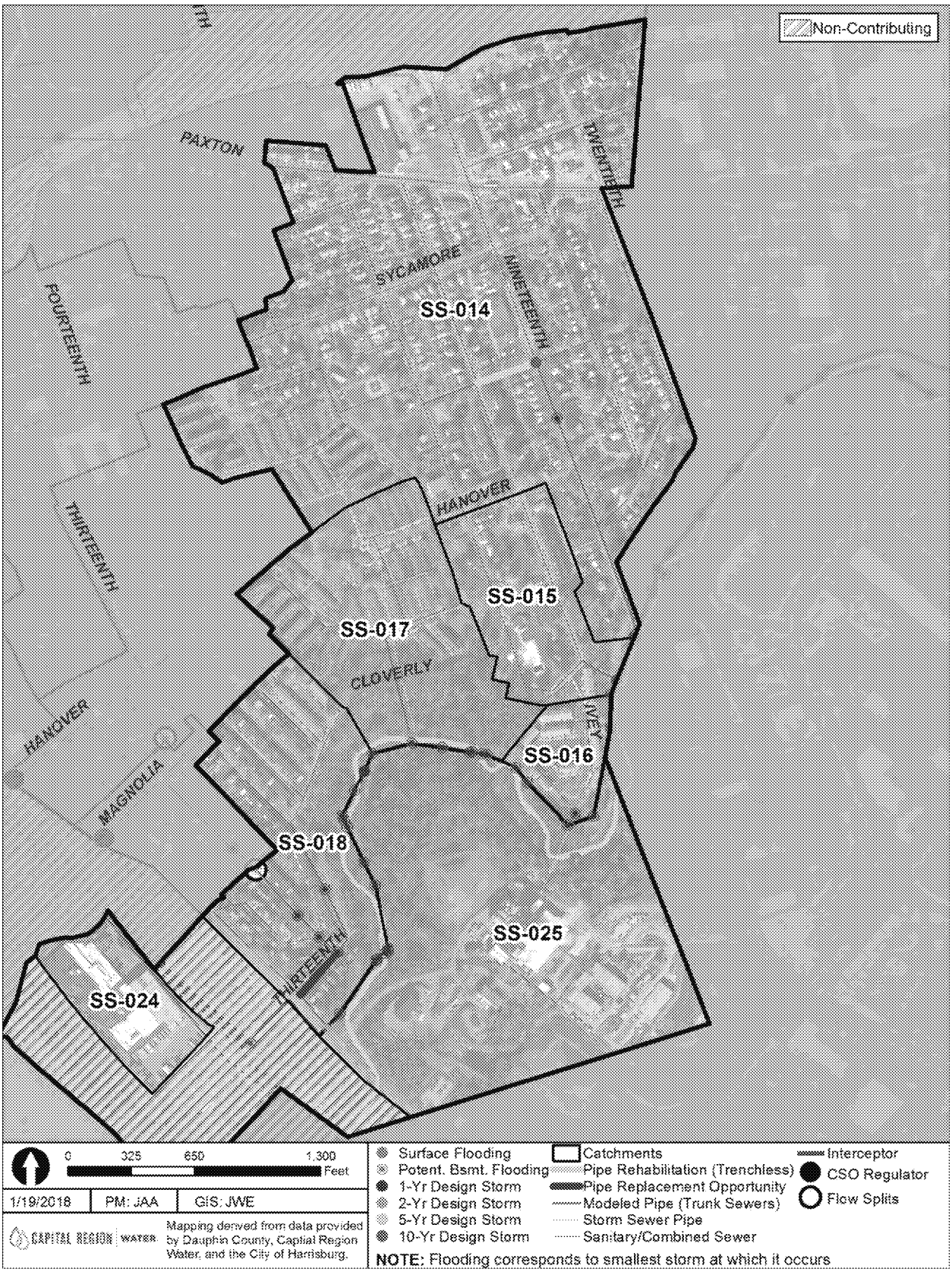

Figure 8.4.15-1: Spring Creek - Existing Hydraulic and Structural Problems

10-year design storm. There are no known or reported basement backups within these buildings.

- ***Catchment SS-016.*** The model indicates that the manhole for the sewer serving the Ivey Lane apartment complex had a freeboard depth less than four feet from the manhole rim during the 2-year design storm. Completed windshield surveys confirmed the apartments had basements. There are no known or reported basement backups in these buildings, but the model predicted a potential for possible basement backups within 12 apartment buildings during a 2-year design storm, with basement backups potential in two additional apartments during the 5-year design storm.

- Stormwater discharges regulated under DEP Municipal Separate Storm Sewer System (MS4) Permit requirements contribute pollutant loading to Spring Creek, the Susquehanna River and Chesapeake Bay. A Joint Pollution Reduction Plan (PRP) submitted with CRW's MS4 permit application proposes pollutant controls to be implemented over the next five years, focused primarily on stream restoration projects addressing the Paxton Creek total maximum daily load (TMDL). No stormwater PRP projects were identified for the Spring Creek Planning Area.

8.4.15.1 Definitions of Controls

Baseline Level of Control

The Baseline Level of Control involves affordable measures to control SSOs and rehabilitate sewer assets. The following Baseline controls are assigned an immediate priority within the Spring Creek Planning Area:

- **Sewer Rehabilitation.** Use an appropriate trenchless technology to repair 585 feet of separate sanitary sewer along Thirteenth Street, at an estimated capital cost of $164,000.
- **Water in Basement.** Monitor potential sewer surcharging at locations along Nineteenth Street and Ivey Lane where H&H modeling indicates a potential for basement backups. If unauthorized releases are identified, installation of backflow prevention on buildings where water in basement caused by sewer surcharging may be considered.
- **Sewer Redirection**. No sewer redirection is recommended in this planning area.

Local Control Strategy 1: Decentralized Green Stormwater and/or Grey Infrastructure Controls

CRW's Community Greening Plan established potential opportunities for GSI implementation. Bold colors on **Figure 8.4.15-2** indicate impervious areas assigned a high potential for control with green/decentralized infrastructure, while more muted colors indicate impervious areas assigned a moderate priority for control with green/decentralized infrastructure. **Table 8.4.15-1** summarizes the decentralized green-grey infrastructure potential by the type of impervious area (i.e., surfaces and buildings). This potential was determined through an opportunity analysis that considered seven physical (e.g., GI site/drainage area ratio, GI site dimensions, conflicts with existing infrastructure) and non-physical (e.g., property ownership, potential for partnerships) criteria. High potential GI sites are those that satisfy at least five of the seven criteria, while moderate potential sites satisfy three to four of the seven criteria.

Decentralized green-grey control alternatives are not effective at resolving sewer surcharging and potential basement flooding within the Spring Creek Planning Area. Decentralized green-grey infrastructure would be effective at controlling stormwater pollutant loads that may be required in the near- to mid-term under MS4 permit requirements.

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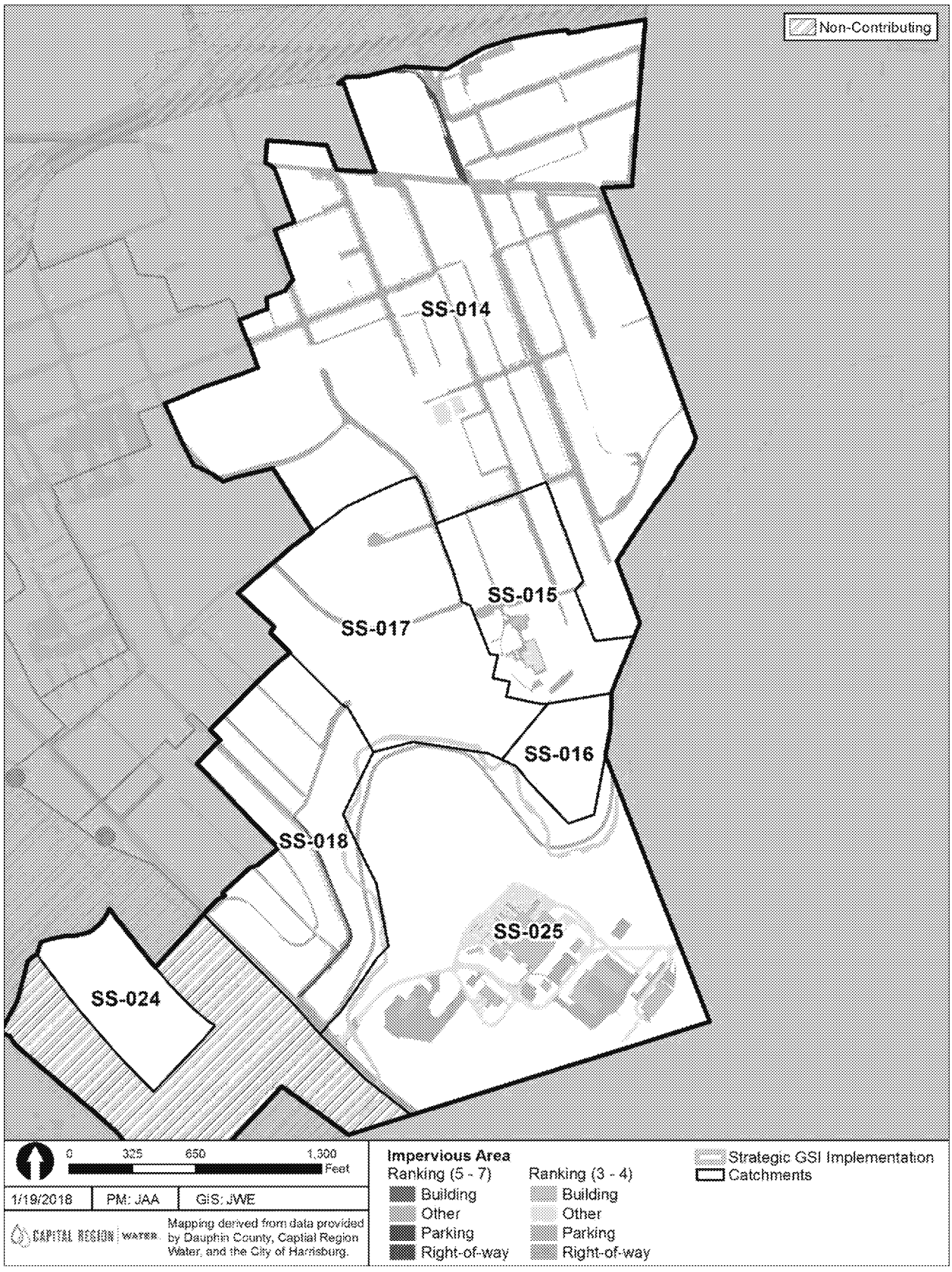

Figure 8.4.15-2: Spring Creek - Green Stormwater Infrastructure / Sediment Reduction Opportunities

Table 8.4.15-1: Spring Creek - High and Moderate Potential Opportunities for GSI

Catchments	High Potential (acres)			Moderate Potential (acres)			Total Moderate + High (acres)
	Surface	Building	Total	Surface	Building	Total	
SS-014	0.47	0.00	0.47	16.42	0.05	16.47	16.94
SS-015	0.00	0.00	0.00	1.94	0.12	2.07	2.07
SS-016	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SS-017	0.00	0.00	0.00	1.14	0.00	1.14	1.14
SS-018	0.35	0.00	0.35	3.40	0.00	3.40	3.75
SS-024	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SS-025	0.00	0.00	0.00	9.65	3.40	13.05	13.05
Total	**0.82**	**0.00**	**0.82**	**32.56**	**3.57**	**36.13**	**36.95**
of Total Impervious	**1%**	**0%**	**1%**	**32%**	**3%**	**35%**	**36%**

Local Control Strategy 2: Satellite Storage and/or Treatment

The following alternatives have been evaluated to address hydraulic capacity limitations and potential SSOs with respect to the Spring Creek Interceptor. Because the suburban communities do not have excessive RDII, an inflow and infiltration reduction program would not significantly reduce flows from the suburban communities. **Figure 8.4.15-3** illustrates these two alternatives:

- ***Option 1: Enlarge Spring Creek Interceptor.*** This alternative consists of replacing and increasing the size of the Spring Creek Interceptor between point of connection flow meter M32 and the Spring Creek Pump Station. To adequately convey the 5-year design storm, the pipe size would need to increase from 30 inches to 42 inches. Total opinion of probable cost is approximately $7 million. Under this scenario, scheduled rehabilitation of the Spring Creek Interceptor at a cost of approximately $2.5 million would not be required.
- ***Option 2: Suburban Community Flow Equalization Storage.*** This alternative consists of constructing a flow equalization storage tank that would be designed to offset existing flood volumes which occur along Spring Creek during the 5-year design storm, approximately 0.42 million gallons. Under this scenario, scheduled rehabilitation of Spring Creek Interceptor at a cost of approximately $2.5 million would still need to be completed. The estimated cost of the storage tank and flow equalization facility is approximately $4.1 million. Including the $2.5 million rehabilitation cost, the total opinion of probable cost is approximately $6.6 million.

Local Control Strategy 3: Combined Sewer System Separation

The Spring Creek Planning Area is served by separate storm and sanitary sewers. As such, the sewer separation control strategy is not applicable to this planning area.

8.4.15.2 Cost Performance Evaluation

Cost-performance evaluations are only used to evaluate control strategies for combined sewer overflow control. As such, they are not applicable to this planning area.

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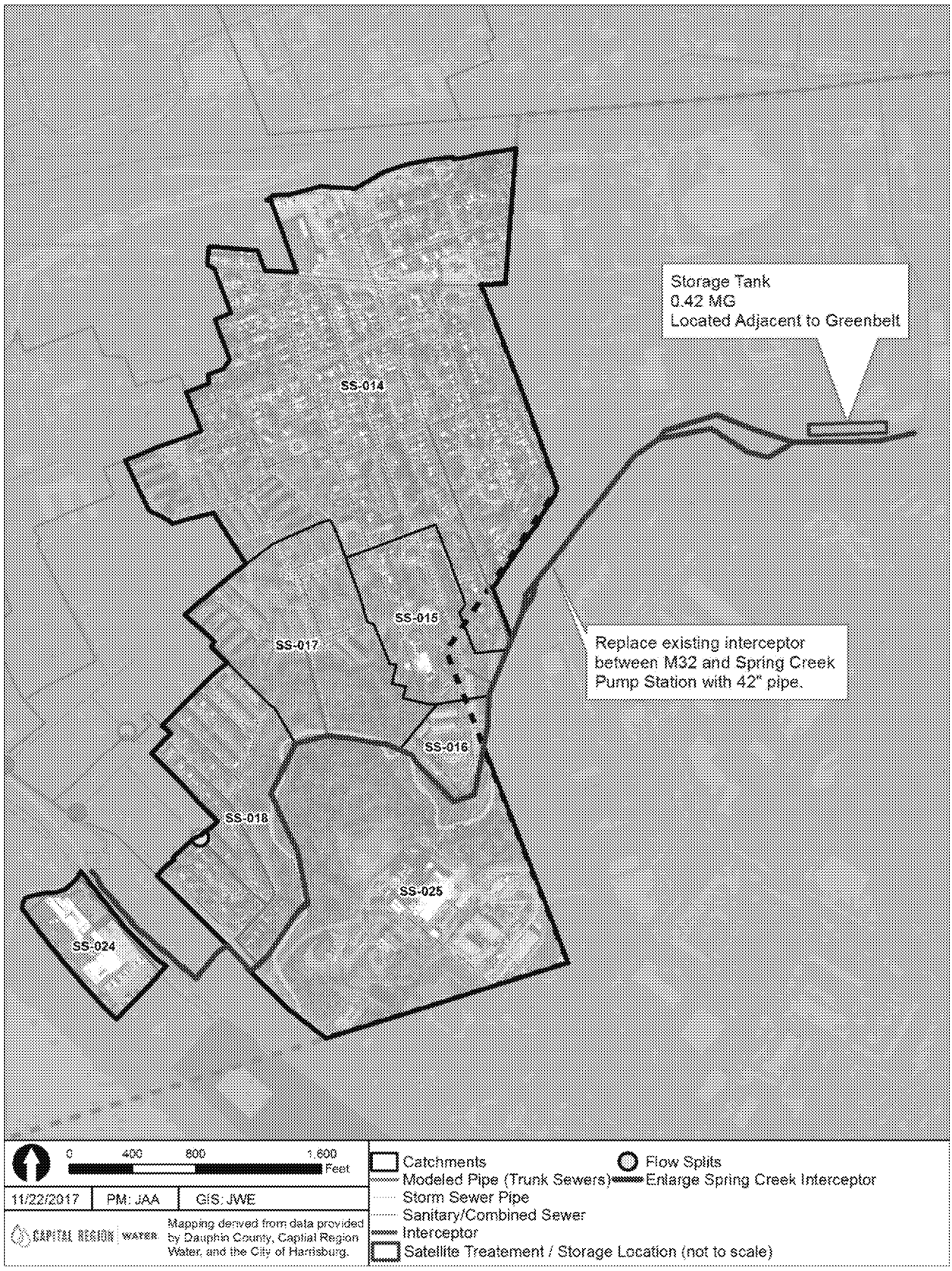

Figure 8.4.15-3: Spring Creek - Conveyance Improvements

8.4.15.3 Local Control Strategy Findings

Based on this evaluation, the Satellite Storage and/or Treatment strategy provides CRW with an affordable, flexible approach to achieving wet weather control objectives in the Spring Creek Planning Area.

Recommended controls consist of:

- Use an appropriate trenchless technology to repair 585 feet of separate sanitary sewer along Thirteenth Street.
- Selection of an alternative to reduce SSO potential along Spring interceptor by either enlarging the interceptor pipe or providing satellite equalization storage facility. The cost of enlarging the interceptor versus adding a satellite storage facility are comparative, therefore further evaluation is necessary to determine the selected approach.

The total estimated opinion of probable cost of these recommended controls is $7 million. Additionally, this planning area does not have any CSO discharges and therefore will not be prioritized for additional stormwater controls, but further wet weather improvements can be achieved with decentralized green-grey controls integrated into private redevelopment and decentralized controls integrated into utility repair and replacement projects to control unauthorized releases within the planning area.

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8.5 Evaluation of Alternative Control Strategies

The CRW Program Plan has adopted a triple bottom line (TBL) framework for evaluating the alternative control strategies that incorporates three dimensions of performance: social, environmental and financial. TBL is a concept which seeks to broaden the focus on the financial bottom line by including social and environmental responsibilities and Program benefits. CRW prepared a strategic plan for the entire organization, setting strategic goals and objectives for measuring performance. Those strategic objectives associated with CRW's stormwater / wastewater system were incorporated into the TBL framework for alternatives evaluation, as illustrated in **Table 8.5-1**. In addition, specific criteria are noted for each TBL objective, which were taken into consideration during the evaluation.

Table 8.5-1: Triple Bottom Line Evaluation Criteria and Relationship to CRW Strategic Goals and Objectives

Triple Bottom Line Category	CRW Strategic Planning Goals	CRW Strategic Planning Objectives	Evaluation Criteria to Consider
Financial	Efficient Use of Resources	Use Financial Resources Efficiently	▪ Capital Cost-Effectiveness ▪ O&M Cost-Effectiveness ▪ Potential Operational/Resource Impacts
		Use Energy Efficiently	▪ Anticipated energy use
		Integrate Infrastructure/Operations to Achieve Multiple Objectives	▪ Strategy addresses multiple objectives ▪ Strategy achieves operational efficiencies ▪ Strategy integrates programs/facilities
	Infrastructure Stability	Ensure Reliable Operations	▪ Technologies are feasible and reliable ▪ Strategy is acceptable to regulators
		Minimize Construction Difficulty/Risk	▪ Anticipated construction difficulty, risk
		Ensure Flexibility, Adaptability, and Expandability of New Infrastructure	▪ Flexibility to address multiple risks ▪ Public-Private Partnership opportunities ▪ Adaptive management opportunities
Social/ community	Customers and stakeholders	Increase customer and stakeholder satisfaction	▪ Is affordable to ratepayers ▪ Has stakeholder support ▪ Integrates with community objectives ▪ Environmental justice population impacts
	Workforce	Create Employment Opportunities at CRW and in the Community	▪ Employment opportunities at CRW ▪ Employment opportunities in City
Environmental	Public Health and the Environment	Improve Water Quality	▪ CSO Volume/Frequency Reduction ▪ Pollutant Load Reduction ▪ Addresses Pollutants of Concern ▪ Addresses Sensitive/Priority Areas ▪ Regulatory Compliance Considerations
		Support Long-term Community Health	▪ Reduced risk of SSOs ▪ Reduced risk of unauthorized releases ▪ Increases green space/vegetation/trees

The CRW planning process included preparing and considering three different (and quite separate) bottom lines. One is ***financial***, the traditional measure of profit, the bottom line of the cost and benefit analysis. The second is ***social/community***, the bottom line of the Plan's "people account", a measure

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in some shape or form of how socially responsible the Plan is in improving the quality of life for CRW's customers. The third is ***environmental,*** the bottom line of the Plan's "planet" account, a measure of how environmentally responsible it is.

Table 8.5-2 provides a summary of qualitative assessment of screening criteria for potential capital improvement alternatives at the conveyance and treatment system assets. A green cell with a "thumbs up" (👍) symbol indicates that the strategy provides a potential net improvement to the CRW objective from existing conditions or compared to other alternatives; a white cell (☜☞) indicates that the strategy has no significant positive or negative effect on this CRW objective; and a red cell with a "thumbs down" (👎) symbol indicates the strategy is less efficient/effective than other strategies for the given CRW objective, or detracts negatively to the existing conditions.

Table 8.5-2: Evaluation of Systemwide and Local Control Strategies

Triple Bottom Line Category	CRW Strategic Plan Objectives	Baseline Level of Control	Alternative Control Strategies: Systemwide: Enhanced Conveyance/ Treatment	Systemwide: Deep Tunnel Storage/ Conveyance	Local: Decentralized Controls (Green/Grey)	Local: Satellite Controls	Local: Sewer Separation
Financial	Use Financial Resources Efficiently	👍	☜☞	👎	☜☞	☜☞	👎
	Use Energy Efficiently	👍	👎	👎	👍	👎	☜☞
	Integrate Infrastructure and Operations	☜☞	☜☞	👎	👍	👎	👎
	Ensure Reliable Operations	👍	👍	👍	👍	☜☞	👍
	Minimize Construction Difficulty	👍	👎	👎	☜☞	👎	👎
	Ensure Flexibility, Adaptability, Expandability	👍	☜☞	👎	👍	☜☞	👎
Social/ community	Increase Customer/ Stakeholder Satisfaction	👍	👎	👎	👍	👎	👎
	Create Employment Opportunities	☜☞	☜☞	☜☞	👍	☜☞	☜☞
Environmental	Improve Water Quality	👍	👍	👍	👍	👍	👍
	Support Long-Term Community Health	☜☞	☜☞	☜☞	👍	☜☞	👍
	Total	+7	-1	-4	+8	-3	-2

The following rationale is offered for the scoring presented.

Financial Bottom Line

The financial bottom line of each strategy is evaluated for the following six CRW Strategic Plan objectives:

- ***Use Financial Resources Efficiently.*** The baseline level of control provides significant improvements in the ability of CRW's system to properly manage wet weather flows while addressing critical AWTF and conveyance system rehabilitation needs. Each of the alternative wet weather control strategies requires expenditures that are generally beyond the cost-effective level of control, based on the "knee of the curve" cost performance evaluation, and

result in CRW reaching or exceeding its financial capabilities. Of the five alternatives, the deep tunnel storage/conveyance and sewer separation strategies are the least cost effective, while the remaining alternatives tend to be cost competitive within CRW's financial capabilities. Note, however, that the decentralized control and small site sewer separations strategies are strong candidates for implementation as part of re-development projects and/or via public-private partnerships, reducing their potential costs to CRW and its ratepayers.

- ***Use Energy Efficiently.*** The baseline level of control incorporates energy efficiency measures into AWTF and pump station improvements while increasing their hydraulic capacity to address wet weather flows. The decentralized control strategy involves green stormwater infrastructure and "static" stormwater controls that are not expected to increase CRW energy costs while providing trees and other green benefits expected to provide communitywide energy efficiency. Other alternative control strategies would involve new treatment / pumping facilities that would increase CRW's energy consumption.

- ***Integrate Infrastructure and Operations.*** Deep tunnel, satellite treatment/storage, and sewer separation strategies focus exclusively on single-purpose wet weather control facilities that must be implemented as major CIP projects, decreasing CRW flexibility to meet multiple objectives like asset rehabilitation and control of unauthorized releases within the collection system. The decentralized control strategy is just the opposite – it involves numerous small-scale projects that can be designed for multiple objectives, with costs potentially shared with other stakeholders.

- ***Ensure Reliable Operations.*** All the control strategies involve technologies with proven track records of implementation, and have regulatory acceptance. The satellite control strategy is somewhat less favorable since CRW crews would need to provide operational and maintenance staff to sites throughout the service area.

- ***Minimize Construction Difficulty.*** The baseline level of control is focused on rehabilitation of existing CRW facilities, presenting limited construction risks to the community. Decentralized controls involve construction throughout the City, but typically integrated with other desired roadway, development, or facility upgrade projects, reducing construction impact. The other strategies involve major construction operations at new sites, anticipated to present significant community impacts.

- ***Ensure Flexibility, Adaptability, Expandability.*** The deep tunnel and sewer separation control strategies involve single-purpose facilities focused exclusively on managing wet weather discharges to receiving waters, with limited opportunities for implementation partners and multi-objective, synergistic benefits. The decentralized control strategy is just the opposite – facility siting and sizing can be adapted to site conditions and multi-objective project goals, giving CRW maximum flexibility to invest funds beneficially, seek partners to share costs, and support a wide array of community-wide objectives.

Social/Community Bottom Line

The social/community bottom line of each strategy is evaluated for the following two CRW Strategic Plan objectives:

- ***Increase Customer/ Stakeholder Satisfaction.*** During preparation for the Community Greening Plan, CRW's ratepayers and other stakeholders expressed a strong desire to

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implement the decentralized controls (green-grey) to meet wet weather control needs. The other alternative control strategies do not provide any community benefits, nor do they address unauthorized releases within the collection system. These strategies in fact cause significant community disruption and dramatic increases in CRW rates for sole-objective controls providing no community benefits.

- ***Create Employment Opportunities.*** Positive employment opportunities suitable for City residents are expected under the decentralized controls strategy, including new GSI maintenance jobs, along with an expectation of improved employment opportunities associated with the "greening" of the City. The other controls strategies are not expected to result in new jobs at CRW, nor are they expected to spur employment opportunities in the City.

Environmental Bottom Line

The environmental bottom line of each strategy is evaluated for the following two CRW Strategic Plan objectives:

- ***Improve Water Quality.*** All control strategies are intended to improve water quality by reducing CSO volumes / frequencies. When combined with the financial bottom line, however, the decentralized control (green-grey) strategy is more cost-effective at reaching comparable control levels as well as providing other multi-objective benefits.

- ***Support Long-Term Community Health.*** Only the decentralized control (green-grey) strategy provides opportunities to address community health issues associated with unauthorized releases and SSOs. This strategy also involves community greening and associated benefits of improved air quality, reduced heat island effect, and promotion of a "walking" community with associated health and safety benefits.

8.5.1 Alternative Analysis for the Advanced Wastewater Treatment Facility

The CRW CSO Control Strategy includes maximizing wet weather flow to the AWTF up to 80 MGD by utilizing additional capacity in the preliminary, primary and disinfection treatment processes. Wet weather flows exceeding the advanced treatment capacity (45 MGD) will bypass advanced treatment and receive disinfection prior to discharge. In accordance with the National CSO Policy and Pennsylvania CSO Policy, a CSO-related bypass of secondary treatment is permissible provided it is part of the implementation of the Nine Minimum Controls and part of a Long-Term Control Plan. The CRW Consent Decree (Part E.24.h) requires that any proposed bypassing of treatment processes at the AWTF include a No Feasible Alternative Analysis in accordance with CSO Policy Section II.C.7. The CSO policy refers to the EPA Bypass Regulations in 40 CFR Section 122.41 (m) that has provisions to allow for intentional diversion of waste streams from any portions of publicly owned treatment works (POTWs) under limited circumstances, when;

- A bypass is unavoidable to prevent loss of life, personal injury, or severe property damage, and

- There are no feasible alternatives to the bypass, such as storage and pump-back for secondary treatment, sewer separation, or satellite treatment.

For wet weather flows proposed to bypass full treatment, the policy requires the bypass flows to receive at least primary clarification, solids and floatables removal and disposal, and disinfection where necessary. In addition, the effluent from the POTW may not cause the discharge to exceed the NPDES permit limitations, or cause or contribute to a violation of water quality standards. The

Pennsylvania Combined Sewer Overflow Policy administered by the Department of Environment Protection (DEP) parallels the EPA CSO policy and bypass regulations regarding POTW bypasses.

This section summarizes an investigation of alternatives to the proposed wet weather bypass of CRW's advanced wastewater treatment facilities (AWTF), including the following:

- Storage and Pump Back
- Sewer Separation
- Satellite Treatment

8.5.1.1 Storage and Pump-Back

The premise of a storage and pump-back alternative is that wet weather flow exceeding the CRW AWTF full treatment capacity (45 MGD) would be diverted to a new storage facility. Then, as peak flow subsides to the AWTF the stored wastewater would be pumped back to the AWTF to receive full treatment. Although wet weather overflow storage volume can be provided via storage tanks, surface storage basins, deep tunnels and other innovative means such as vertical shafts and street storage, most operating agencies with large storage volume requirements utilize deep tunnels. Therefore, it is assumed for this analysis that the "storage" component would be provided by a deep tunnel system.

Utilizing the Baseline Control Strategy time series of plant flows, the storage capacity required to store peak flows from the largest storm above the AWTF capacity is 20 million gallons. This assumes the storage facility is located at/near the AWTF.

Figure 8.5-1 shows the simulated hydrographs of incoming plant flow from the pumping stations in blue (without pump-back from storage; maximum of 45 MGD), inflow to the storage facility in orange (when incoming plant flow exceeds 45 MGD), combined flow to the WWTP in grey (pump-back plus incoming flow), and plant flow assuming no storage (maximum of 80 MGD).

This approach is not considered technically feasible since the storage and pump facility size exceeds the space limitations at the AWTF.

The storage and pump-back approach is also considered financially infeasible. For this alternative application a 20 million gallon storage tank and 35 MGD pump station would have a capital cost of $110 million, which cannot fit within the program affordability limits described in Section 7.

8.5.1.2 Sewer Separation

The objective of the sewer separation alternative is to eliminate 35 MGD peak flow to the AWTF, in lieu of the proposed wet weather bypass at the AWTF.

A new biological advanced wastewater treatment facility with 35 MGD peak flow capacity would require an average daily wastewater flow (ADF) of at least 10 MGD to sustain a biological treatment system. This assumes the new satellite advanced treatment (SAT) facility could be designed with a peaking factor of 3.5 (Peak to ADF). Since the existing CRW AWTF currently operates at an ADF of 20.2 MGD (2016 average), a new SAT would require diverting 50-percent of the ADF away from the existing AWTF.

This approach is not considered technically feasible since a significant reduction in flow to the existing AWTF is not feasible without full sewer separation.

The sewer separation approach is also considered financially infeasible, with complete sewer separation costs in excess of $1 billion, well above the financial capability described in Section 7.

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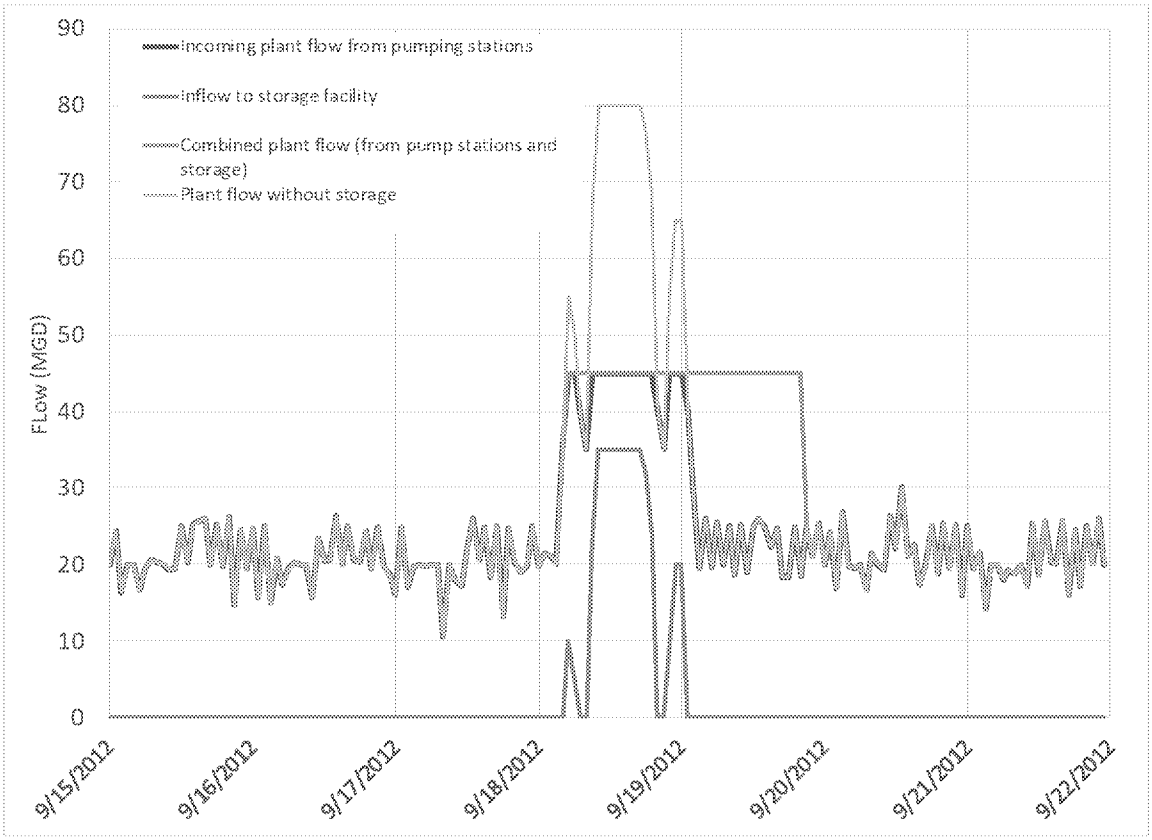

Figure 8.5-1: Flow Distribution and Storage Pump-Back with 45 MGD AWTF Capacity

8.5.1.3 Satellite Treatment

The objective of the satellite treatment alternative is to provide sufficient advanced wastewater treatment capacity at a remote facility, or facilities, in lieu of the proposed wet weather bypass at the AWTF. For this evaluation, the additional SAT facility peak flow capacity needed is 35 MGD which is the maximum bypass proposed at the AWTF.

A new biological advanced wastewater treatment facility with 35 MGD peak flow capacity would require an average daily wastewater flow (ADF) of at least 10 MGD to sustain a biological treatment system. This assumes the new SAT facility could be designed with a peaking factor of 3.5 (Peak to ADF). Since the existing CRW AWTF currently operates at an ADF of 20.2 MGD (2016 average), a new SAT would require diverting 50-percent of the ADF away from the existing AWTF.

This approach is not considered technically feasible since the SAT results in a significant reduction in flow to the existing AWTF, thereby, reducing the peak flow capacity for advanced biological treatment. In addition, this conflicts with the National CSO Policy (Nine Minimum Controls) to maximize treatment at existing facilities.

The SAT approach is also considered financially infeasible. The LTCP alternatives cost comparison is based on similar analyses performed in western Pennsylvania wherein the cost was developed for satellite secondary treatment (SST) and SAT. The liquid treatment process conceptual design for a satellite advanced treatment plant includes influent pumping, mechanical bar screens, grit chambers,

sequencing batch reactors, followed by effluent filtration and ultraviolet disinfection and cascade reaeration. The biosolids handling conceptual design includes mechanical thickening and dewatering via gravity belt thickeners and centrifuges with a lime stabilization process for dewatered biosolids and truck hauling disposal.

Cost curves were developed for SST and SATs from 5 MGD to 20 MGD ADF as shown in Appendix B, Basis of Cost Opinions. For the CRW application a 10 MGD SAT would have a capital cost of $136 million and an annual O&M cost of $3.4 million. The SAT alternative to the proposed bypass at the existing AWTF is financially infeasible since it cannot fit within the program affordability limits.

8.5.1.4 NPDES Permit Requirements

Through the NPDES permit renewal and waste load allocation processes, the DEP has established discharge limits and pollutant load limits in accordance with the Chesapeake Bay Tributary Strategy. DEP set annual nitrogen and phosphorus discharge loading and effluent concentration limits for the CRW AWTF that were approximately one-half historical requirements. **Table 8.5-3** summarizes the effluent limitations assigned to the CRW AWTF. An evaluation of wastewater characteristics and effluent quality was conducted to demonstrate that the CRW Baseline CSO Strategy will meet current NPDES discharge limits and waste load allocations for discharge into the Susquehanna River.

Table 8.5-3: CRW AWTF NPDES Discharge Limits (Excerpts from NPDES Permit No. PA 0027197)

Discharge Parameter	Effluent Limitations					
	Mass Units (lbs./day)		Concentrations (mg/L)			
	Monthly Average	Weekly Average	Minimum	Monthly Average	Weekly Average	Instantaneous Maximum
pH	--	--	6.0	--	--	9.0
Dissolved Oxygen	--	--	5.0	--	--	--
Total Residual Chlorine	--	--	--	0.5	--	1.6
Total Suspended Solids	9,411	14,149	--	30	45	60
$CBOD_5$	7,860	12,577	--	25	40	50
Ammonia (5/1 to 10/31)	3,458	--	--	11	--	22
Total Phosphorus	629	--	--	2	--	4
Fecal Coliform (5/1 to 9/30)	--	--	--	200	--	--
Fecal Coliform (10/1 to 4/30)	--	--	--	2,000	--	--

In addition to the limits noted above the AWTF has annual mass load discharge limits of 688,575 pounds for Net Total Nitrogen and 91,810 pounds for Net Total Phosphorus. The net totals include any nutrient loading credits either bought or sold.

Predicted Discharge Quality: An estimate of the discharge pollutant loadings from the AWTF was achieved by using the Hydraulic and Hydrologic (H&H) model developed for the CRW collection system and average wastewater discharge characteristics. The H&H model was used to generate a hydrograph of flow to the AWTF during the typical year under the base CSO control strategy. Wastewater characteristics of treated final effluent and primary effluent (bypass flow) were

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established by review of the 2017 plant discharge data and the results of the full-scale primary clarifiers stress testing.

A hydrograph of the H&H modeled plant flow is shown in **Figure 8.5-2** for the typical year (October 1, 2011 through September 30, 2012). To predict the discharge mass pollutant loadings, assumptions were made based on operating data as shown in **Table 8.5-4**. Primary effluent characteristics were obtained through the sampling program performed during the Primary Stress Testing Program (see Section 4). The final effluent characteristics were analyzed based on the 2017 monthly plant monitoring data.

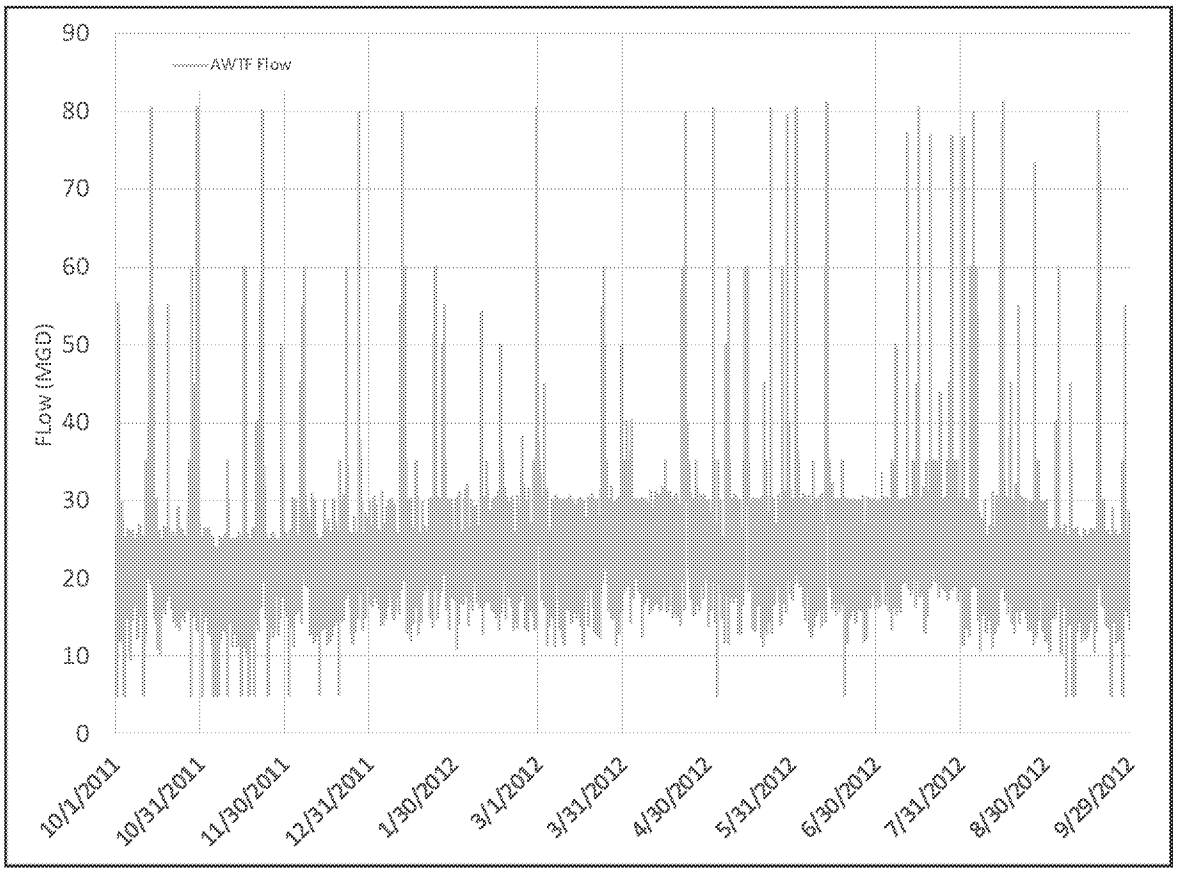

Figure 8.5-2: Typical Year Plant Flow Hydrograph

Table 8.5-4: CRW AWTF Average Discharge Characteristics

Discharge Parameter	Concentration, mg/L				
	TSS	BOD	Ammonia	Total Nitrogen	Total Phosphorus
Primary Effluent	76	71	15.2	19.1	2.2
Advanced Treatment Effluent	5	3	1.5	4.9	1.0

The pollutant loadings during a wet weather event while bypassing flow above 45 MGD were calculated using hourly flow rates from the H&H model hydrograph and the assumed primary effluent

and advance treatment effluent concentrations. The H&H model predicted the plant flow will exceed 45 MGD approximately 55 times as summarized in **Table 8.5-5**. Several of the short duration bypasses may be avoided by brief periods of increased settled sludge pumping to the advanced treatment process. However, for this discharge loading analysis all hourly flows exceeding 45 MGD were routed to the bypass.

Table 8.5-5: Predicted Advanced Treatment Bypasses at the CRW AWTF

Bypass Duration	Number of Occurrences
1 to 3 hours	31
4 to 8 hours	18
Greater than 8 hours	6

The total discharge pollutant loadings during the typical year are summarized in **Table 8.5-6**.

Table 8.5-6: CRW AWTF Total Discharge Mass Loadings Summary

Discharge Condition	Mass Loadings				
	Total Nitrogen	Total Phosphorus	Total Suspended Solids	BOD	Ammonia
Annual Loading Limit, lbs/year	688,575	91,810	--	--	--
Predicted Annual Load, lbs/year	306,220	60,370	--	--	--
Monthly Average Load Limit, lbs/day	--	629	9,411	7,860	3,458*
Predicted Monthly Average Load, lbs/day	--	150-180	860-1,230	540-860	280-330
Weekly Average Load Limit, lbs/day	--	--	14,149	12,577	--
Predicted Weekly Average Load, lbs/day	--	--	610-2,140	370-1,730	--

* Load limit from May 1 through October 31.

Conclusions: This evaluation demonstrates that the discharges will remain within the pollutant discharge mass load limits established by the DEP via the NPDES permit and the Chesapeake Bay Tributary Strategy. The discharge monitoring data for the AWTF demonstrate the upgrades to the advanced treatment process performed very well in 2017.

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8.6 Recommended Control Strategy

Based on the cost-performance evaluation presented throughout this chapter, and the TBL evaluation of alternative strategies presented in the previous section, the Decentralized Control (Green/Grey) Control Strategy is recommended as the preferred strategy for meeting CRW's strategic objectives. In summary, the following major reasons support this recommendation:

- ***It is most cost-effective***, meeting wet weather control objectives and supporting a multitude of multi-objective benefits, with significant opportunity for public-private partnerships to share implementation costs with CRW ratepayers.
- ***It is most flexible,*** installed in small, incremental investments throughout the system, using technologies that can be designed to also address unauthorized releases and integrate with sewer rehabilitation projects, and suitable for integration with a broad range of redevelopment and public works projects. Indeed, with the limited financial capabilities of CRW and the remaining uncertainty in the magnitude of collection system renewal needs, it may represent the only viable strategy to begin meaningful wet weather control.
- ***It is balanced,*** providing CRW the opportunity to invest throughout the community as well as avoid areas of excessive community impacts. It does not favor or place undue burden on any part of the community and, in fact, is designed to "lift up" the community through strategic investments that benefit water quality, public health and safety, and promote re-investment in the community.
- ***It builds upon the baseline level of control,*** with its initial focus on the rehabilitation and enhanced reliability of CRW's AWTF and conveyance system, anticipated to provide significant wet weather control benefits within the first 10 years of program implementation, with deployment of decentralized controls in priority areas to "fill gaps" in existing system performance.
- ***It has community support,*** consistently demonstrated through public engagement opportunities, and representing the only strategy that "gives back" to the community, potentially providing ancillary economic benefits that enhance the financial capabilities of CRW and its ratepayers.

Section 9

Implementation and Adaptive Management Plan

9.1 Implementation Overview

The *City Beautiful H_20 Program Plan* (Program Plan) involves a range of operational and administrative services to support implementation of the proposed controls. Four distinct strategies will be implemented under the Program:

- An ***Asset Rehabilitation and Renewal Strategy*** will entail the continual inspection, assessment, and prioritized renewal of CRW's wastewater/stormwater assets as part of the overall Asset Management Program. Asset Probability of Failure (POF), a function of remaining service life, and Asset Consequence of Failure (COF), are evaluated based on triple bottom line assessment of the failure of the asset.

- A ***Decentralized Green / Grey Implementation Strategy*** will continually seek affordable and cost-effective opportunities to implement stormwater controls within the context of related infrastructure and community renewal and redevelopment projects. Selected pilot projects will demonstrate the utility of various green stormwater infrastructure (GSI) control technologies in highly urbanized areas. GSI elements will be incorporated into public works and redevelopment projects by intent and/or through enhanced standardized design requirements/regulations. CRW will evaluate implementing an impervious area-based stormwater fee to provide a fair and true cost of service allocation that provides incentives for non-residential and stormwater-only customers to incorporate stormwater control measures (SCMs) where practicable.

- An ***Asset Operation and Maintenance Strategy*** will keep CRW's treatment, collection, and conveyance assets in good working order, free from structural deficiencies, debris, and blockages, allowing them to continue to operate as designed. CRW will also seek opportunities to integrate monitoring and control technologies into its assets as part of rehabilitation projects, with a goal of implementing telemetered surveillance and control where proven to enhance system operation and performance. CRW will determine

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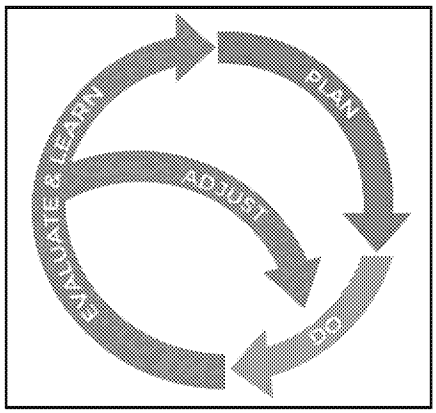
the maintenance needs associated with various types of SCMs to guide their maintenance by public agencies and by private entities on private property.

- An ***Internal and Intergovernmental Communications and Coordination Strategy*** will build implementation partnerships with various stakeholders. CRW will continue to promote effective interagency coordination to define strategic policies and streamline protocols and communication pathways to better align with full-scale GSI implementation. In addition, an Internal Communications Plan to improve synchronization within CRW will be developed. This communications plan will identify and evaluate policy barriers to implement the Program Plan, and will initiate strategies to address these challenges.

Adaptive Management Process

Implementation of the Program Plan elements will rely upon an Adaptive Management Process. This adaptive management approach will require flexibility and periodic program assessments throughout the implementation period. Adaptations in the management approaches are expected throughout this period to ensure that compliance goals are met, to optimize and enhance the program, to maximize benefits, and minimize the costs of implementation. Major decisions on management approaches will be made starting in Year 10 and every five years thereafter based on progress toward the goals and will be described in Evaluation and Adaptation Plans (EAPs). These EAPs will also identify specific program modifications. Each EAP will be a comprehensive assessment of CRW's progress towards full implementation of the approved Program Plan with descriptions of program elements expected to be implemented in the next five-year period. Through CRW's annual reporting process, continuous updates on the adaptation of the implementation program will be provided to US-EPA and PA-DEP.



Implementation Schedule

This section describes the various implementation strategies and the adaptive management processes that will be followed during the execution of the Program Plan. An implementation schedule for carrying out the Program Plan is provided in Section 11.

9.2 Prioritized Implementation Strategy

CRW's Program Plan involves a range of operational and administrative services to support implementation of the controls defined in Section 8. This section describes four distinct strategies to guide Program implementation:

- An ***Asset Rehabilitation and Renewal Strategy*** involving the continual inspection, assessment, and prioritized renewal of CRW's wastewater/stormwater assets.

- A ***Decentralized Green / Grey Implementation Strategy*** that continually seeks affordable and cost-effective opportunities to implement stormwater controls within the context of related infrastructure and community renewal and redevelopment projects.

- An ***Asset Operation and Maintenance Strategy*** intended to keep CRW's treatment, collection, and conveyance assets in good working order, free from structural deficiencies, debris, and blockages and consider integration of system surveillance and telemetry technology where proven operational efficiencies can be realized.
- An ***Internal and Intergovernmental Communications and Coordination Strategy*** that builds implementation partnerships with various stakeholders.

9.2.1 Asset Rehabilitation and Renewal Strategy

This section describes CRW's planned approach to identifying, prioritizing, and scheduling asset renewal needs as part of the overall Asset Management Program. CRW's asset management framework is being implemented based on the US-EPA/Water Environment Research Foundation (WERF) Five Core Question Framework, and thus incorporates asset level risk-based investment prioritization. In this framework, there are two parameters used for prioritization decision-making: 1) Asset probability of failure (POF), and 2) Asset consequence of failure (COF). These two parameters are multiplied together and the resulting product is referred to as Core Risk.

9.2.1.1 Asset Probability of Failure

Asset probability of failure is a function of remaining service life and is correlated to the asset's physical condition and other performance considerations such as the asset's ability to meet its required demand (e.g., whether the capacity of a reach of gravity sewer pipe can meet the hydraulic demand). Per the EPA Framework, at any given time, there are four major failure modes acting upon an asset. These four major failure modes are defined as shown in **Table 9-1**.

Table 9-1: Major Failure Modes and Their Definitions

Failure Mode	Definition
Physical Mortality	Physical degradation of asset reduces performance below acceptable level
Capacity	Volume of demand exceeds design capacity
Financial Efficiency	Operations and maintenance costs exceed that of feasible alternatives
Levels of Service	Functional requirements exceed specified performance criteria of the asset (e.g., the treatment technology used for the removal of a pollutant no longer removes enough of the pollutant to meet permit requirements)

While all four major failure modes may be acting on an asset at any given time, the asset will experience its failure due to only one failure mode, referred to as the imminent failure mode. CRW's approach identifies the imminent failure mode and recommends corrective action to intervene prior to the asset's failure. In the case of buried infrastructure, influences on physical mortality may include pipe material, age, construction methods, operational environment, external influences such as corrosive soils, and other factors. A condition rating system with a scoring range of 1 to 5 based on scales used by National Association of Sewer Service Companies (NASSCO) for Pipeline Assessment and Certification Program (PACP) is used by CRW, as illustrated in **Figure 9-1**.

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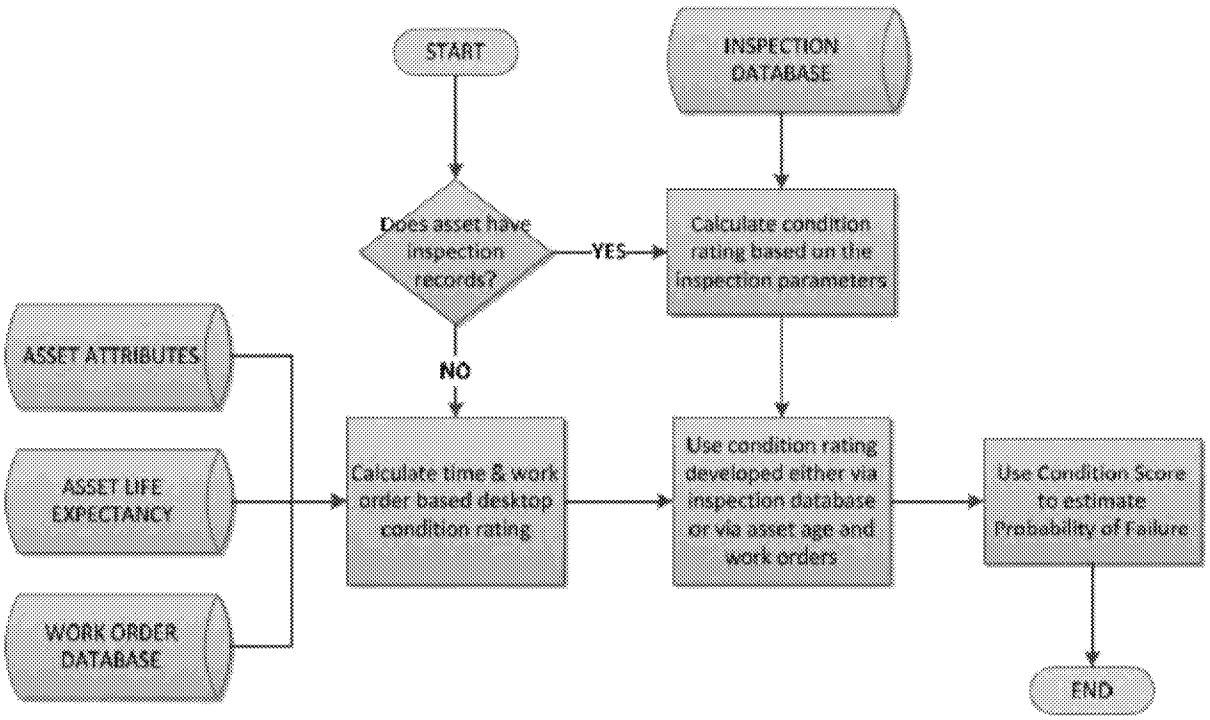

Figure 9-1: Process Flow Diagram for Estimating Asset Condition for Wastewater Infrastructure Assets

Generally, unless the external environmental demands change, the imminent failure mode is physical mortality. As a result, the failure mode of physical mortality is used predominantly for long term asset renewal decision making. Therefore, an asset's physical condition is the predominant factor for estimating remaining useful life of an asset. Hydrologic and Hydraulic (H&H) modeling and level of service are used jointly to define the capacity of wastewater/ stormwater assets, particularly within CRW's collection system, and may trigger capacity expansion and/or stormwater management control projects in advance of physical mortality.

At this time, the Advanced Wastewater Treatment Facility (AWTF) and the conveyance system have been assigned a high COF because their possible failure would result in a major, systemwide disruption of wastewater service. As such, AWTF and conveyance system assets found to have a high POF are given the highest priority for implementation under the Program Plan's baseline level of control. In the collection system, each asset has been assigned a preliminary POF based upon a combination of GIS data and the findings of the rapid assessment described in Section 4. A systemwide CCTV program is being conducted according to priorities based on the preliminary POF, with sewers exhibiting significant to near total deterioration (PACP condition score 4 and 5) evaluated first for potential repair during the immediate implementation phase (first ten years) of this Program Plan.

9.2.1.2 Asset Consequence of Failure

Asset consequence of failure is evaluated based on estimating the environmental/ regulatory, financial and social impacts of a defined failure of the asset. These three broad categories of consequence of failure are often referred to as the Triple Bottom Line (TBL) and goes beyond only the assessment of the direct financial consequences of an asset's failure (e.g. cost to repair or

resource impacts). Assets are assigned COF elemental scores from 1 to 5 for each of seven elements under the three TBL categories. The highest individual score across these elements for each asset is referred to as the dominant COF score and is used in the calculation of the asset Core Risk. The TBL categories and elements used by CRW to define the COF score are shown in **Table 9-2**.

Table 9-2: Triple Bottom Line Evaluation Criteria and Relationship to CRW Strategic Goals and Objectives

Triple Bottom Line Category	CRW Strategic Planning Goals	CRW Strategic Planning Objectives (Consequence of Failure Elements)
Financial	Efficient Use of Resources	Use Financial Resources Efficiently
		Use Energy Efficiently
		Integrate Infrastructure/Operations to Achieve Multiple Objectives
	Infrastructure Stability	Ensure Reliable Operations
		Minimize Construction Difficulty/Risk
		Ensure Flexibility, Adaptability, Expandability of New Infrastructure
Social/ community	Customers and stakeholders	Increase customer and stakeholder satisfaction
	Workforce	Create Employment Opportunities at CRW and in the Community
Environmental	Public Health and the Environment	Improve Water Quality
		Support Long-term Community Health

These TBL criteria are similar to those applied in Section 8.5 for evaluating alternative controls strategies, but have been simplified for use in asset management decision making. For vertical assets (e.g. a pump in a lift station), COF elements can be assessed individually (or in groups of similar assets as long as the consequence of the failures are similar within the group). However, doing so for a vast number of pipe segments can be prohibitively time consuming. Therefore, calculating the impact of pipeline failures for the various elements is performed via a spatial analysis of the proxy attributes shown in **Table 9-3**. Not every attribute shown applies to all of the elements. The attributes that are applicable for a given element are marked with an 'X' in **Table 9-3.**

9.2.1.3 Risk Management Zones

Assets are assigned elemental COF scores from 1 to 5 for each of the seven elements under the three TBL categories listed in **Table 9-2**. The highest individual score across these elements for each asset is referred to as the dominant COF score. The dominant COF score ranges from 1 to 5, and when multiplied by an asset's probability of failure (POF) rating, is used to calculate the Core Risk posed by an asset.

The maximum Core Risk is 25 (POF = 5 and dominant COF = 5).

Core Risk is the metric used to assign assets to risk management zones. Risk management zones and recommended interventions for each zone are illustrated in **Figure 9-2**. The risk management zone establishes the initial prioritization consideration (prioritization bucket) for asset operations & maintenance (O&M) and capital investment needs.

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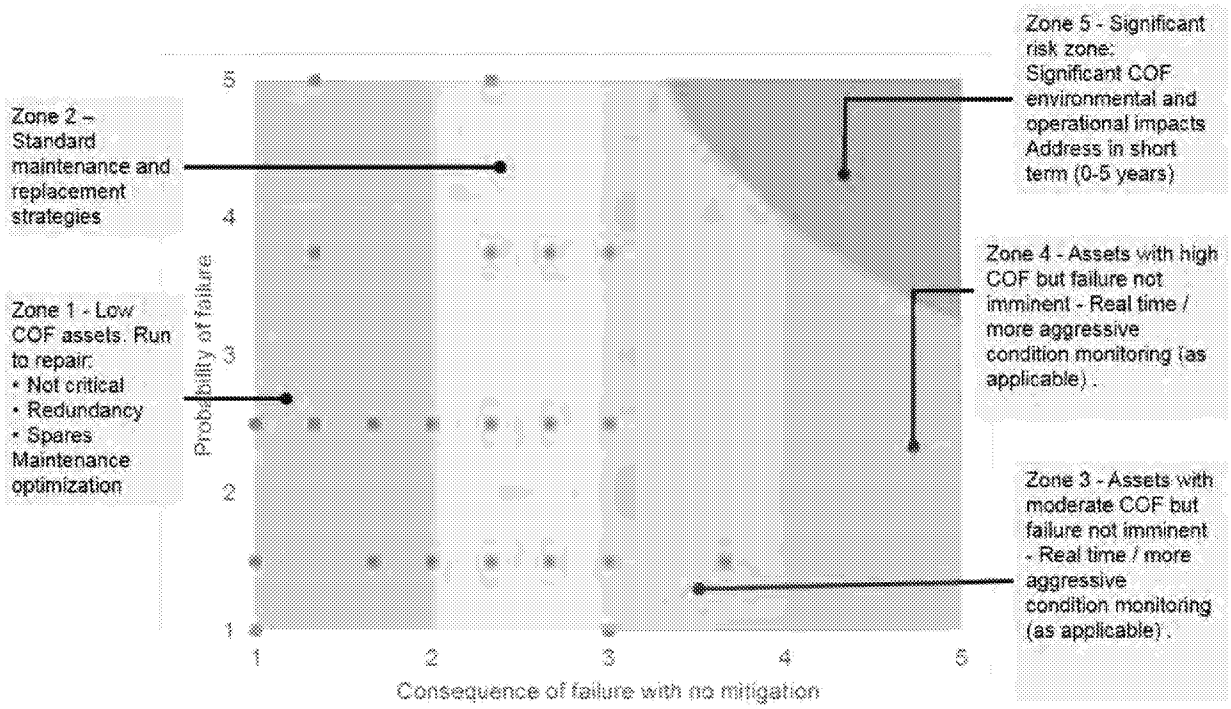

Figure 9-2: Core Risk Plot with Risk Management Zones

Table 9-3: Proxy Attributes for TBL Consequence of Failure Elements

	Financial						Social/ Community		Environmental	
Proxy Attributes	Use Financial Resources Efficiently	Use Energy Efficiently	Integrate Infrastructure/Operations to Achieve Multiple Objectives	Ensure Reliable Operations	Minimize Construction Difficulty/Risk	Ensure Flexibility, Adaptability, Expandability of New Infrastructure	Increase customer and stakeholder satisfaction	Create Employment Opportunities at CRW and in the Community	Improve Water Quality	Support Long-term Community Health
Critical Customers							X			
Proximity to Roads	X						X			X
Proximity to Railroads	X						X			X
Proximity to Environmentally Sensitive Areas	X						X		x	X
Proximity to Buildings	X						X			X
Proximity to Other Utilities	X						X			X
Repair Costs	X									
Depth of Pipe	X			X						
Zoning and Land Use				X			X			X

As shown in **Figure 9-2**, there are five risk management zones. Zone 5 includes the highest risk assets and zone 1 includes the assets with the lowest COF ratings. The risk management zones can be further explained as follows:

- ***Zone 5***: Contains assets that represent significant risk to the organization. In general, these assets are approaching the end of their useful life and upon failure, may cause significant social, financial, and environmental impacts.
- ***Zone 4***: Contains assets that have high consequence of failure but have not deteriorated enough to be included in the significant risk zone (Zone 5). For vertical assets, increased visual and/or predictive condition assessments (thermal scanning, oil analysis, etc.) may be justified as their condition deteriorates and they move vertically in the graph approaching Zone 5. In the case of pipes, assets in Zone 4 may be candidates for more frequent inspections than the pipes falling in Zones 3, 2, or 1.
- ***Zone 3***: Contains assets that would experience failure consequences that are tolerable because they may be managed through designed redundancy and operational mitigation such as spares and condition monitoring. Zone 3 assets can also migrate into Zone 5 and as such, require additional focus by management.
- ***Zones 1 & 2***: Contains assets with lower consequences of failure. Applicable management strategies for these assets may be run or manage to failure, maintenance optimization for assets with low COF scores, or standard maintenance practices for assets with low to medium COF scores.

9.2.1.4 Asset Prioritization Approach

This section describes CRW's risk-based asset management approach to asset investment prioritization and scheduling given the concepts previously described. In order to prioritize assets that need inspection, repair, replacement, or rehabilitation, the following steps are undertaken:

1. Determine the risk management zone for each asset as described in Section 9.2.1.3, using Core Risk (POF X dominant COF).
2. Identify any assets that are failing from one of the other remaining three failure modes (other than physical mortality). This is performed on a case-by-case basis around specific assets, location, or with the help of a hydraulic model in the case of pipes.
3. Assign assets to respective investment priority levels based on risk and condition (as explained in this Section).
4. Identify mitigation factors that may lessen the probability or impacts of an asset's failure (e.g., available installed or uninstalled spares, emergency response plans, on-call contracts with external parties that facilitate expedited response times, and implementing a standard operating procedure for manual operations).
5. Merge core risk and mitigation factors to prioritize assets within each priority level, considering geographic location, available funding, and engineering judgement.

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Assets are organized into five priority levels, or "buckets" based on the risk management zone into which they fall and their condition ratings.

- ***Priority 1***: Assets falling in Risk Zone 5 (core risk is 16 or greater). Schedule for replacement or renewal during immediate implementation phase (next 10 years).
- ***Priority 2***: Assets with a COF of 3 AND Condition greater than or equal to 4 (or assets with imminent failure due to one of the non-physical mortality failure modes). Schedule for replacement or renewal during near-term implementation phase (beyond 10 years, as affordable).
- ***Priority 3***: Assets with a COF greater than or equal to 3, AND Condition greater than or equal to 3; OR COF equal to 5 and Condition less than 3. High priority for initial condition assessment and frequent re-assessment.
- ***Priority 4***: Assets falling in Risk Zone 1 AND Condition equal to 5. Medium priority for initial condition assessment and periodic re-assessment.
- ***Priority 5***: All remaining assets with Condition greater than or equal to 4, or COF greater than or equal to 4. Low priority for initial condition assessment and re-assessment.

9.2.1.5 Implementation Services

Table 9-4 lists the services to implement CRW's Asset Rehabilitation and Renewal Strategy.

Table 9-4: Services to Implement CRW's Asset Rehabilitation and Renewal Strategy

Type of Service	Description	Existing Service?
Asset Management	Implement and administer Cityworks-based asset operation and condition tracking system.	Yes
GIS Mapping	Populate and maintain GIS mapping of assets and associated hardware/software.	Yes
CCTV Inspections	On-going CCTV inspections of underground assets, supplemented with a second CCTV truck/crew beginning in 2018.	Yes
Engineering Assessment	Routinely review asset management information and develop engineering designs for asset renewal projects.	Yes

9.2.2 Decentralized Green / Grey Implementation Strategy

The Program Plan includes a long-term commitment to direct the impervious cover of the City to decentralized green / grey stormwater infrastructure (GSI), as feasible and affordable. Of that total, CRW has determined that it may be affordable to install GSI serving up to 100 impervious acres over the next 20 years following the approval of this Program Plan. This Program Plan describes a number of programmatic themes that CRW would evaluate for implementation potential including:

- Pilot and Demonstration Projects,
- Synergistic Project Opportunities,

- Development-Driven Project Opportunities,
- Incentive-Driven Project Opportunities,
- Opportunities on Public Lands and Rights of Way,
- Vacant Property Re-Utilization Opportunities, and
- Green Parking Lots Initiative.

CRW is developing a *Neighborhood Planning and Concept Development Program* to guide these programmatic themes and otherwise support coordinated investment in GSI and other stormwater management improvements.

9.2.2.1 Pilot and Demonstration Projects

Prior to the submission of this Program Plan, CRW prepared its Community Greening Plan, including a significant commitment to demonstrating land-based stormwater management projects in the City. Subsequently, CRW designed and is in position to implement a number of pilot projects aimed at demonstrating the utility of various green stormwater control technologies in highly urbanized areas. These pilot projects are intended to help raise awareness of GSI among City residents and the regulatory community.

Pilot projects are defined as GSI projects designed, constructed, and monitored under controlled conditions to provide information for optimal design and program development. Information from pilot projects will be collected to develop a cost effective GSI program by testing a variety of projects and evaluating them for a number of factors, including:

- Ability to meet performance requirements,
- Ease of implementation for on-street and off-street settings,
- Affordability and cost-effectiveness of various physical conditions,
- Efficiency of various systems,
- Effectiveness of various materials, and
- Ease of maintenance.

GSI pilot projects can take many forms, be located in a variety of settings, and consist of differing technologies. The pilot program is designed to test the feasibility of GSI projects under the full range of potential conditions, captured by numerous variables. An initial list of variables has been organized into of the following categories:

- Location,
- Physical Settings,
- Systems,
- Policies and Partnerships,
- Implementation Strategies, and
- Materials/Technologies.

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The intent of the pilot program is to design, construct, and monitor several projects for each variable during the course of the ten years leading up to the first EAP delivery. In this way, by year 10, it is expected that the pilot projects will be built and monitoring complete, providing insights into the most cost-efficient designs, locations, maintenance procedures, and partners. This information will be used to continually enhance the program.

9.2.2.2 Synergistic Project Opportunities

Synergistic project opportunities are defined as GSI elements incorporated into other public works projects by intent and/or through enhanced standardized design requirements. CRW will develop a structure that will allow for implementation of GSI through modifications to some of the standard "public works" processes performed by CRW, the City, and PennDOT. During the 20-year planning horizon of this Program Plan, CRW is committed to including GSI elements in an increasing percentage of CRW water and sewer line replacement projects, City/PennDOT paving and streetscaping projects, including installations of street trees. CRW is calling this collective set of tools the "synergistic project opportunities" component of the program due to the opportunity to trigger GSI implementation as a standard procedure as the public works projects are designed and constructed. Although CRW will not have complete control of the number of projects and impervious areas controlled through these projects, the development of standard processes for implementation will decrease the need for stand-alone GSI projects implemented solely and independently by CRW. This Section of the Program Plan describes the "synergistic project opportunities" project concepts, implementation strategies and projections for anticipated GSIs.

Commitment to Incorporating Green Stormwater Infrastructure into Water and Sewer Projects

Most CRW infrastructure projects are implemented within the right-of-way and require opening streets. CRW is working to synchronize the traditional infrastructure design process with the GSI design process. Wherever possible, standard infrastructure constructed by CRW will be coupled with GSI at or near the street surface. During the first year of implementation, CRW Engineering will lead the integration of GSI into the design process. CRW Engineering currently evaluates each water and sewer replacement project, and documents opportunities for adding GSI. This process will evolve to a standardized process for adding GSI to this work, accompanied by standard design details and specifications for GSI components and adaptations to traditional infrastructure. As standardization occurs, contractors and design professionals working on water and sewer projects will act with minimal assistance from CRW.

Green Streets Design Manual

Streets and sidewalks are the largest category of publicly-owned impervious cover, accounting for approximately 45 percent of the impervious cover within the City. CRW's Community Greening Plan recognizes that streets can provide a significant portion of the total target for GSI. To that end, CRW is focusing a great deal of attention on demonstrating various GSI tools in the streets including stormwater tree pits, curb cuts, bump-outs, porous pavement and tree trenches aimed at developing a series of standards and specifications, to be prepared during the immediate implementation phase of the Program Plan. To support this initiative, CRW will develop a *Green Streets Design Manual and Complete Streets Handbook* during the immediate implementation Phase of the Program Plan. Upon release of this manual, CRW, the City of Harrisburg, PennDOT,

and any others performing work in the streets will begin to use the new Green Streets Design Manual, to guide when and how to apply GSI on street-related projects.

Streetscaping

Streetscaping projects may present CRW with an opportunity to utilize creative solutions and go beyond the standard Green Streets implementation toolbox. There are many different partners in the City of Harrisburg that may become involved in streetscaping projects. These may include neighborhood associations, non-Governmental Organizations (NGOs), Business Improvement Districts (BIDs), and others. CRW has been approached by a number of these agents with the request to partner on projects to increase the greening and stormwater management potential for the street design. The Green Streets Design Manual will increase the effectiveness of working with these partners as it provides standard details, specifications, and other information on the review process for those projects.

Partnership with City Parks & Recreation

CRW has been coordinating with City Parks & Recreation (CPR) to incorporate GSI elements into scheduled projects to renew City Parks. One of the seven identified pilot projects involves implementation of GSI into four City Parks:

- Fourth and Dauphin Park
- Penn and Sayford Playground
- Royal Terrace Park
- Norwood and Holly Park

These pilot projects will serve as a demonstration of such integration, and will be used to collaboratively seek grants for additional parks improvements projects.

In addition, CRW will work with the City to establish a budget for annual street tree installation, including tree removal/replacement. The program will include standard design details for tree pits, along with language that allows for CRW to add additional designs and specifications for stormwater management tree pits as these are developed. Coordinating with the City's tree planting program offers an opportunity to increase the number of trees planted in the City while piloting various types of stormwater tree pits. This effort will allow different tree pit technologies to be tested to confirm adequacy of designs, constructability, cost, and maintenance requirements. In addition, the opportunity to integrate stormwater tree pits into the more traditional tree planting contracts will be vetted.

9.2.2.3 Development-Driven Project Opportunities

Private investment in GSI on private property is a well-established implementation practice nationally, but requires modifications to current CRW/City stormwater regulations focused on Act 167 compliance. As projects are developed in the combined sewer area, some or all of their impervious area could be controlled by GSI through compliance with the regulations. This section describes the current and proposed regulations, the plan review process, and incentives that the CRW plans to develop to encourage the private sector to build GSI, such as a parcel-based billing structure and a stormwater credit program.

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Existing / Proposed CRW-City Stormwater Regulations

The existing City/CRW Stormwater Regulations are consistent with MS4-compliant model regulations proposed by PA-DEP, and are primarily intended to comply with the Act 167 Plan developed for Paxton Creek (e.g., watershed-wide detention requirements for the 100-year storm event). In addition, current regulations generally control increased runoff when impervious area is increased, yielding little to no reduction in runoff/CSOs/MS4 discharges. Modified regulations are envisioned that would add the following conditions:

- Require control of some or all of the existing impervious area of a development site using GSI, with the level of control dependent upon on-site conditions.
- Providing increased flexibility in integrating GSI within public right-of-way (ROW) to serve development projects.
- Providing incentives for developers to cost-share GSI projects within a development site that is also able to control runoff from adjoining properties/ROW.
- Establishing a fee-in-lieu-of policy to allow developers to implement off-site GSI projects or contribute an equitable share of CRW off-site GSI projects.

Modified stormwater management regulations will be implemented in conjunction with CRW's anticipated new MS4 permit, which requires certain stormwater regulation updates to be performed by year 4 of the MS4 permit term. CRW's goal is to work with stakeholders at the City and within the development community to develop modified regulations within this time frame. As a starting point, the following performance standards are envisioned for the modified stormwater regulations:

- ***Water Quality***: The first inch of precipitation over directly connected impervious cover must be recharged. Where recharge is not feasible, or limited, any remaining volume is subject to an acceptable water quality practice.
- ***Channel Protection:*** The 1-year, 24-hour storm must be detained and slowly released over a minimum of 24-hours and maximum of 72-hours.
- ***Flood Control:*** Development projects throughout CRW's service area should be required to control the rate of runoff to the capacity of the existing CRW drainage system. In addition, development projects in the Paxton Creek Watershed are subject to an Act 167 planning effort and must follow the model results for flood management districts.
- ***Fee-in-lieu-of Requirements:*** Development projects unable to achieve CRW regulatory requirements through on-site controls should be required to pay a fee-in-lieu-of equivalent to an equitable share of an equivalent level of control in a CRW stormwater conveyance and/or control project determined through H&H modeling.
- ***Non-Structural Site Design:*** Projects are required to maximize the site potential for stormwater management through appropriate placement and integration of stormwater control measures.

- ***Erosion and Sediment Control (E&S) Best Management Practices (BMPs):*** Stormwater BMP's are required for any earth disturbance projects by the Pennsylvania Clean Streams Law regulations, to prevent site soil erosion and reduce sediment pollution in nearby streams. Development or redevelopment projects disturbing more than 5,000 square feet are required to have Dauphin County Conservation District review an E&S Control Plan, and those greater than one acre require an NPDES permit issued by PA-DEP.

Stormwater Plan Review

The process and level of review of a private development project varies depending on the size of the earth disturbance associated with the development, the individual watershed requirements based on Act 167 Stormwater Management Plans and special zoning code regulations, and the associated state and federal permit requirements.

CRW's Stormwater Plan Review is provided by CRW Engineering staff, supplemented by consultant support. Their responsibility is to review Post Construction Stormwater Management Plans for compliance with CRW/City Stormwater Regulations. This plan review process ensures that CRW's stormwater program meets state and federal requirements while also coordinating with changing regulations in upstream municipalities. The stormwater plan review process will be refined as necessary to include the following phases:

1. ***Conceptual Review:*** Conceptual plan reviews should occur in the early stages of design to ensure that the SCMs are included in the overall site design. CRW will work with the City to require a signed and stamped Conceptual Approval as one of the required components of a complete zoning application.

2. ***Technical Review:*** The technical review includes details on the size and function of each individual SCM. The Post Construction Stormwater Management Plan is approved once the site's design meets Stormwater Regulations, and the SMP will be properly operated and maintained.

3. ***Construction and Inspections:*** CRW will provide staff to inspect construction sites for compliance with the Post Construction Stormwater Management Plan, and work with Dauphin County Conservation District to inspect for compliance with the E&S Control Plan. Any sub-surface SCM will require a CRW inspector to be present during the installation.

4. ***Project Close-out:*** In the coming years, CRW will focus on streamlining the Stormwater Plan Review close-out process and creating additional enforcement mechanisms to ensure SCMs are built as designed and approved. The primary component of this requirement is the submission of as-built plans, or record drawings, after SCMs are constructed. CRW staff will work with the City to develop the requirement that as-built plans of SCMs be submitted and approved before the City will issue a Certificate of Occupancy to assist in enforcing this requirement.

Inventorying GSI Implemented During Development

The redevelopment rate within the City of Harrisburg is low and is not projected to increase in the future at this time. The number of technically approved plans will be monitored by CRW as a

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surrogate for tracking the redevelopment rate. Close monitoring of this process will help to establish short-term goals for the CRW's capital GSI planning program. The impact of the regulations in terms of total acres developed, area removed from contributing to the sewer system, available slow release and infiltration storage volumes, increase in number of GSI projects (*i.e.*, structural basins, green roofs, porous paving, and rain gardens) will be calculated and tracked in a Project Tracking System. In order to calculate the impervious area served by GSI within private development, CRW must verify the number of sites with technically approved plans that are constructed. GSI projects and impervious area controlled will be counted once SCMs are constructed, inspected and accepted by CRW as functioning. CRW plans to conduct detailed inspections on all constructed approvals to verify that all approved SCM components are properly installed and that the overall systems have been maintained and are properly functioning.

9.2.2.4 Incentive-Driven Project Opportunities

CRW is evaluating the implementation of an impervious area-based stormwater fee to supplement its current water meter based charge for wastewater/stormwater services. The transition from an exclusively meter-based system to a combination meter and impervious area based system results in fees representative of the relationship between the stormwater runoff contribution from a parcel to the sewer collection system or nearby stream. An impervious area-based stormwater fee results in a fair and true cost of service allocation that provides incentives for non-residential and stormwater-only customers to incorporate SCMs where practicable. In addition, customers will become more aware of stormwater runoff impacts and the importance of urban SCMs. Customers are impacted by impervious area-based rates in a variety of ways. In general, properties with a small footprint and large water use, such as hospitals or high-rise residential buildings, will see a rate decrease, while large impervious parcels with little to no water use, such as parking lots, will see a significant increase in their utility bill. This leads to opportunities to implement a range of incentives for customers to implement GSI.

Stormwater Credits

CRW intends to develop a credit system to allow customers to decrease their bills by implementing structural and/or non-structural SCMs on their property, with the value of the credit equivalent to the stormwater services provided by CRW to the property owner. CRW intends to offer free design assistance and site evaluation to the most highly impacted customers to identify potential stormwater management opportunities that might exist on the site, and to perform cost-benefit analyses to help the property owner weigh the cost of the retrofit against the annual savings on the stormwater bill. CRW believes that the Impervious Area-Based fee likely will incentivize some large parcels to retrofit SCMs and receive a credit.

In order to receive a credit, the property owner will be required to prepare and receive approval of a credit application describing the SCMs and how they will be implemented and routinely maintained according to criteria developed by CRW. Any development/ redevelopment that meets CRW's Stormwater Regulations, to be updated prior to implementing the fee, will be eligible for stormwater credit, and approved development plans will serve as a credit application. Credit applications will be approved if (a) an as-built plan is submitted showing the SCMs are constructed as designed and properly functioning, (b) a long-term Operations and Maintenance

plan is prepared and recorded as a legal instrument tied to the property, and (c) the owner operates and maintains the SCM according to this Plan.

Stormwater credits will need to be renewed periodically. This requirement will create a financial incentive for the land owner to keep their SCMs functioning. CRW will implement an SCM inspection program (see Section 9.2.3) requiring a CRW inspection or self-inspection report for a customer to renew their credit eligibility.

Other Incentives for Private Green Stormwater Infrastructure Development

CRW is considering other standards, incentives, and programs to encourage GSI, including:

- ***Fast-Track Stormwater Plan Review Project Review:*** Projects with 95 percent or more of the impervious area disconnected from the combined or separate storm sewer can qualify for a fast track Green Review in which the stormwater management section of the project will be reviewed within five days of submittal.
- ***Free Assistance Program:*** CRW proposes to provide free assistance through site inspections and design recommendations for green retrofits that allow customers to obtain fee credits.
- ***Stormwater Management Incentive Program:*** CRW is considering incentives to private parcel owners to implement stormwater management best practices through both a low-interest loan program and a grant.
- ***Residential Rain Barrel Program:*** CRW is considering a program to encourage residential participation in stormwater management through a program providing free rain barrels and free installation for residential properties.

CRW intends to convene an advisory committee to examine rate relief options, special rate issues, and revisions to the credits and incentives programs. This customer group will make recommendations to CRW on these and other issues that customers have brought to CRW's attention. Any changes resulting from these recommendations will be incorporated into the next rate case filing.

9.2.2.5 Opportunities on Public Lands and Rights of Way

An important component of the strategy for identifying candidate GSI project sites is to target publicly owned facilities. These include publicly-owned properties, streets and rights-of-way, which constitute more than 45 percent of the impervious cover within the City. Stormwater capture associated with public property is enhanced by routing runoff from areas adjacent to public land and managing that stormwater on the public land. Initial efforts to identify additional projects for the GSI conceptualized project list will focus on publicly owned impervious cover and schools. As implementation progresses, additional programmatic elements will be explored and developed. Pilot and demonstration projects are primarily focused on building the relationships and partnerships needed to support a larger GSI program, and are located on recreation facilities or other properties managed by CRW's partners. Through this process, CRW is developing a number of tools for implementing GSI based on lessons learned in the GSI Pilot Projects. Project

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identification is based partially on following opportunities, existing partnerships, and ease of implementation.

CRW will continue to follow opportunities and collaborative efforts with partners through a number of strategic planning processes for queuing projects. An initial set of strategies for CRW-sponsored projects is described below, including:

- Development of Strategic Green Stormwater Infrastructure (GSI) Implementation Areas,
- Greening of publicly owned facilities,
- Evaluation of vacant lands, and
- Other strategic initiatives.

Strategic GSI Implementation Areas

Strategic GSI Implementation Areas (SGIAs) are areas where the potential exists for concentrated contiguous and interconnected use of GSI controls that may offer greater efficiencies than if those same controls were implemented in a non-coordinated manner. Section 8 of this Program Plan suggests specific areas within each planning area for concentrated implementation, specifically within the three planning areas where baseline implementation strategy is unable to achieve the presumptive level of control. Each of these areas will be further evaluated and prioritized as potential SGIAs project areas, based on the criteria on the next page.

Once a SGIA has been identified by CRW, staff and/or a consultant may be tasked with completing a comprehensive evaluation and Stormwater Improvements Plan (SIP) for the project area. Each SGIA may be evaluated for potential to meet the following objectives:

- ***Stakeholder Involvement***: Success in implementing stormwater improvements in a SGIA will be partly and, in particular cases, largely dependent on effective involvement and participation of key stakeholders. An effective strategy for identifying and coordinating with key stakeholders in a SGIA is required.
- ***Coordination with Other Planning Initiatives***: SGIA evaluations should investigate and identify cohesion and potential synergy with planning initiatives within a SGIA as well as with other relevant initiatives.
- ***Coordination with Land Development***: SGIA evaluations should investigate and identify cohesion and potential synergy with near and long-term development within a SGIA.
- ***Effective Visual Presentation***: All graphics from a SGIA evaluation including maps, renderings, schematics, and other items that require visual representation must be prepared in a highly professional and effective illustrative format.
- ***Creativity***: Incorporating creativity such as artistic and/or historic elements into stormwater improvements is important.
- ***Feasibility***: In addition to physical considerations, benefits, and costs, other feasibility issues to be considered should include, at a minimum, financing issues, public/private

ownership relationships and interaction, operation and maintenance, and area specific sensitivities.

- ***Comparison and Rating Methodology***: Both for the comparison of different stormwater management improvements in the same physical space and for the combination of stormwater management improvements area wide, an effective comparison and rating methodology must be developed to prioritize and recommend stormwater management improvements for a SGIA. The ability to compare multiple stormwater improvements and various combinations of those improvements to arrive at a selected set is absolutely imperative. Comparison and rating methodology can be flexible but sustainability, multiuse benefits, and triple bottom line benefits are important considerations and should be included.

- ***Implementation Strategy***: To make the SGIA Stormwater Improvement Plan more practical, a phasing and implementation strategy should be prepared for the combination of stormwater improvements.

Each Stormwater Improvement Plan will be a combination of text and supporting graphics that demonstrates how the evaluation objectives were addressed and resulting outcomes including the recommended type of stormwater management facilities; approximate sizing, layouts, and placement based upon drainage patterns; the impervious area managed; and the runoff volume managed and cost estimates for implementation. Cost estimates will include estimated project costs as defined by the Association for the Advancement of Cost Engineering Practice No. 18R- 97 and present worth costs for operation and maintenance. Detailed concept designs would include a higher level of detail, and would be completed as a next phase.

SGIA Prioritization Criteria

Feasibility/Cost of GSI implementation:
- Large, contiguous impervious cover
- Topography/surface drainage
- Area served by separate storm sewers
- Land use type
- Open space for GSI installation

Visibility, Community Gateways:
- Showcase early successes
- Demonstrations to stakeholder group
- High visibility areas with uniform land ownership (*i.e.* campus scale)

Partnership Opportunities:
- Substantial stakeholder interest
- Favorable partnership opportunities
- Consistency with City master plan

Social Benefits:
- Addresses community needs
- Equitable distribution of investment
- Benefits to underserved neighborhoods

Other Planned Investments:
- Area of flooding, water-in-basement, or other unauthorized releases
- Areas where other planned water and sewer or GSI investments are needed
- Areas of concentrated development or redevelopment investment

Existing framework
- Concentration of properties impacted by parcel based stormwater charges,
- Existing neighborhoods
- Areas of common land use
- Business or industrial districts

Interagency Collaboration and Synergies:
- Collaborating with other potential implementation initiatives

Other criteria yet to be identified

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Greening of Publicly-Owned Facilities and Tax-Exempt Properties

Major public entities within the City include the Commonwealth of Pennsylvania, Harrisburg Public Schools, public parking facilities, Harrisburg-Area Community College, the Harrisburg Housing Authority, and City/County Parks. Hospitals/medical facilities, churches/religious institutions, and railroads make up the majority of non-public tax-exempt properties.

Publicly-owned facilities and tax-exempt properties are highly visible, engage a broad segment of CRW's rate payers, and are potential partners in public education and "green" job training. As such, they have been afforded a high priority in CRW's GSI program. Improvements at public/tax exempt institutions are envisioned to utilize an array of stormwater measures such as rain gardens, green roofs, rain barrels, and cisterns. These sites offer significant potential for the incorporation of pervious pavement and tree plantings both on parking and recreational facilities, transforming heat-trapping asphalt zones into more welcoming, cooler, green areas. This initiative will provide educational opportunities for students and instructors, enhanced recreational amenities, aesthetic improvements, and potential reductions to stormwater bills. CRW intends to develop a cooperative implementation approach with these institutions with the following functions:

- Evaluate and prioritize sites based on the following factors: impervious area, provision of additional amenities, maintenance requirements, etc.
- Collaborate with project partners to develop a coordinated implementation process that addresses gaps/inefficiencies in design, outreach, and construction schedules.
- Use community feedback to begin design of stormwater management features on selected school sites, coordinating with project partners at predetermined intervals of the design process.
- Obtain proper easements and/or deed restrictions required for maintenance obligations.

9.2.2.6 Vacant Property Re-Utilization Opportunities

Vacant land, while not all publicly owned, presents an opportunity for stormwater management, both for permanent green redevelopment and for more temporary measures such as the creative use of vacant parcels for management of stormwater from surrounding areas. The challenge, however, is that vacant lands by nature may be vacant only temporarily, and it is often difficult to assess the future potential use of a vacant site. As such, CRW has prioritized larger sites, and plans to continue to consider the opportunities that may exist on smaller sites.

In the Community Greening Plan, vacant parcels within the combined sewer area of Harrisburg were reviewed to identify sites that could manage runoff from both impervious areas within the site and from adjacent streets and sidewalks (see below).

Sites were assigned low priorities if they had unfavorable site characteristics, such as small drainage area, poorly suited topography, structures, severe dumping activity, a long distance to a CRW stormwater inlet, mature trees on site, or potential soil contamination. Sites were eliminated during this initial analysis if they are scheduled for future development. Site visits

Vacant Land Screening Process

Complete a GIS analysis to identify vacant land groupings (adjacent parcels)

- Exclude parcels that are potential pollutant hotspots (those that have known histories of industrial land use)
- Search for sites within 15 feet of a CRW inlet – these are sites that are most likely to be able to collect runoff from the right-of-way (ROW)

Categorize groupings by ownership as public, private or multiple owners

- Public: minimum total site area: 2,000 square feet
- Private: minimum total site area: ¼ acre
- Multiple: minimum total site area: ¼ acre

Phase 1: Desktop Analysis

- Primary consideration: determining the amount of runoff that could be collected from the ROW
- Adjacent drainage areas were calculated including streets and sidewalks along the site
- Potential drainage areas were calculated including areas across the street where appropriate
- Minimum adjacent drainage area: 9,000 square feet – sites not meeting this criterion were eliminated
- The list of potential sites was further refined to exclude sites currently in use, sites with impeding structures or sites with development initiatives underway
- Additional impervious area on site for which runoff could be managed was included in the final potential project area amount.

Phase 2: Perform Site Visits

- Site visits were conducted to verify data or adjust information as needed
- Constraints and opportunities were observed and documented related to topography, on-site structures, dumping and adjacent land uses

were conducted to verify data or adjust information as needed. Potential partners for the re-utilization of vacant land include the Harrisburg Redevelopment Authority (Land Bank) and the Dauphin County Land Bank Authority.

9.2.2.7 Green Parking Lots Initiative

Parking lots constitute approximately 25 percent of the impervious cover in the City and greening them offers significant opportunities to reduce stormwater runoff. The greening of parking lots can improve the appearance of the City's commercial and business districts. Additionally, the incentives provided by CRW's Parcel Based Billing initiative may make retrofits aimed at reducing stormwater fees more feasible for private parking lots. A variety of stormwater measures can be used to remediate the effects of parking lot runoff, including vegetative strips, infiltration beds, tree plantings, porous pavement, and the development of green roof areas on parking garages. Benefits to the City of greening parking facilities may include:

- Improved community aesthetics and urban design
- Potential low-cost solutions
- Potential community engagement opportunities
- Reductions to stormwater bills for the parking lot owners

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City-owned parking facilities will be targeted as a demonstration of the City's commitment to using GSI in the role of CSO control. CRW will work with the City to consider Zoning Code and/or additional ordinance enhancements to require green buffers around parking facilities to include the function of a stormwater management measure.

CRW's green parking lot initiative will evaluate two strategies: depaving and prioritizing public parking lots for incorporating GSI. Some projects may utilize both strategies. Depaving projects would involve the removal of large sections of asphalt, replacing it with GSI such as rain gardens to manage stormwater runoff from the remaining impervious areas. CRW is following a nationwide movement to remove unnecessary impervious surfaces to create urban green space (see www.depave.org). CRW believes depaving projects offer a high benefit-to-cost ratio. These projects may be eligible for grant funding and are of relatively low cost due to little if any design necessary and the potential for volunteer labor to break apart the paving materials. In addition to depaving project areas, one of the goals of the depaving projects is to educate local volunteers and community members about watershed health, by involving them in the design and construction of a collaborative project.

9.2.2.8 Implementation Services

Table 9-5 lists the types of services under CRW's Decentralized Green / Grey Implementation Strategy.

Table 9-5: Services to Implement CRW's Decentralized Green / Grey Implementation Strategy

Type of Service	Description	Existing Service?
Neighborhood Planning and Concept Development	Administer Pilot and Demonstration Projects, integrate GSI into Synergistic Project Opportunities, prepare stormwater improvement plans for Strategic GSI Implementation Areas, evaluate vacant property re-utilization opportunities and green parking lots initiative.	Partial
Development Review/ Storm-water Control Inspections	Review/approve development/redevelopment plans and credit applications, inspect Stormwater Control Measures.	Partial
Integrated CRW Regulations/ Technical Guidelines	Enhance and enforce stormwater regulations, prepare guidance documents, typical details, and standard specifications for GSI	Partial
Stakeholder Engagement Services	Engage stakeholders as necessary to support decentralized green/grey implementation strategy	Yes

9.2.3 Asset Operation and Maintenance Strategy

CRW is committed to ensuring that its stormwater/wastewater assets, including SCMs implemented to control CSOs, MS4 discharges, and unauthorized releases, continue to operate as designed. CRW is evaluating and documenting maintenance requirements of green stormwater infrastructure, and plans to prepare a Green Stormwater Infrastructure Maintenance Manual Process Plan. CRW anticipates SCMs both from public and private investments, each requiring ongoing inspection and maintenance. CRW's GSI maintenance program seeks to:

- Ensure sufficient maintenance of GSI to keep assets performing as designed,
- Develop long-term maintenance and monitoring protocols,

- Assess existing organizational capacity for supporting maintenance and monitoring among CRW's partnering organizations, and
- Provide feedback loops to inform the GSI design group based on maintenance, inspection and monitoring experiences to improve future designs.

Over the initial implementation phase, CRW will develop guidelines for an expanded maintenance program as the number of GSI sites increases.

9.2.3.1 Monitoring, Controls and Telemetry

Most components of CRW's AWTF and collection system are old and in need of replacement and renewal. Outmoded monitoring and control systems are in need of replacement, a key consideration of the many baseline alternatives to rehabilitate and enhance major systems at the AWTF and two major pumping stations. It is anticipated that modern monitoring and control technologies will be included in these projects.

In addition, the baseline alternative describes a major upgrade to CRW's CSO regulators, replacing existing Brown and Brown regulators with modern gates and controls to better direct wastewater flows to the interceptor, prevent interceptors from surcharging into the regulators, and limit river intrusion. Design of these enhancements will include evaluation of appropriate technologies, and give consideration to technologies that can provide real-time operation and have the capability to be linked into a telemetered system. Pilot testing of monitoring and telemetry of CSO detection devices found promise in such technologies, but observed that technologies are rapidly evolving and a final decision on the level of monitoring, control, and telemetry should be deferred until regulator upgrades are imminent. At this time, CRW will apply its H&H model to evaluate potential operational strategies and further define beneficial uses of available technologies to optimize system operation and minimize CSOs.

9.2.3.2 Maintenance of Public Facilities

CRW intends to maintain publicly funded GSI projects at regular intervals. To do this, CRW needs to determine the maintenance needs associated with various types of SCMs, to better understand maintenance costs, and to gather information needed to establish a long-term maintenance and monitoring program for CRW. CRW anticipates that future SCM design modifications may be influenced by previously built demonstration projects through multiple feedback and communication pathways.

9.2.3.3 Maintenance of Private Facilities

CRW anticipates that SCMs will be designed, built, owned, and operated by the private sector as areas of the City are redeveloped, triggering the City's Stormwater Regulations. CRW needs to develop several mechanisms to ensure that the stormwater management facilities put in place by private entities will continue to function as designed.

The City's Stormwater Regulations will be revised to require that an Operations and Maintenance (O&M) Agreement is recorded against the land deed(s) associated with the development project prior to CRW signing off on a building permit application. The O&M Agreement's purpose is to clearly define the location of the SCMs on the property and to record the proper maintenance practices and schedule for each SCM type.

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The O&M Agreements must also provide CRW with the right to inspect SCMs to verify that they are properly functioning and that maintenance is occurring. If a property owner fails to properly maintain the system, the Agreement must provide CRW with the ability to correct deficiencies and charge the costs of repairs to the property owner.

CRW inspects construction sites during the installation of SCMs so that functional problems can be addressed before the maintenance period starts. As-built plans are required after SCMs are constructed and the provision of detailed drawings is important for planning and administering proper maintenance activities.

Maintenance and monitoring activities will remain the responsibility of the private owner or operator. If inspection or monitoring reports indicate that an SCM is no longer functioning, there are several maintenance response mechanisms CRW should have the right to implement. CRW will evaluate the following options to increase enforcement and ensure the long-term maintenance of private GSI:

- Remove the stormwater credit from the property's water bill,
- Perform necessary maintenance or repairs on the SCM and bill the work back to the property owner,
- Work with PA-DEP to enforce compliance with NDPES permits and Post Construction Stormwater Management Plans, and
- Develop a new enforcement procedure in the Harrisburg Stormwater Regulations allowing CRW to issue fines for non-compliance with the approved Stormwater Management Plan.

CRW will use a combination of these approaches to ensure long-term maintenance of private SCMs.

9.2.3.4 Green Stormwater Infrastructure Maintenance Manual Process

CRW intends to prepare a Green Stormwater Infrastructure Maintenance Manual Development Process Plan that describes the process leading to the development of the Green Stormwater Infrastructure Maintenance Manual. Described herein are anticipated tasks necessary for developing this deliverable and preparing CRW for development of the Green Stormwater Infrastructure Maintenance Manual.

Green Stormwater Infrastructure Maintenance Manual Process Plan Development Tasks

Program support needs will be evaluated as the number of SCMs to be maintained increases. Initial estimates will be based on current staffing and budgeting, with an evaluation of the projected needs as the program evolves.

Quantitative and qualitative data from monitoring reports will be used to determine the appropriate level of monitoring, maintenance and data reporting for each type of SCM in the long-term. Data from on-going maintenance of current publicly-owned SCMs will also provide cost estimates for the maintenance of SCMs and will help CRW determine a budget for SCM maintenance.

CRW intends to compile SCM maintenance protocols from across the country. The compiled information will be used to better understand routine maintenance tasks and their recommended frequency. This research will also help CRW develop standard operating procedures (SOPs) for maintenance and construction processes.

As described in Section 10, CRW is developing a *City Beautiful H_20 Program* tracking system to store standard data input forms, process the input data, and connect with the Cityworks Maintenance Management System. The Cityworks system is where maintenance, monitoring and inspection activities will be scheduled and tracked. The tracking system will track information collected during the maintenance process. This system could be used to electronically notify the respective units of projects requiring attention. CRW views this centralized system as a tool for staff and contractors to view equipment needs for the assigned tasks, to view past work on the site, and to download site plans including as-built plans. Reporting and feedback loops between CRW and other agencies for public and private SCM development should be formalized so that maintenance activities are triggered by appropriate monitoring and inspection data.

CRW will continue research to refine SOPs for SCMs, and will determine maintenance schedules and checklists, as appropriate. Maintenance responsibilities specific to each SCM type will be added to the Green Stormwater Infrastructure Maintenance Manual. This will standardize maintenance practices and eliminate the need for details to be located in individual O&M agreements attached to deeds.

The training of maintenance staff and contractors should be integrated with the training of inspection and monitoring staff. This will ensure that all three groups understand how their actions and testing results can trigger actions by another group. Common monitoring and inspection triggers and maintenance responses should be extracted from CRW research and earlier maintenance contract reports. Once the common triggers are identified, monitoring and inspections units must be informed of what to look for and what data to collect. It is also important to ensure that there is communication with property owners adjacent to SCMs to inform them how they may support site maintenance with periodic evaluation for trash removal, by watering of vegetation, and by contacting the appropriate unit within CRW if an issue emerges.

The Private Green Stormwater Infrastructure Inspections program will expand to include periodic post-construction inspections to ensure long-term maintenance of the SCMs. This will require additional staff, training for developers and contractors, and establishment of a defined inspection schedule based on a number of criteria. A framework for this program's development will be included in the Green Stormwater Infrastructure Maintenance Manual Development Process Plan. A full program description will be included in the Green Stormwater Infrastructure Maintenance Manual.

To formalize the post-construction process to ensure long-term maintenance, CRW is considering the following options:

- Use right-to-access for regular inspections of all sites at least once a permit cycle (every 5 years)
- Random inspections

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- Targeted inspections to supplement and enforce a self-inspection program
- On-going inspection program

Table 9-6 lists the types of services under CRW's Asset Maintenance Strategy.

Table 9-6: Services to Implement CRW's Asset Maintenance Strategy

Type of Service	Description	Existing Service?
AWTF O&M	Operate and maintain CRW's AWTF	Yes
Pump Station O&M	Operate and maintain CRW's pumping stations	Yes
Interceptor O&M	Operate and maintain CRW's interceptors	Yes
Collection System O&M	Operate and maintain CRW's inlets and collection system	Yes
Street Sweeping	Perform as necessary	Yes
Environmental Compliance/ Illicit Discharge Investigations	Administer industrial pretreatment program, enforce pollution prevention and illicit discharge detection/elimination regulations	No
GSI/SCM inspections and O&M	Inspect private and maintain public GSI/SCMs, including preparation of O&M guidance and plans	No
Other Operations Management		Yes

9.2.4 Internal and Intergovernmental Communications and Coordination

CRW will continue to promote effective interagency coordination to define strategic policies and streamline protocols and communication pathways to better align with full-scale GSI implementation. In addition, an Internal Communications Plan to improve synchronization within CRW is in development.

9.2.4.1 Strategic Policy and Coordination Program

One of the first steps in the evolution from demonstration to implementation is the initiation of an internal staff evaluation aimed at understanding staffing needs to support programmatic expansion. This Strategic Policy and Coordination Program will identify and evaluate policy barriers to the Program Plan implementation, and will initiate strategies to address these challenges. Many of the priority policy and coordination needs will be identified by CRW Engineering to build the queue of projects for implementation. A liaison position will be created to collect and prioritize policy and coordination needs as they develop, and to ensure that they are evaluated by the Strategic Policy and Coordination staff.

The group also will track local, state and federal policy developments that may affect *City Beautiful H_2O Program* goals, and will identify strategies to address or respond to them. This group will centralize coordination with other City and Non-City agencies to achieve policy goals and realize opportunities to enhance the *City Beautiful H_2O Program*.

9.2.4.2 Internal Communications Plan

As described in Section 2, CRW is a large agency with employees that run its various programs and meet compliance obligations. With so many regulatory tasks under its purview, CRW has over the years separated responsibilities among its working groups for the sake of efficiency. In an effort to better understand the responsibilities of these groups, to streamline processes where

possible, and to raise efficiency in tackling implementation commitments, CRW is developing an Internal Communications Plan. This plan will identify key points of contact and clarify roles and responsibilities intended to improve the effectiveness of internal collaboration, maintain a shared vision, and support the realization of Partial Consent Decree (PCD) obligations.

9.3 Implementation Assessment and Adaptive Management Strategy

Implementation of the requirements within the approved PCD will rely upon an adaptive management process. An adaptive management approach requires flexibility and periodic program assessments throughout the implementation period. Adaptations in the management approaches are expected throughout this period to ensure that compliance goals are met, to optimize and enhance the program, to maximize benefits and minimize the costs of implementation. Major decisions on management approaches will be made in year 10 of the Program Plan and every five years thereafter based on progress toward the goals and will be described in EAPs.

9.3.1 Adaptive Management Triggers

This Program Plan outlines an adaptive management process with "decision points". These decision points are used to evaluate progress towards Program Plan implementation and determine refinements to the implementation approach gained from "lessons learned" and new information acquired during the implementation period. These quantitative targets require the development of a number of policy and infrastructure tools in the first ten years, and in subsequent years, in particular to support GSI implementation within affordability constraints. The GSI component of the Program Plan is intended to provide for the gradual, continual conversion of the hydrologic characteristics of the Harrisburg combined and separate sewer areas that will consequently reduce the frequency and volume of overflows from the combined sewer system and improve the quality of MS4 discharges. The more traditional infrastructure elements of the Program Plan implementation program, including implementation of AWTF and conveyance system upgrades, also should be evaluated to assess their progress toward the process components outlined in the facility concept plans.

9.3.2 Financial Capability Re-Assessment

Financial capability will help determine what programmatic changes will be feasible, necessary, and achievable. Local economic conditions, including changes in household income, revenue, capital spending in response to new regulations or requirements, construction and operating costs, and CRW's financial position and cost of capital, will be assessed. Adjustments to the program that either increase the rate of progress toward goals or decrease spending to avoid economic hardship will be considered.

9.3.3 Evaluation and Adaptation Plans

To illustrate potential program modifications with approved EAPs, CRW developed a program implementation schedule, presented in Section 11. This schedule is intended to illustrate that a program modification could be made once, at year, 10, 15 or 20 and then not needed again for the life of the program, or a program modification might be incorporated at each decision point, or may never be needed at all. Each EAP will be a comprehensive assessment of CRW's progress

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towards full implementation of the approved Program Plan with descriptions of program elements expected to be implemented in the next reporting period. Each EAP also should include the following components:

- Performance tracking of the Program Plan using H&H models that have been validated with monitoring data, as described in Section 10 of this Program Plan.
- Up-to-date values for each reporting metric with detailed descriptions of how the reported values are estimated and an assessment of how each metric's reported value compares to the Performance Standards defined in this Program Plan.
- If any reported metric value does not equal or exceed the corresponding Performance Standard, CRW will include in that EAP an adaptive strategy for altering appropriate elements of program implementation. This strategy shall describe how CRW proposes to ensure that the metric will meet the appropriate Performance Standard by the date of the next EAP.
- Up-to-date values for the following additional metrics:
  - Number of decentralized control (green/grey) projects and the impervious area they control.
  - Volume of stormwater (in million gallons per year) managed by new infrastructure, not including decentralized control (green/grey) projects.
  - Volume percent capture for the combined sewer system as a whole.
  - Customer reports of unauthorized releases and SSOs, and detailed plans/schedules for system improvements to address them.
  - CCTV inspection results and collection system assessment findings, defining risks, priorities, and budgets for collection system rehabilitation.

The EAP will include a description of the outcome of adaptive management decisions and changes in implementation for the next reporting period. Any proposed change in priorities or approach for meeting the milestones in the reporting period will be described in this section, including altering approaches to implementing GSI and, if necessary, targeted traditional infrastructure investments or changes in design approaches. The modified approach would provide details on a project or series of projects that would compensate for missed metrics associated with the Performance Standards.

9.3.4 Adaptive Management Reporting

Updates on the adaptation of the implementation program will be provided through CRW's annual reporting process. If CRW fails to achieve one or more of the metrics documented in an EAP, the subsequent Annual Reports shall include an update describing progress towards meeting those metrics. Such updates must be provided in subsequent Annual Reports until all the applicable metrics have been achieved.

Section 10

Post-Construction Monitoring

10.1 Post-Construction Monitoring Overview

Post-construction compliance monitoring is a required element for all long term wet weather plans, and is intended to provide sufficient information to estimate the effectiveness of the control measures implemented under the *City Beautiful H_2O Program Plan* (Program Plan). It includes measures appropriate for determining the success of the Program Plan in achieving the designated performance standards and in meeting the water quality requirements of the federal Clean Water Act. Section 9 describes the phased implementation and adaptive management strategy for the Program Plan.

This section describes the Post Construction Monitoring Plan (PCMP) developed to verify that activity commitments have been implemented and to quantify and characterize the effectiveness of CRW Program Plan improvements. The PCMP monitoring and reporting activities presented in this section will document the findings of the Immediate Implementation Phase of the Program Plan. PCMP reporting will have two aspects:

- The first will be conducted on an annual basis and implemented through the existing series of annual Chapter 94 reports submitted by CRW to the US Environmental Protection Agency (US-EPA) and the PA Department of Environmental Protection (PA-DEP). Annual reporting will require the following categories of monitoring defined in this Section: administrative monitoring and reporting, precipitation monitoring and assessment, suburban community system monitoring and assessment, CSO overflow detection monitoring, and CSO discharge projections through H&H modeling.

- The second aspect will be the preparation and submission of a comprehensive report after the Immediate Implementation Phase of the Program Plan has been implemented, anticipated approximately 10 years following approval of this Program Plan. The full suite of monitoring defined in this section will be required to support this comprehensive report, including a full re-validation that the hydrologic and hydraulic (H&H) model reflects the collection and conveyance system improvements achieved during the Immediate Implementation Phase.

Eight categories of monitoring and reporting are included in the PCMP and summarized below.

- ***Administrative Monitoring and Reporting:*** Accounting-based factors including impervious area draining to green infrastructure, miles of rehabilitated sewers, annual debris removal volumes, system maintenance efforts, and other appropriate measures will be documented and reported to verify Program Plan commitments have been implemented.

- ***Precipitation Monitoring and Assessment:*** The existing gauge network and gauge adjusted radar rainfall (GARR) data will be used to quantify and characterize precipitation for the PCMP. The current typical year precipitation volumes and frequencies will be used

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by the updated H&H models to quantify and characterize typical year CSO discharge statistics. The high resolution, spatially distributed gauge adjusted radar rainfall (GARR) precipitation data will be used by the H&H models to provide the annual CSO discharge volume, frequency and duration for each CRW CSO outfall location.

- ***Interceptor Monitoring and Assessment:*** The existing network of nine interceptor monitoring sites will be used to quantify and characterize interceptor flow for the PCMP. The flow monitoring equipment will provide the necessary data to successfully measure and typify the distribution of wastewater flow along the CRW interceptor sewer system. Existing interceptor monitoring activities may be suspended until needed to assess the benefits of system improvements as key Immediate Implementation Phase Program Plan items are completed.

- ***Suburban Community System Monitoring and Assessment:*** The existing network of four POC monitoring sites will be used for the PCMP to quantify and characterize dry and wet weather flow from the suburban community separate sanitary sewer systems. The monitors collect and record redundantly monitored wastewater depth, monitored velocity, and calculate flow in 5-minute increments.

- ***CSO Regulator Structure Monitoring and Assessment:***

  - For annual reporting, the daily inspections conducted by CRW crews at all the CSO regulator structures will continue as the Program Plan is implemented. Wooden blocks placed on the crests of the diversion weirs indicate CSO activity, and observations will continue to be logged on a daily basis in the Cityworks asset management system for the PCMP. CRW may use a network of real-time information monitors if a cost effective and reliable technology is identified.

  - To support preparation of the comprehensive report for the Immediate Implementation Phase, the PCMP will also include installing area-velocity meters at 10 selected CSO regulators for a 6-month duration. The resulting data from the inspections and monitoring will be used to validate the revised H&H model.

- ***CSO Discharge Projections through H&H Modeling:*** The calibrated CRW hydrologic and hydraulic model will be used to simulate dry and wet weather flow from all catchment areas within the City of Harrisburg, for both separate and combined sewer systems, and from the suburban community systems. As system improvements are completed as part of the Program Plan, corresponding revisions and updates will be made to the H&H model to reflect these revisions. For the PCMP, the typical year precipitation data will be applied to the updated H&H model, and typical year CSO discharge volume, frequency and duration at each CSO regulator will be computed. The improved condition model results will be compared with the existing condition results to quantify and characterize the performance of the improved CRW system and verify that the level of CSO reductions predicted in the Program Plan are achieved.

- ***Water Quality Monitoring and Assessment:*** Water quality monitoring and characterization for the PCMP will be implemented by partnering with PA-DEP to collect

and assess water quality data. The water quality parameters previously measured by PA-DEP have been total settleable solids, total suspended solids, BOD_5, total nitrogen, total phosphorus, and fecal Coliform bacteria.

- ***Paxton Creek Use Attainability Assessment:*** The water quality compliance strategy for Paxton Creek is to coordinate with PA-DEP to have a Use Attainability Study conducted that would change the use designation for the creek. For the PCMP, CRW will provide progress updates on its coordination activities with PA-DEP as part of its annual Program Plan reporting.

Upon completion of the Immediate Implementation Phase of the Program Plan and annual PCMP reporting activities, a comprehensive Post Construction Monitoring Report will be prepared and submitted to US-EPA and PA-DEP to estimate the effectiveness of the control measures implemented under the Immediate Implementation Phase of the *City Beautiful H_2O Program Plan.*

10.2 Administrative Monitoring and Reporting

Administrative monitoring and reporting activities will be conducted as part of the PCMP to verify that commitments in the Immediate Implementation Phase of the CRW Program Plan have been implemented. Administrative monitoring for the PCMP will be conducted on an annual basis and will be implemented through the existing series of annual Chapter 94 reports submitted by CRW to US-EPA and PA-DEP.

Categories of annual administrative monitoring and reporting for the PCMP will include the following categories of parameters:

- Miles of completed combined sewer CCTV inspections and cleaning that are implemented as part of CRW's ongoing program under its Nine Minimum Control Plan (NMCP).
- Completed rehabilitation or replacement measures to structurally deficient sewer reaches that were identified through CCTV inspections to have NASSCO PACP defect severities of grade 4 and 5 and/or serve as a source of high groundwater infiltration, as identified in the Program Plan.
- Number of catch basins and storm inlets inspected and cleaned under the NMCP and documented using the Cityworks asset management program.
- Miles of street sweeping conducted and tons of debris and solids removed.
- Completed repairs to the Advanced Wastewater Treatment Facility (AWTF), pump stations, CSO outfall pipes, flap gates, and other CRW assets other than sewer pipes.
- Completed modifications to CSO regulator structures such as revising control orifice openings, raising diversion dam crest elevations, repairing outfall pipes, and repairing backflow/river intrusion prevention gates.
- Acres of impervious area draining to completed decentralized green or grey stormwater infrastructure (GSI) control facilities to verify the GSI commitments made in the Program Plan were implemented and functioning properly.

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- Acres of combined sewer system separation completed or acres of completed rerouting to an adjacent storm sewer system to verify that Program Plan commitments were implemented.
- Stakeholder engagement activities
- Environment compliance and enforcement activities achieved such as illicit discharges removed, pollution prevention actions, etc.

10.3 Precipitation Monitoring and Assessment

To quantify and characterize precipitation patterns within the CRW service area, and support the development of the Program Plan, CRW successfully developed and implemented a precipitation gauge network consisting of eight tipping bucket rain gauges located throughout the service area. The gauge network records rainfall depths in 5-minute intervals with a minimum recorded depth of 0.01 inches. All the gauges are heated to allow for accurate measurement of frozen precipitation events during winter. Hourly rainfall data are also collected from the two National Weather Service gauges located at the Capital City Airport and at the Harrisburg International Airport.

Like any rain gauge network, the CRW network cannot quantify and characterize precipitation volumes, intensities, and patterns that occur between the gauge locations. To characterize the spatial variability of rainfall events over the CRW service area, gauge adjusted radar rainfall (GARR) data are obtained and used along with the gauge network data. GARR precipitation data are provided in 5-minute intervals within a high-resolution pixel grid comprised of 1-km by 1-km (0.6-mi by 0.6-mi) cells. A total of 586 pixel cells define precipitation patterns over the CRW service area, including the City of Harrisburg and the separate sanitary sewer collection systems serving the suburban communities.

The existing gauge network and GARR data will be used to quantify and characterize precipitation for the PCMP. The locations of the gauges and the GARR pixels are provided in Figure 3-14. A listing of the gauge locations and their status are provided in **Table 10-1**. The current typical year precipitation volumes and patterns will be used by the updated H&H models to quantify and characterize typical year CSO discharge statistics. The GARR precipitation data will be used by the H&H models to provide the annual CSO discharge volume, frequency, and duration for each CRW CSO outfall location. The GARR precipitation data will also be used to quantify and characterize the monthly and annual differences between actual precipitation volumes and frequencies with those calculated from the long-term record for typical year precipitation. Under Partial Consent Decree (PCD) requirements, precipitation monitoring will continue through the implementation of the Program Plan.

The currently developed synthetic design storm rainfall volumes and patterns for the 2-year, 5-year, and 10-year statistical recurrence intervals will be used to assess the hydraulic performance of the separate sanitary sewer systems within the City and five of the six suburban communities.

Table 10-1: PCMP Precipitation Monitoring Sites

Gauge Name /Number	Gauge Location	Period of Record	Data Collection Status	Data Analysis Status
FAA_ Hourly-KCXY	Capital City Airport	1996 – Present	Ongoing	Ongoing
Harrisburg Int. Airport	Harrisburg Int. Airport	10/1/1991 – Present	Ongoing	Ongoing
RG1	Koons Park	9/3/2014 – Present	Ongoing	Ongoing
RG2	Market Street	8/1/2014 - Present	Ongoing	Ongoing
RG3	CRW AWTP	8/1/2014- Present	Ongoing	Ongoing
RG4	Swatara	9/5/2014 - Present	Ongoing	Ongoing
RG5	United Water	9/12/2014 - Present	Ongoing	Ongoing
RG6	Lower Paxton	9/9/2014 - Present	Ongoing	Ongoing
RG7	East Pennsboro	9/6/2014 – Present	Ongoing	Ongoing
RG8	Steelton	9/5/2014 - Present	Ongoing	Ongoing

10.4 Interceptor Monitoring and Assessment

CRW successfully installed and maintained flow monitors at nine critical interceptor sites to provide the necessary data to successfully quantify and characterize the distribution of wastewater flow along the CRW interceptor sewer system. The monitors collect and record redundantly monitored wastewater depth, monitored velocity, and calculated flow in 5-minute time-step increments. The existing network of interceptor monitoring sites will be used to quantify and characterize interceptor flow for the PCMP. The locations of monitoring sites are provided in **Figure 3-21**. A listing of the monitoring sites and their status are provided in **Table 10-2**. The monitoring duration for PCMP reporting will be a 12-month period after the Immediate Implementation Phase of the Program Plan (approximately 10 years after Plan approval).

The following additional interceptor monitoring activities will be conducted to allow CRW to quantify the impacts of system improvements as key Immediate Implementation Phase Program Plan items are implemented. The monitoring data will allow CRW to verify the system-wide hydraulic performance of the rehabilitated pump stations and the reconfigured regulators.

- After the completion of the rehabilitation measures at the Front Street Pump Station, monitoring will be conducted for a duration of 3 months at the FSI and IS1 monitoring sites along the Front Street Interceptor, at the IS3 and IS2 sites along the Paxton Creek Interceptor, and at the PCRI monitoring site along the Paxton Creek Relief Interceptor.
- After the completion of the reconfiguration of the CSO regulator structures, along the Front Street Interceptor, monitoring will be conducted for a 3-month duration at the FSI and IS1 monitoring sites.
- After the completion of the reconfiguration of the CSO regulator structures, along the Paxton Creek Interceptor, monitoring will be conducted for a 3-month duration at the IS3 and IS2 monitoring sites.

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- After rehabilitation of the Spring Creek Pump Station is completed, monitoring will be conducted for a 3-month duration at the SCI monitoring site along the Spring Creek Interceptor.

Table 10-2: PCMP Interceptor System Monitoring Sites

Monitor ID	Interceptor System	Pipe Diameter (inches)	Data Collection Initiated	Data Collection Status	Data Analysis Status
IS1	Front Street	35.5 H x 30.5 W	8/01/2014	Ongoing	Ongoing
FSI	Front Street	41 H x 42.5 W	8/01/2014	Ongoing	Ongoing
PCI	Paxton Creek	60 diameter	8/01/2014	Ongoing	Ongoing
PCRI	Paxton Creek	48 diameter	8/13/2014	Ongoing	Ongoing
IS2	Paxton Creek	48 H x 59 W (arch)	8/21/2014	Ongoing	Ongoing
IS3	Paxton Creek	60 diameter	8/22/2014	Ongoing	Ongoing
IS4	Paxton Creek	42 diameter	8/18/2014	Ongoing	Ongoing
M250	Hemlock Creek	24 diameter	8/01/2014	Ongoing	Ongoing
SCI	Spring Creek	34 H x 32.5 W	8/13/2014	Ongoing	Ongoing

10.5 Suburban Community System Monitoring/Assessment

CRW installed and maintained flow monitors at each of the four point of connection (POC) monitoring sites where most of the wastewater flows from the suburban community collection systems are conveyed to the CRW system. The existing network of four POC monitoring sites will be used for the PCMP to quantify and characterize dry and wet weather flow from the suburban community separate sanitary sewer systems. The monitors collect and record redundantly monitored wastewater depth and monitored velocity, and calculate flow in 5-minute time-step increments. The monitoring site information and status are summarized in **Table 10-3** and the monitoring locations are provided in **Figure 3-21**. Under Partial Consent Decree (PCD) requirements, suburban community POC monitoring will continue through the implementation of the Program Plan. The collected data for a 12-month period will be analyzed for integration into the PCMP after the Immediate Implementation Phase of the Program Plan (approximately 10 years after Plan approval).

Table 10-3: PCMP Suburban Community POC Monitoring Sits

Monitor ID	Pipe Diameter	Catchment Area (acres)	Data Collection Initiated	Data Collection Status	Data Analysis Status
M9	24 inches	847	8/01/2014	Ongoing	Ongoing
M13	42 inches	12,602	8/15/2014	Ongoing	Ongoing
M32	34 inches	6,716	8/14/2014	Ongoing	Ongoing
M167	24 inches	2,334	8/14/2014	Ongoing	Ongoing

10.6 CSO Regulator Structure Monitoring and Assessment

CRW crews conduct daily inspections of all the CSO regulator structures. Wooden blocks are placed on the diversion weirs and wired to the side wall, and serve as indicators if CSO activity

occurred. If the water level in a regulator structure topped the crest elevation of the diversion dam, and a CSO discharge occurred, the wooden block would be dislodged from the weir crest. The crews check the wooden blocks as part of their daily inspections and log their observation in the Cityworks asset management system. The resulting Cityworks records are used to verify that the H&H model simulations accurately reflect the field inspection observations.

These activities will continue as the Immediate Implementation Phase of the Program Plan is implemented and will serve as the CSO regulator structure monitoring component of the PCMP. The recorded wooden block inspection observation data will be used to verify that as revisions are made to the H&H model to reflect completed improvements to the sewer system, the model simulation results continue to correlate with field observations. As a potential alternative regulator structure monitoring activity, and a possible extension of the completed CSO Activation Monitoring Pilot (CAMP) Study, CRW may elect to use a network of real-time information monitors if an affordable and reliable technology can be identified. The recommendation of the 2016 *CAMP Study Report*[1] was that while a more automated approach of detecting CSO and dry weather overflow activity shows promise, it is premature to implement such technology at present. Existing manual monitoring methods remain reliable and are currently affordable and cost effective compared to the automated approaches. Available technologies are anticipated to evolve as the Program Plan is implemented.

The PCMP will also include installing area-velocity monitoring equipment at eight selected CSO regulators. The equipment will continuously monitor the depth and velocity of the wastewater flowing into the regulator structures, in 5-minute increments, and calculate the influent flow. Redundant depth sensors will also be placed at the diversion dam to monitor the frequency and duration of CSO discharges and estimate the corresponding CSO volumes. The monitoring duration for all eight sites will be a six-month period, after the Immediate Implementation Phase of the Program Plan (approximately 10 years after Plan approval), extending through the spring and summer seasons, and the resulting data will be used to further validate the revised H&H model. A listing of these eight CSO regulator sites is provided in **Table 10-4** and their locations are shown in **Figure 3-22**.

Each of these sites were successfully monitored for a 12-month duration in 2014 and 2015 to calibrate and verify the existing condition model. The eight sites for the PCMP were selected because significant reductions to CSO discharges were predicted to result from implementing the Immediate Implementation Phase of the Program Plan. Previous monitoring sites at regulator structures where significant CSO reductions were not expected under the Immediate Implementation Phase activities were not selected for the PCMP.

In addition to the regulator structure monitoring activities, CSO catchment area monitoring will be conducted at selected sites after the Immediate Implementation Phase of the Program Plan (approximately 10 years after Plan approval), At this point, CRW should have completed its NMCP activity of cleaning and, where necessary, reconstructing all of its catch basins and storm inlets, as well as cleaning and repairing high priority structural deficiencies in collection system sewers. The monitoring will be conducted at four selected sites for a duration of four months to quantify

[1] *CSO Activation Monitoring Pilot Study Evaluation Report*, December 2016.

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the increase in wet weather flow resulting from removing existing bottlenecks in the City combined sewer system due to historical practices of deferred maintenance.

Table 10-4: PCMP CSO Regulator Structure Monitoring Sites

Monitored CSO Regulator Identification	Monitored Catchment Identification	Catchment Area (acres)	Pipe Size H x W or Diameter (inches)	Interceptor System
CSO-005	S-005	69.5	61 H x 48 W	Front Street
CSO-014	S-014	29.9	34.5	Front Street
CSO-021	S-021	149.3	51 and 24	Paxton Creek
CSO-031	S-031	220.0	60 H x 48 W	Paxton Creek
CSO-037	S-037	74.2	66 H x 48 W	Paxton Creek
CSO-050	S-050	41.8	48	Front Street
CSO-052	S-052	21.9	30 H x 36 W	Front Street
CSO-062	S-062	10.4	15	Hemlock Street

10.7 CSO Discharge Projections through H&H Modeling

The calibrated CRW hydrologic model simulates dry and wet weather flow and represents all catchment areas within the City of Harrisburg contributing to the conveyance system, for both separate and combined sewer systems. The hydrologic model also simulates the wastewater flows from the suburban community systems. The hydraulic model simulates how the flows are conveyed through the sewer system, including the CSO regulator structures and pump stations, to the AWTF. The GARR high-resolution precipitation data are input to the H&H model, and CSO discharge volume, frequency and duration at each CSO outfall are computed. These CSO discharge statistics are reported to PA-DEP. These modeling and reporting activities will continue, on an annual basis, as the Immediate Implementation Phase of the Program Plan is implemented during the first 10 years after Plan approval. Existing condition CSO discharge statistics resulting from typical year precipitation were computed for the CRW Program Plan, and will serve as a baseline for quantifying the CSO reduction benefits resulting from implementing the Program Plan.

As system improvements are completed as part of the Program Plan, such as the rehabilitation of pump stations, the reconstruction of regulator structures, and the installation of green stormwater infrastructure projects, corresponding revisions and updates will be made to the H&H model to reflect these revisions. It is envisioned that these model revisions will be made on an annual basis. For the PCMP, the typical year precipitation data will be applied to the updated H&H model, and typical year CSO discharge volume, frequency and duration at each CSO regulator will be computed. The improved condition model results will be compared with the existing condition results to quantify and characterize the performance of the improved CRW system and verify that the level of CSO reductions predicted in the Program Plan are actually achieved.

10.8 Water Quality Monitoring and Assessment

Water quality monitoring and characterization for the CRW PCMP will be implemented by partnering with the PA Department of Environmental Protection (PA-DEP) to collect and assess

water quality data. Available sampling data and analysis results from ongoing PA-DEP studies and those of the Susquehanna River Basin Commission will be obtained and reviewed. The water quality parameters previously measured by PA-DEP have included total settleable solids, total suspended solids, BOD_5, total nitrogen, total phosphorus, and Fecal Coliform bacteria.

10.9 Performance Standards

The CRW PCMP will include quality assurance and quality control (QA/QC) measures to determine if the network of precipitation and flow monitoring equipment provides representative, accurate, and reliable data. QA refers to programmatic efforts to ensure the quality of monitored and field measured data and increase confidence in the validity of the reported analytical data. QC, a subset of quality assurance, refers to the application of procedures designed to obtain prescribed standards of performance in monitoring. The QA/QC protocols, standards and procedures used to implement past and existing monitoring and sampling activities will continue to be utilized and implemented for the PCMP.

10.10 Paxton Creek Use Attainability Assessment

There is currently no contact recreation within Paxon Creek and the physical configuration of the channel would not support or encourage contact recreation. The compliance strategy for CRW is to coordinate with PA-DEP to have a Use Attainability Study conducted that would change the use designation for Paxton Creek. For the PCMP, CRW will provide progress updates on its coordination activities with PA-DEP as part of its annual Program Plan reporting.

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Section 11

Recommended Plan and Implementation Schedule

11.1 Overview of the Recommended Plan

The *City Beautiful H_2O Program Plan* (Program Plan) is a long-term, integrated strategy to address the hydraulic and structural deficiencies of Capital Region Water's (CRW) wastewater and stormwater assets, improve in-stream water quality, and protect public health. Many alternative technologies, specific decentralized green/grey projects, and levels of control were evaluated. This section summarizes the measures recommended by the following sections of the Program Plan:

- Recommended capital projects (Section 8)
- Implementation/adaptive management programs (Section 9)
- Post-construction monitoring measures (Section 10).

This recommended plan and implementation schedule represents the most affordable and cost-effective balance between control of wet weather issues (CSOs, SSOs, and MS4 discharges), rehabilitation of CRW assets, and enhancing service area communities.

The Financial Capability Assessment (FCA) presented in Section 7 is used to identify an affordable level of investment in this Program Plan, one that maintains CRW wastewater rates at no more than two percent of the median household income (MHI) within the City of Harrisburg ($33,289 in 2015). This level of investment would fund the following components of the Program Plan over the next 20 years:

- CRW's 2018 budgeted and anticipated operational expenses of $14.3 million annually.
- An estimated bond repayment amount of approximately $18.8 million annually, used to finance:
  - Past capital improvements (e.g., biological nutrient removal at CRW's AWTF),
  - Up to approximately $13 million (escalated and in 2017 dollars) for early action wet weather control projects,
  - Up to approximately $113 million (escalated), or $102 million (in 2017 dollars) for priority projects to address critical Advanced Wastewater Treatment Facility (AWTF) and conveyance system rehabilitation needs, some that also provide significant CSO control benefits.
  - Up to approximately $88 million (escalated), or $64 million (in 2017 dollars) for additional wet weather control projects, and

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- Up to $101 million (escalated), or $74 million (in 2017 dollars) be expended on collection system rehabilitation projects.

Table 11-1 defines implementation phases, the anticipated level of CSO volume control achieved, and the estimated available level of expenditure within each phase to maintain CRW wastewater rates at no more than two percent of the MHI. While CSO volume capture is presented as the primary metric for compliance during each implementation time frame, more affordable and cost-effective projects that improve water quality and/or reduce SSOs/unauthorized releases may receive a higher priority for implementation under the integrated stormwater/wastewater planning framework.

Table 11-1. Implementation Phases, Affordable Costs, and CSO Control Volume Targets

Phase	Anticipated Time Frame	Projected Type	Affordable Spending (Escalated)	Affordable Spending (2017$)[2]	CSO Volume Capture[3]
Existing	N/A	N/A	N/A	N/A	53%
Immediate	0-10 years	Rehabilitation	$165 million	$146 million	79%
		Wet Weather	$60 million	$50 million	
Near-Term	10-20 years	Rehabilitation	$49 million	$31 million	80%
		Wet Weather	$41 million	$26 million	
		Total	**$315 million**	**$253 million**	

[1] Partially funded via 30-year revenue bond
[2] Includes up to $5M annual stormwater fee revenue
[3] During the typical year

Specific investments to CRW's stormwater/wastewater assets will be defined periodically through a decision-making process, implemented through the ongoing adaptive management process presented in Section 9, that weighs the following factors:

- The Business Risk Exposure of each asset, established through CRW's asset management program.
- The public health and welfare benefits to CRW ratepayers provided by the investment.
- The degree of water quality enhancement achieved by the investment.
- Synergies with other investments within the City, including opportunities for collaboration with other implementation partners and/or sources of funding.
- The affordability and cost-effectiveness of the investment.
- The effectiveness of previous investments determined through post-construction monitoring and hydrologic and hydraulic (H&H) modeling.
- Appropriate phasing of investments to avoid short-term degradation to current conditions.
- An appropriate investment in the operation and maintenance of the CRW wastewater/stormwater systems and administration of the Program Plan.

- Changes to the financial capabilities of CRW's ratepayers.

The Program Plan is an opportunity to select an alternative to bolster public support for improvements that address modern challenges to managing water resources and infrastructure in a sustainable way. CRW's recommended alternative provides a clear pathway that reinvests and rehabilitates wastewater/stormwater assets; brings community leaders, stakeholders, and residents together; and complies with environmental laws and regulations to improve the health of local waterways.

11.2 Primary Objectives of the Program Plan

The primary objectives of the Program Plan, that must be met for the recommended plan, are:

- To address priority risks and achieve regulatory compliance within the financial capabilities of CRW and its ratepayers.
- To rehabilitate wastewater/stormwater assets that have been compromised by deferred maintenance, improve substandard operations of these assets, and restore their structural and operational integrity.
- To reduce pollutant discharges to receiving waters from CSOs, MS4s, and the AWTF.
- To mitigate the effects of hydraulic capacity constraints projected to cause separate sanitary sewer overflows (SSOs) and unauthorized releases from combined sewers, as these impact public health and safety.
- To stabilize streambanks where excessive erosion causes stream degradation.
- To establish an administrative framework with sufficient resources to collaborate with stakeholders affecting, affected by and/or participating in the Program Plan.
- To implement an ongoing operation and maintenance program and an asset management plan, with sufficient budget, labor and equipment resources to protect and preserve the integrity and functionality of the wastewater/stormwater systems.
- To enhance benefits to and minimize impacts on environmental justice populations.

11.3 Recommended Program Plan

This section summarizes the primary recommendations of the Program Plan and describes how the recommended program plan will meet the primary objectives itemized above.

11.3.1 CRW's Financial Capabilities

A financial capability assessment for the Program Plan was prepared using criteria suggested by the US Environmental Protection Agency (US-EPA) (see Section 7). The US-EPA's approach calls for an evaluation of costs of the proposed improvements against Harrisburg citizen's MHI. In general, the US-EPA considers wastewater costs above two percent of median household income to be an unacceptable cost burden to ratepayers. The affordability and financial capability analysis presented in Section 7 identifies an upper limit on the level of spending that CRW and its

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ratepayers can sustain without severe hardship. Socioeconomic analyses generally point to slow economic growth in the Harrisburg region for the next 20 years. The trends highlighted in the analysis provided in Section 7 are predictive of an increasing burden on ratepayers for wastewater treatment costs prior to the enactment of any wet weather compliance measures by CRW. It is important for CRW, the Pennsylvania Department of Environmental Protection (PA-DEP) and the US-EPA to negotiate a level of wet weather control and an implementation schedule that recognizes the financial burden on ratepayers and the permittee that will result from wet weather compliance measures, and that the affordability of the selected alternative must be one of the considerations in selecting the preferred alternative. This recommended plan serves as an optimal starting point for those negotiations.

11.3.2 A Recommended Program Plan Defined by CRW's Financial Capabilities

CRW's recommended plan, based upon an Affordable Level of Control laid out in Section 8, is the combination of the Baseline Control Strategy, a decentralized control (green-grey) strategy, and a rehabilitation and renewal strategy that can be implemented within reasonable limits of affordability for the ratepayers of CRW. The Affordable Level of Control establishes a cap to investments in the operation, maintenance, rehabilitation, and enhancement of CRW stormwater / wastewater assets under the recommended program plan. This cap on the investment for regulatory compliance retains sufficient resources for the rehabilitation of critical sewer system facilities and sustains a healthy balance between environmental compliance and system renewal.

CRW is progressing through broad scale capital improvements to the wastewater collection, conveyance, and treatment system. These investments are to improve system function and performance to ensure reliable operation of system components. In addition to these renewal and remedial costs, CRW is committed to addressing requirements under the Clean Water Act while recognizing the financial burden imposed on ratepayers for these improvements.

For some customers within the City, the cost as a percentage of income will far exceed two percent. The cost as a percentage of income for some Census tracks within the City, representing approximately 17 percent of the population, are anticipated to exceed three percent, of MHI, and several census tracts, representing an additional four percent of the population, will be in the 2.5 – 3.0 percent range. This indicates that increases in wastewater and stormwater costs to residential customers within the City would result in an unreasonably high economic burden for some customers, even if the cost as a percentage of the MHI stays near two percent.

11.3.3 Rehabilitation of Wastewater/Stormwater Assets

A primary objective of the recommended Program Plan is the rehabilitation of wastewater/stormwater assets to resolve deferred maintenance of these assets, improve substandard operations of these assets, and restore their structural integrity. Improvements listed in **Table 11-2,** considered to be the baseline level of control in Chapter 8, strive to rehabilitate and repair the most critical system assets during the Immediate Implementation Phase. The recommended projects will both restore the structural integrity of these systems (minimizing failures that could potentially threaten severe water quality degradation and public safety) and optimize conveyance to the AWTF, increasing CSO capture from 53 to 78 percent during the typical year. CRW anticipates investing up to $113 million (escalated), or $102 million (in 2017 dollars) on these projects during the 20-year planning horizon of the Program Plan. It is

anticipated that additional AWTF and conveyance system assets may require rehabilitation and renewal over the next 20 years beyond that programmed in Table 11-2. These costs also cannot be projected at this time, and any costs that do emerge must also be funded through CRW's remaining financial capabilities.

Table 11-2: Recommended Projects for Rehabilitation of Wastewater/Stormwater Assets

Project	Existing/ Planned Project?	Implementation Phase	Wet Weather Control?
Paxton Creek Interceptor Rehabilitation	Yes	Immediate	Yes
Asylum Run Rehabilitation	Yes	Immediate	Yes
Front St. Rehabilitation	Yes	Immediate	Yes
Spring Creek Rehabilitation	Yes	Immediate	Yes
Headworks Screening	Yes	Immediate	Yes
Primary Clarifier Improvements/Repair	Yes	Immediate	Yes
Front St. Pump Station	Yes	Immediate	Yes
Spring Creek Pump Stations	Yes	Near-Term	Yes
City Island Pump Stations	Yes	Near-Term	No
Other WWTP Rehabilitation (not wet weather)	Yes	Immediate	No
CSO Regulator Enhancements	No	Immediate	Yes
Collection System Rehabilitation (known)	Yes	Immediate	Yes
Collection System Rehabilitation (unknown)	No	Both	Yes
Long-Term AWTF/Conveyance System Renewal	No	Near-Term	Yes

CRW is unable to provide an accurate estimate of the anticipated cost to rehabilitate collection system assets. The rapid assessment described in Section 4 developed an initial estimate of over $100 million (in 2017 dollars) to repair collection system assets. These estimates and their repair priority are considered preliminary based on the limited visibility of pole zoom camera technology. A comprehensive CCTV inspection of the entire collection system is underway, prioritized based on the rapid inspection findings, and critical collection system rehabilitation projects have already been identified for implementation in 2018. Additional projects are anticipated; however, the scope, breadth, timing, and cost of these projects cannot be determined at this time. As a result, a significant portion of CRW's remaining financial capability will be required indefinitely to support critical collection system repair, diminishing opportunities for wet weather control beyond that achieved through baseline improvements.

11.3.4 Reduce Pollutant Discharges to Receiving Waters

Reducing pollutant discharges to receiving waters from CSOs, MS4s, and the AWTF is a core objective of CRWs recommended Program Plan. In addition to requirements of achieving compliance with the National CSO Policy, CRW must also address the objectives of the Pennsylvania Chesapeake Watershed Implementation Plan. Decentralized control (green-grey) supplements the control achieved though conveyance/treatment system rehabilitation, further

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controlling pollutant releases from CSOs and MS4s. This is the primary recommendation to reduce pollutants to address these separate objectives. **Figure 11-1** illustrates the amount of green stormwater infrastructure that can be installed within CRW's financial capabilities, and the level of CSO control achieved through this investment. For example, **Table 11-3** lists pilot decentralized control (green-grey) and streambank stabilization projects that CRW is committed to build during the Immediate Implementation Phase, estimated to cost approximately $13 million (escalated and in 3017 dollars). CRW anticipates that other public works and development projects will emerge during this period where decentralized controls are feasibly

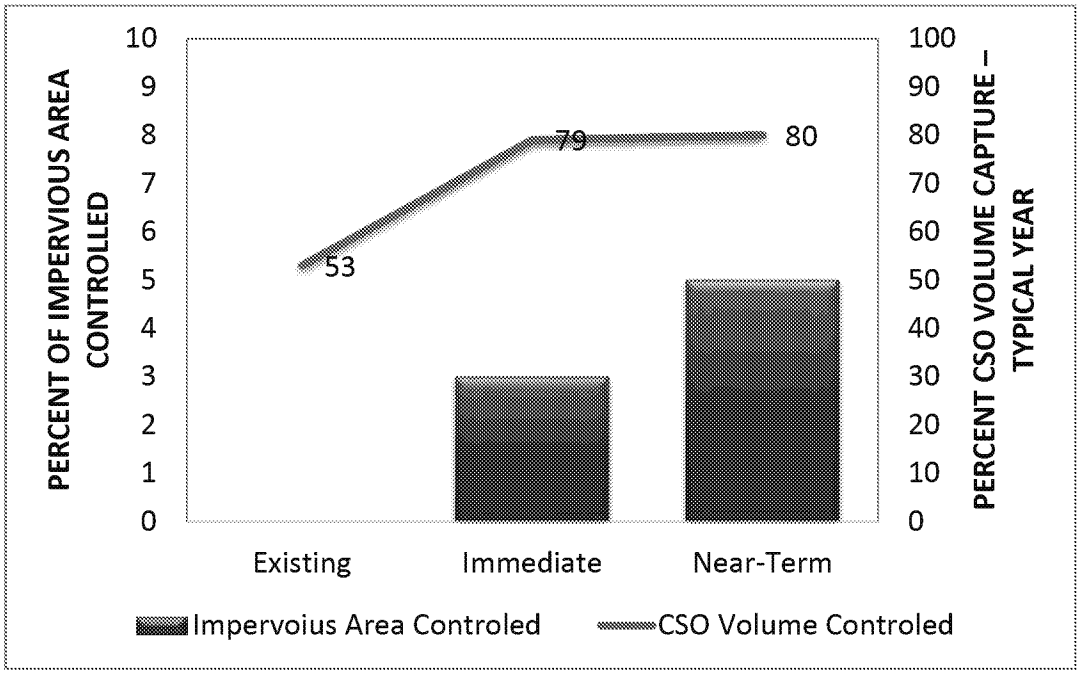

Figure 11-1. Typical Year CSO Volume Controlled through Phased implementation of Decentralized Controls (Green-Grey)

integrated.

Table 11-3. Recommended Early Action Wet Weather Control Projects

Project Name	Existing/ Planned Project?	Implementation Phase
Third St. Multi-Modal GSI	Yes	Immediate
Parks GSI	Yes	Immediate
Summit Terrace Green Neighborhood GSI	Yes	Immediate
Camp Curtain Big Green Block GSI	Yes	Immediate
MulDer Square GSI	Yes	Immediate
South Allison Hill GSI	Yes	Immediate
2nd St. / 7th St. Multi-Modal GSI	Yes	Immediate
Paxton Creek Stream Restoration	Yes	Immediate

While CRW expects to implement this recommended level of green stormwater infrastructure (GSI) over the Immediate and Near-Term Implementation Phases of this Program Plan, competing uncertainties may affect the level of implementation CRW is able to implement:

- The cost and risk associated with collection system structural rehabilitation discovered via the CCTV program.
- The amount of outside funding (e.g., development contributions, grant funds, public-private partnerships) that emerge to implement GSI over the 20-year implementation period.

Adaptive management will monitor these unknown factors and adjust CRW's ability to meet this demand. This process is illustrated in **Figure 11-2**, which indicates the routine decision-making process required to properly balance the risks associated with unmet system rehabilitation and renewal, and the opportunities, benefits, and outside funding potential of decentralized control projects.

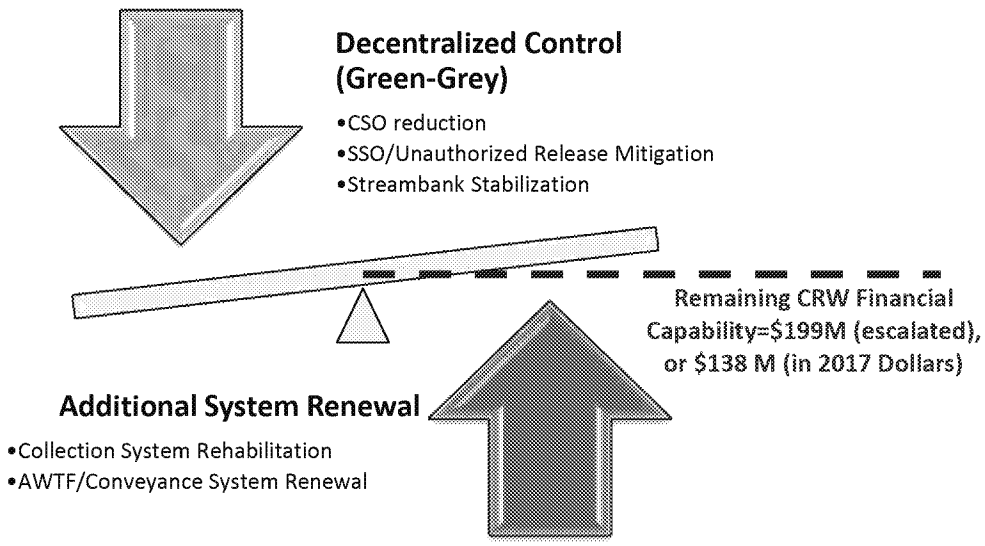

Figure 11-2. Adaptive Management Strategy for Additional, Affordable Investments

According to the Financial Capabilities Assessment presented in Section 7, CRW's remaining annual financial capability is approximately $199 million (escalated), or $138 million (in 2017 dollars) over the next 20 years. Remaining financial capability is defined as the revenue CRW wastewater rates can generate within a median household indicator of two percent to provide funding for project/programs, beyond its existing commitments, (as reflected in CRW's 2018 operational budget) and existing/known capital improvements (reflected in CRW's latest Consulting Engineers Assessment Report).

11.3.5 Mitigate Unauthorized Releases

The recommended Program Plan also seeks to mitigate the effects of hydraulic capacity constraints projected to cause SSOs and unauthorized releases from combined sewers, as these impact public health and safety. Hydrologic and hydraulic modeling was used to quantify and characterize the hydraulic performance of the sewer system and identify locations for potential

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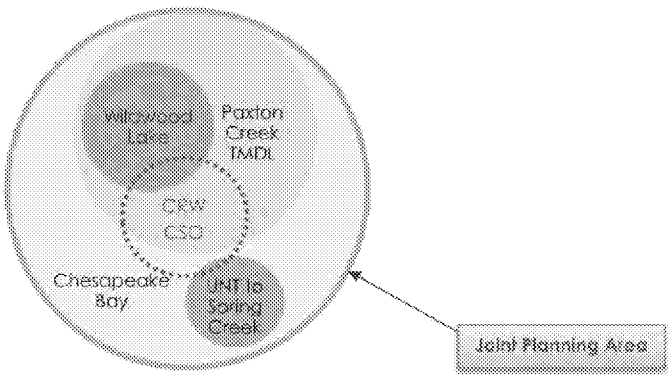
SSO discharges and/or unauthorized releases from the combined sewer system. System inspection data and subsequent analyses were used to characterize the condition of the existing conveyance and collection systems, and to identify critical defects and hydraulic bottlenecks that need to be corrected as part of the Program Plan. Together these analyses identify the most critical areas to address and mitigate unauthorize releases from the sewer systems. CRW will prioritize projects to address these releases along with achieving other objectives of the Program Plan. A decentralized control (green-grey) strategy allows capital improvements to control both pollution and unauthorized releases at several scales, from basement to street flooding. Resources can be shared with multi-objective projects that reduce CSO volumes and repair and rehabilitate existing assets.

11.3.6 Stabilization of Streambanks



An additional objective of CRW's recommended Program Plan is to stabilize streambanks where excessive erosion causes stream degradation. During the immediate implementation phase, CRW has teamed with Lower Paxton and Susquehanna Townships on a Joint Pollution Reduction Plan (PRP), a requirement of PA-DEP's MS4 permitting program. The Joint PRP commits CRW and its partner jurisdictions to implement nearly 18,000 feet of bank stabilization, at an estimated cost of $8,220,000 (in 2017 dollars) over the next 5-year MS4 permit term, with CRW responsible for approximately 23 percent of this cost. This recommended level of stream restoration, in conjunction with meeting MS4 minimum control measures and CSO minimum controls, is projected to achieve full compliance with the Paxton Creek Sediment Total Maximum Daily Load (TMDL). Successful implementation of the PRP is projected to reduce sediment loads by nearly 2.7M pounds per year. This represents a 35 percent reduction in average annual sediment loads, as well as meeting initial 5-year PRP requirements to achieve a ten percent sediment load reduction and five percent nutrient load reduction to Chesapeake Bay and a small tributary to Spring Creek. Additional streambank restoration will be examined during future implementation phases.

11.3.7 Stakeholder Engagement

Engaging the Harrisburg community is a key component of effectively implementing the recommended Program Plan. Not only does public involvement improve the plan itself, effective stakeholder engagement builds partnerships to collaboratively maximize multi-objective opportunities and share funding, leveraging the affordable financial contribution of CRW's ratepayers. CRW's engagement for the Program Plan is a multifaceted approach including advisory committees, individual stakeholder meetings, media outreach, public meetings, neighborhood and community meetings, digital outreach, and printed communications. Establishing an administrative framework with sufficient resources to collaborate with stakeholders is an additional objective of the Plan.

11.3.8 Sustainable Asset Management

CRW is implementing an asset management program to define the risk presented by the condition and criticality of its various assets, and to make risk-based investment decisions to prioritize remedial repairs, balance remedial repair and regulatory compliance investments, support proactive system maintenance and renewal, and maintain a reasonable level of resiliency within its assets. As new assets are added to the system to address wet weather issues, CRW will continue to make decisions about rehabilitation and renewal of assets using the asset management program. Ensuring sufficient budget, labor, and equipment resources are available to protect and preserve the integrity and functionality of the wastewater/stormwater systems is an additional objective of the recommended Program Plan. **Table 11-4** tabulates CRW's existing / future annual program to properly maintain its system, administer its capital improvements program, and guide adaptive management decision-making on future investments in system rehabilitation and decentralized controls.

Table 11-4 Existing and Anticipated Future CRW Administrative and Operational Components

	Projects and Services	Existing Service?	Phase
Program Administration	Asset Management	Yes	Immediate
	GIS Mapping	Yes	Immediate
	Stakeholder Engagement Services	Yes	Immediate
	Development Review/Stormwater Control Inspections	Yes	Immediate
	Precipitation/Flow/Receiving Water Monitoring Services	Yes	Immediate
	Updates to Plan Documents (NMC Plan, OMM, LTCP, etc.)	Yes	Immediate
	Semi-annual progress reporting / CSO Volume estimates	Yes	Immediate
	Coordination with Regulatory Agencies	Yes	Immediate
	Neighborhood Planning and Concept Development	No	Immediate
	Integrated CRW Regulations/Technical Guidelines	Yes	Immediate
	Other Wastewater/Stormwater Administrative Components	Yes	Immediate
Operations & Maintenance	AWTF O&M	Yes	Immediate
	Pump Station O&M	Yes	Immediate
	Interceptor O&M	Yes	Immediate
	Collection System O&M	Yes	Immediate
	Contracted CCTV/Pipe Cleaning	No	Immediate
	Interceptor Inspection / Cleaning	No	Near-Term
	Street Sweeping	Yes	Immediate
	Environmental Compliance/Illicit Discharge Investigations	No	Immediate
	Other Operations Management	Yes	Immediate
	Green Stormwater Infrastructure O&M (average for first 20 years)	No	Immediate

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11.3.9 Maximization of Benefits

The final objective of the recommended Program Plan is to enhance benefits to and minimize impacts on environmental justice populations. As part of the Plan, CRW has undertaken a Triple Bottom Line (TBL) analysis of the environmental, social, and economic benefits of the program. This TBL accounting means expanding the traditional financial reporting framework to take into account ecological and social performance so that the total benefits can be evaluated against the financial investment. TBL accounting attempts to describe the social and environmental impact of CRW's proposed infrastructure investment such that they can account for not only the water quality benefit that the infrastructure would produce, but also the additional environmental and societal benefits generated by the various alternatives evaluated.

The decentralized control (green-grey) strategy will yield water quality benefits and improvements uniformly to the aquatic habitat and living resources of the City's waterways, restoring resources long forsaken as assets by most residents. The decentralized nature of green stormwater infrastructure implementation tends to distribute its expected environmental, social, and economic benefits. In that way, the program is designed to maximize return on investment to benefit the residents across all neighborhoods, to strive for a more fair and equitable distribution of those benefits, and to garner maximum popular support. This keystone socioeconomic aspect of the recommended Program Plan lays the groundwork for the revitalization of the City in areas of public health, recreation, housing, and neighborhood values.

11.4 Implementation Approach

The Financial Capability Assessment (FCA) presented in Section 7 is used to identify an affordable level of investment in this Program Plan, one that maintains CRW wastewater rates at no more than two percent of the mean annual household income (MHI) within the City of Harrisburg ($33,289 in 2015). Level of investment would fund the following four components of the Program Plan over the next 20 years:

- CRW's 2018 budgeted and anticipated operational expenses of $14.3 million annually.
- An estimated bond repayment amount of approximately $18.8 million annually, used to finance:
  - Past capital improvements (e.g., biological nutrient removal at CRW's AWTF),
  - Up to approximately $13 million (escalated and in 2017dollars) for early action wet weather control projects,
  - Up to approximately $113 million (escalated), or $102 million (in 2017dollars) for priority projects to address critical Advanced Wastewater Treatment Facility (AWTF) and conveyance system rehabilitation needs, some that also provide significant CSO control benefits.
  - Up to approximately $88 million (escalated), or $64 million (in 2017dollars) for additional wet weather control projects, and

- Up to $101 million (escalated), or $74 million (in 2017dollars) be expended on collection system rehabilitation projects.

Figure 11-3 illustrates how the projected capital cost of $315 million (escalated), or $253 million (in 2017 dollars) are allocated between rehabilitation projects and wet weather control projects.

Specific investments to CRW's stormwater / wastewater assets will be defined periodically

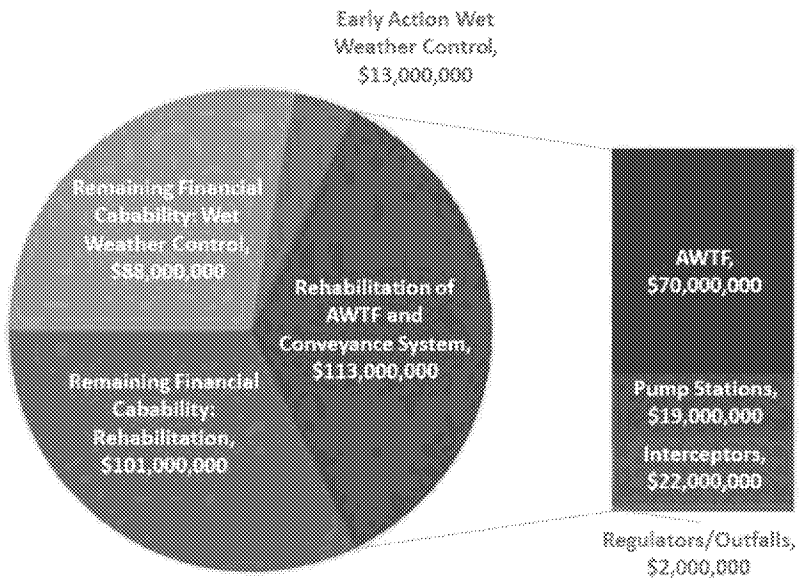

Figure 11-3. Estimated Capital Cost of Affordable Rehabilitation and Wet Weather Control Projects over the 20-year Planning Horizon

through a decision-making process, implemented through an ongoing adaptive management process, presented in Section 9, that weighs the following factors:

- The Business Risk Exposure of each asset, established through CRW's asset management program.
- The public health and welfare benefits to CRW ratepayers provided by the investment.
- The degree of water quality enhancement achieved by the investment.
- Synergies with other investments within the City, including opportunities for collaboration with other implementation partners and/or sources of funding.
- The affordability and cost-effectiveness of the investment.
- The effectiveness of previous investments determined through post-construction monitoring and hydrologic and hydraulic (H&H) modeling.
- Appropriate phasing of investments to avoid short-term degradation to current conditions.

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- An appropriate investment in the operation and maintenance of the CRW wastewater/stormwater systems and administration of the Program Plan.
- Changes to the financial capabilities of CRW's ratepayers.

11.5 Implementation Schedule

Implementation of the recommended Program Plan is divided into two major phases based upon the priorities established by the Plan:

- An ***Immediate Implementation Phase***, expected to occur within the first ten years of Program Plan approval by US-EPA and PA-DEP.
- A ***Near-Term Implementation Phase,*** expected to occur 11 to 20 years following Program Plan approval by US-EPA and PA-DEP.

CRW does not expect to achieve compliance with water quality objectives for designated uses of receiving waters within this 20-year time frame for three primary reasons:

- The severe limitations in CRW's financial capabilities,
- The significant financial commitment required to restore the effective function of CRW's existing wastewater/stormwater assets after years of deferred maintenance, and
- The heightened risk of SSOs and unauthorized releases from CRW's combined collection system, a priority control need to protect public health and safety.

The following sections describe the project and program implementation priorities within each phase.

11.5.1 Immediate Implementation Phase Schedule

This section summarizes the Immediate Implementation Phase, to be accomplished during the first 10 years of the Program; significant priority functions and projects include:

- The minimum controls defined in CRW's Nine Minimum Control (NMC) Plan for its combined sewer system, and in the six minimum control measures under its MS4 permit (included in existing annual O&M budget, see **Table 11-5**).
- Complete the CCTV inspection of the CRW collection system, use the findings to establish the CRW's Business Risk Exposure and priorities for system rehabilitation, (CCTV included in annual O&M program, see **Table 11-5**).
- Complete the inspection, cleaning and rehabilitation of the network of catch basins and storm inlets so stormwater is adequately captured and conveyed to the interceptor system (included in annual O&M program, see **Table 11-5**).
- Complete the rehabilitation of CRW's interceptors, pumping stations, and AWTF to minimize the risk of catastrophic failure and, where possible, enhance their hydraulic capacity (capital projects presented in **Table 11-2**).

Table 11-5: Program Implementation Schedule – Immediate Implementation Phase

Description	Function or Projects	Years after Program Plan Approval									
		1	2	3	4	5	6	7	8	9	10
Policy and Program Administration	Wastewater/Stormwater Program Administration										
	Regulations/Technical Guideline Development										
	Private Development Stormwater Program										
AWTF	Headworks Screening										
	Primary Clarifier Improvements/Repair										
	Other WWTP Rehabilitation (not wet weather)										
	AWTF O&M										
Conveyance System Pump Stations	Paxton Creek Interceptor Rehabilitation										
	Asylum Run Rehabilitation										
	Front St. Rehabilitation										
	Spring Creek Rehabilitation/Enhancement										
	Front St. Pump Station										
	City Island / Spring Creek Pump Stations										
	Conveyance System O&M										
CSO Regulator/Outfall Enhancements	Outfall / River Intrusion Repairs										
	Regulator Modifications										
	Interceptor Pipe Replacement										
Collection System	Collection System Rehabilitation										
	Inlet/Catch Basin Repair/Floatable Control										
	Collection System O&M										
Green/Gray Stormwater Management	Pilot GSI Projects										
	Planning and Concept Development										
	Decentralized Projects - Strategic										
	Decentralized Projects - Priority Areas										
	GSI O&M										
In-Stream Enhancement	Paxton Creek Stream Restoration										

Legend

- Administrative/Analysis
- Operations and Maintenance
- Planning / Design
- Capital Project Construction
- Reporting/Milestone

  - Paxton Creek Interceptor Rehabilitation
  - Asylum Run Interceptor Rehabilitation
  - Front St. Interceptor Rehabilitation
  - Spring Creek Interceptor Rehabilitation
  - Headworks Screening
  - Primary Clarifier Improvements/Repair
  - Front St. Pump Station
  - Other WWTP Rehabilitation (not wet weather)
- Rehabilitate CRW regulators, diversion dams, fixed and variable orifice controls, flap gates, and outfalls to increase conveyance to interceptor / AWTF, minimize interceptor backflow into the regulator, improve structural integrity, and minimize river intrusion.
- Implement early-action pilot green stormwater infrastructure (GSI) projects and decentralized stormwater management controls (SCMs) to serve as an example of such projects to the community.
- Within CRW's remaining annual financial capability:
  - Implement rehabilitation projects for collection system sewers with critical structural defects defined as grade 5 under the NASSCO PACP grading scale.
  - Implement the following levels of decentralized green-gray stormwater controls within the three priority planning areas for CSO control:
    - *Uptown: up to 4 percent of impervious area controlled*
    - *Lower Front Street: up to 15 percent of impervious area controlled*
    - *Lower Paxton Creek: up to 5 percent of impervious area controlled*
  - Collaborate with developers, transportation projects, and other stakeholders to capitalize on opportunities to implement green stormwater infrastructure.
- Enhance engineering and administrative functions as necessary to implement the Program Plan (included in annual O&M program, see **Table 11-5**).
- Assess the costs and effectiveness of controls implemented and refine Program Plan objectives and priority controls for the next phase of program implementation (included in annual O&M program, see **Table 11-5**).

The early part of the implementation phasing for this recommended Program Plan is based on the 2017 Consulting Engineer's Annual Report and commitments identified in the Nine Minimum

Controls. After the early part of the program implementation (year 5, presently year 2022) wet weather capital projects begin implementation through the ongoing adaptive management process presented in Section 9. As described in Section 9, there is a 10-year evaluation and reporting milestone where progress towards wet weather performance is summarized in an Evaluation and Adaptation Plan and any changes to the program plan for the next 5 years is summarized.

11.5.2 Performance of the Immediate Implementation Priorities

Implementing the Baseline Control Strategy with decentralized stormwater infrastructure is efficient at reducing the volume of CSOs, increasing percent capture of combined sewage, and reducing surface flooding and unauthorized releases. The selected alternative will result in both immediate and continuous progress in increasing percent capture, resulting in approximately 79 percent capture after ten years, as illustrated in **Figure 11-4**.

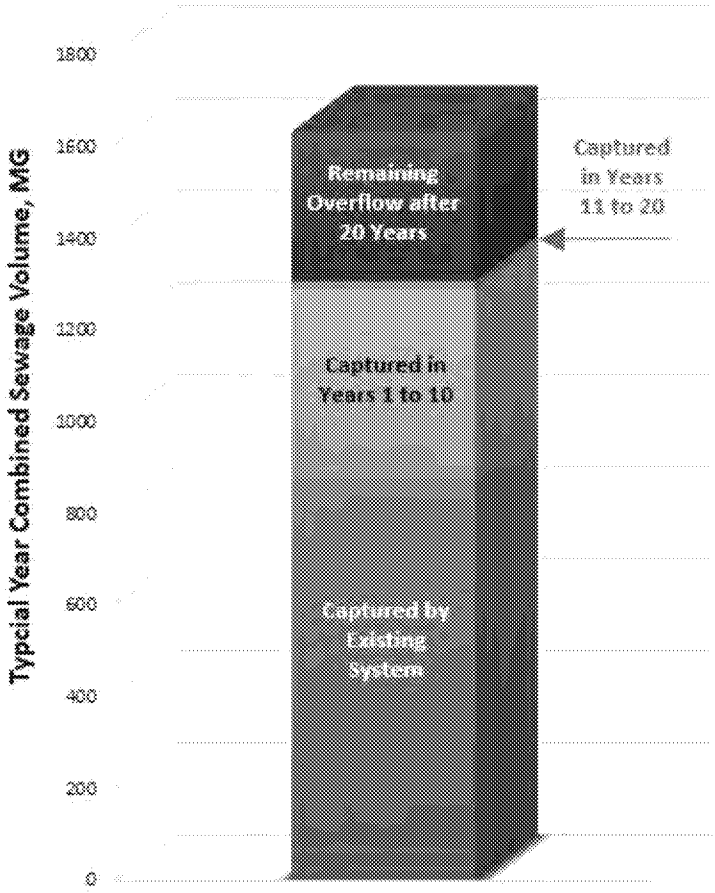

Figure 11-4. Projected CSO Volume Control over the 20-year Planning Horizon.

The 79 percent capture represents a reduction in volume of CSOs of 446 million gallons per year, a significant decrease in the amount of combined sewage discharged to Harrisburg's waterways. This also represents a mean reduction in the duration of overflows of 131 hours per year across all outfalls in the city, a 75 percent reduction in duration of CSOs.

11.5.3 Near-Term Implementation Priorities

This section summarizes the Near-Term Implementation priorities to be accomplished during years 11 to 20 of the Program, intended to partially achieve the affordable level of control:

- Implement SSO controls in the following planning areas, defined in **Table 11-2**:
  - Spring Creek: Install a 0.43 MG storage facility to control rainfall-related infiltration-inflow from separate sanitary sewer areas outside the City of Harrisburg.

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  - Industrial Road: Rehabilitate 4,900 ft. of separate sanitary sewer to reduce groundwater infiltration, and divert away from CSO 021 regulator to Paxton Creek Interceptor.

- Reinvest and rehabilitate the following pump stations, defined in **Table 11-2**:
  - Rehabilitate/Repair/Replace Spring Creek Pump Station.
  - Rehabilitate/Repair/Replace City Island Pump Station.
- Reassess the remaining structural defects identified under the CCTV inspections and risk management analyses. Reassess the balance between the level of investment in system renewal and the corresponding level of investment for environmental compliance as part of the adaptive management plan (CCTV included in existing annual O&M program, see **Table 11-4**).
- Within CRW's remaining annual financial capability:
  - Implement rehabilitation projects for collection system sewers with critical structural defects defined as grade 5 and, where budget allows, grade 4, under the NASSCO PACP grading scale.
  - Implement the following levels of decentralized green-gray stormwater controls within the three priority planning areas for CSO control:
    - *Uptown: up to 4 percent of additional impervious area controlled, total of 8 percent.*
    - *Lower Paxton Creek: up to 4 percent of additional impervious area controlled, total of 9 percent.*
  - Collaborate with developers, transportation projects, and other stakeholders to capitalize on opportunities to implement green stormwater infrastructure.
- Enhance engineering and administrative functions as necessary to implement the Program Plan (included in annual O&M program, see **Table 11-4**).
- Assess the costs and effectiveness of controls implemented and refine Program Plan objectives and priority controls for the next phase of program implementation (included in annual O&M program, see **Table 11-4**).

A proposed implementation phasing and schedule of the wastewater and wet weather-related program elements during the near-term implementation phase is presented in **Table 11-6**. The wet weather capital projects continue implementation, with priorities developed and implemented through the ongoing adaptive management process presented in Section 9. As described in Section 9, there are 5-year reporting milestones where progress towards wet weather performance is summarized in an Evaluation and Adaptation Plan and any changes to the program plan for the next five years are summarized.

Table 11-6 Program Implementation Phasing – Near-Term

Description	Function or Projects	Years after Program Plan Approval									
		11	12	13	14	15	16	17	18	19	20
Policy and Program Administration	Wastewater/Stormwater Program Administration										
	Private Development Stormwater Program										
	SCADA and Real-Time Control Systems										
AWTF	AWTF O&M										
Conveyance System	Conveyance System/Pump Station O&M										
Collection System	Ongoing Collection System Renewal										
	Inlet/Catch Basin Repair/Floatable Control										
	Collection System O&M										
Green/Gray Stormwater Management	Planning and Concept Development										
	Decentralized Projects - Strategic										
	Decentralized Projects - Priority Areas										
	GSI O&M										

Legend

- Administrative/Analysis
- Operations and Maintenance
- Planning / Design
- Capital Project Construction
- Reporting/Milestone

11.5.4 Performance of the Near-Term Implementation Priorities

The recommended Program Plan will result in both immediate and continuous progress in increasing percent capture, resulting in approximately 80percent capture after 20 years, as illustrated in **Figure 11-4**.

The 80 percent capture represents a reduction in volume of CSOs of 460 million gallons per year, a significant decrease in the amount of combined sewage discharged to Harrisburg's waterways. This also represents a mean reduction in the duration of overflows of 125 hours per year across all outfalls in the city.

11.5.5 Post-Construction Monitoring

As described in Section 10, the Post Construction Monitoring Plan (PCMP) will be developed to verify that activity commitments have been implemented at reporting milestones and to quantify and characterize the effectiveness of CRW's recommended Program Plan improvements. The PCMP monitoring and reporting activities presented in this section will document the progress made at meeting Program Plan objectives during the Immediate Implementation Phase and the Near-Term Implementation Phase. PCMP reporting will have two aspects:

- The first will be conducted on an annual basis and implemented through the existing series of annual Section 94 reports submitted by CRW to US-EPA and PA-DEP.

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- The second aspect will be the preparation and submission of a comprehensive report after the Immediate Implementation Phase of the Program Plan has been implemented, anticipated approximately ten years following approval of this Program Plan, and at five-year intervals thereafter.

Eight categories of monitoring and reporting are included in the PCMP (and described in Section 10):

- Administrative Monitoring and Reporting
- Precipitation Monitoring and Assessment
- Interceptor Monitoring and Assessment
- Suburban Community System Monitoring and Assessment
- CSO Regulator Structure Monitoring and Assessment
- CSO Discharge Projections through H&H Modeling
- Water Quality Monitoring and Assessment
- Paxton Creek Use Attainability Assessment

Upon completion of the Immediate Implementation Phase of the recommended Program Plan and annual PCMP reporting activities, a comprehensive Post Construction Monitoring Report will be prepared and submitted to the US-EPA and the PA-DEP to estimate the effectiveness of the control measures implemented under the Immediate Implementation Phase of the recommended *City Beautiful H_2O Program Plan.*

CAPITAL REGION WATER

Flooding Volume (MG)
- 0.001 - 0.02
- > 0.02

Depth from RIM (ft)
- > 8
- 6 - 7.99
- 4 - 5.99
- < 4

Percent Full (%)
- < 30
- 30 - 60
- 60 - 90
- > 90

- Sanitary/Combined Sewer
- Interceptor
- Force Main
- Sanitary/Combined Pump Station
- AWTF

- Municipalities

Catchments
- Combined
- Non-Contributing
- Separate Sanitary (Flooding Not Shown)

0 425 850 1,700 Feet

HYDRAULIC CONDITIONS
COMBINED TRUNK SEWERS

Figure 4-6: Hydraulic Conditions within Combined Trunk Sewers, 1-year Design Storm

CAPITAL REGION WATER

Flooding Volume (MG)
- 0.001 - 0.02
- > 0.02

Depth from RIM (ft)
- > 8
- 6 - 7.99
- 4 - 5.99
- < 4

Percent Full (%)
- < 30
- 30 - 60
- 60 - 90
- > 90

- Sanitary/Combined Sewer
- Interceptor
- Force Main
- Sanitary/Combined Pump Station
- AWTF
- Municipalities

Catchments
- Combined
- Non-Contributing
- Separate Sanitary (Flooding Not Shown)

0 425 850 1,700 Feet

HYDRAULIC CONDITIONS
COMBINED TRUNK SEWERS

Figure 4-7: Hydraulic Conditions within Combined Trunk Sewers, 2-year Design Storm

CAPITAL REGION WATER

Flooding Volume (MG)
- 0.001 - 0.02
- > 0.02

Depth from RIM (ft)
- > 8
- 6 - 7.99
- 4 - 5.99
- < 4

Percent Full (%)
- < 30
- 30 - 60
- 60 - 90
- > 90

- Sanitary/Combined Sewer
- Interceptor
- Force Main
- Sanitary/Combined Pump Station
- AWTF
- Municipalities

Catchments
- Combined
- Non-Contributing
- Separate Sanitary (Flooding Not Shown)

0 425 850 1,700 Feet

HYDRAULIC CONDITIONS
COMBINED TRUNK SEWERS

Figure 4-8: Hydraulic Conditions within Combined Trunk Sewers, 5-year Design Storm

CAPITAL REGION WATER

Flooding Volume (MG)
- 0.001 - 0.02
- > 0.02

Depth from RIM (ft)
- > 8
- 6 - 7.99
- 4 - 5.99
- < 4

Percent Full (%)
- < 30
- 30 - 60
- 60 - 90
- > 90

- Sanitary/Combined Sewer
- Interceptor
- Force Main
- Sanitary/Combined Pump Station
- AWTF
- Municipalities

Catchments
- Combined
- Non-Contributing
- Separate Sanitary (Flooding Not Shown)

0 425 850 1,700 Feet

HYDRAULIC CONDITIONS
COMBINED TRUNK SEWERS

Figure 4-9: Hydraulic Conditions within Combined Trunk Sewers, 10-year Design Storm

Appendix B - Basis of Cost Opinions

Costs for Combined Sewer Overflow Control Technologies and Alternatives

Table of Contents

1.0 Introduction

1.1 Alternatives Costing Scope 1

1.2 Control Technologies 1

1.3 Terminology 2

1.3.1 Control Element 2

1.3.2 Control Alternative 3

1.3.3 Construction Costs 3

1.3.4 Non-Construction Costs 3

1.3.5 Capital Costs 3

1.3.6 Planning Period 3

1.3.7 Useful Life 3

1.4 Economic Parameters 3

1.4.1 Useful Life 3

1.4.2 Discount Rate 4

1.4.3 Construction Cost Base Date 4

1.4.4 Cost Inflation 4

1.4.5 Cost Indexes 4

2.0 Cost Estimating Approach

2.1 Non Construction Costs 6

2.1.1 Construction Contingency 6

2.1.2 Project Contingency 6

2.1.3 Capitalized Interest 6

2.1.4 Land Acquisition and Easements/Right-of-Way 6

2.1.5 Engineering & Implementation 7

2.1.6 Contractor's Overhead and Profit and Indirect 7

2.2 Construction Cost Approach 8

2.2.1 Cost Scaling 8

2.2.2 Cost Data Sources 8
2.3 Cost Estimation Methodology 8
2.3.1 Green Stormwater Infrastructure 8
2.3.2 Municipal Inflow and Infiltration Reduction 22
2.3.3 Private Inflow and Infiltration Removal 23
2.3.4 Sewer Separation 25
2.3.5 Open Cut Pipe 25
2.3.6 Pump Stations 35
2.3.7 Force Mains 41
2.3.8 Short-Bore Tunnel (Trenchless) 41
2.3.9 Conventional Tunnel - Storage/Conveyance 53
2.3.10 Tank Storage 57
2.3.11 Screening 60
2.3.12 Vortex Separation 62
2.3.13 Retention Treatment Basins 64
2.3.14 High-Rate Clarification 70
2.3.15 Disinfection 71
3.0 Lifecycle Costs
3.1 Introduction to Life Cycle Costs 76
3.2 Planning Period and Temporal Framework 76
3.3 Present Worth Analysis 76
3.4 Replacement Costs 76
4.0 References

ED_005060A_00001812-00458

Appendix B - Basis of Cost Opinions

1.0 Introduction

Capital Region Water (CRW) has utilized cost estimation data for use in planning level screening and comparison of CSO control technologies. The data was derived from other CSO LTCP cost estimation data. The basis of cost opinions data provides planning-level cost estimates to facilitate the evaluation and comparison of preliminary alternatives1.

Costs were updated for 2016 inflation and adjusted to the Harrisburg region. The Inflation adjustment is based on the ENR Construction Cost Index and the location adjustment factor is based on RS Means. Both are described in Section 1.4.5. The ENR CCI is 10338 (an average of 2016, most recent available at the time of cost opinion development) and RS Means factor is 99.8 for Harrisburg. One additional refinement/ update is the use of the updated green stormwater infrastructure construction and maintenance cost, per the 2016 Philadelphia Water Department Pilot Program Report[2].

The cost opinions created are to be considered Level 4 cost estimates, as designated by The Association for the Advancement of Cost Engineering Recommended Practice No. 18R-97 (AACE, 2005), and actual costs are expected to fall within a range of 30% less to 50% more than the cost opinions given in this section and shown on the cost performance curves in Section 8. This estimate class and accuracy is appropriate for long term planning level use.

This appendix presents an overview of the data and logic to derive alternative costs.

1.1 Alternatives Costing Scope

The basis of cost opinions data provides capital and operation and maintenance (O&M) costs of wet-weather conveyance, storage and treatment facilities based on costing algorithms utilized from evolving and expanding national data sets, from regional capital and O&M cost data. Key cost results considered as part of the analysis include:

- Current year (anticipated 2016) capital cost
- Current year O&M costs
- Present worth based on capital costs and projected O&M costs
- Future years' O&M costs based on assumed inflation
- Total capital costs

Control alternatives are utilized which include conceptual level determinations of facility size, type, and configuration.

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[1] Philadelphia Water Department, *Philadelphia Combined Sewer Overflow Long Term Control Plan Update Supplemental Documentation Volume 3 Basis of Cost Opinions*, 2009, which can be found at: http://www.phillywatersheds.org/ltcpu/Vol03_Cost.pdf

[2] Philadelphia Water Department, *Pilot Program Report*, 2016, which can be found at: http://phillywatersheds.org/doc/Year5_EAPCombinedAppendices_website.pdf Appendix B, Section 4 (Construction Cost) and Section 5 (Maintenance)

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1.2 Control Technologies

The control technologies considered are provided below. The costing methodologies, cost variables (conceptual design values), and conceptual design approach assumptions are detailed in Section 2.0.

Source Controls

- Green Stormwater Infrastructure
- Private I/I Reduction
- Municipal I/I Reduction

Storage

- Conventional Tunnel
- Tank Storage

Conveyance

- Open Cut Pipe
- Pump Station
- Short-Bore Tunnel (Trenchless)
- Sewer Separation

Treatment

- Retention Treatment Basin
- Vortex Separation
- High-Rate Clarification
- Screening
- Disinfection

Miscellaneous

1.3 Terminology

For purposes of this documentation the following definitions will apply. The specific meanings of some terms may vary depending on the context.

1.3.1 Control Element

"Control Element" means a facility serving as one component of a control alternative. A high-rate treatment (HRT) facility or a relief interceptor would be examples of control elements. Source reduction through municipal collection system rehabilitation or through green stormwater infrastructure would also be examples of control elements. Estimated capital costs for control elements (e.g., the capital cost of a 30 million gallon per day (mgd) HRT) based on the design and other parameters and the system-wide design assumptions are discussed below in Section 2.

1.3.2 Control Alternative

"Control alternative" means an array of one or more control elements providing watershed-level overflow control at some specified level of performance. A relief interceptor sewer discharging to a HRT facility that was sized for eight overflows per typical year would be an example of a

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watershed-control alternative. The capital cost of a control alternative is the sum of the control element capital costs.

1.3.3 Construction Costs

"Construction costs" means the raw costs of building new control facilities, upgrading or expanding existing facilities or rehabilitating existing sewerage (i.e., the contractors' bid costs). Construction costs include: general conditions, overhead and profit, mobilization, demobilization, contractor's bonds and insurance, and sub-contractor markups.

1.3.4 Non-Construction Costs

Non-construction costs include all costs related to a control alternative other than building costs. Design and construction engineering costs are examples. Estimated non-construction costs, except for land acquisition, are based on a percentage of construction costs.

1.3.5 Capital Costs

Capital costs will be the sum of the estimated construction costs and the estimated non-construction costs.

1.3.6 Planning Period

For purposes of control alternatives evaluation, the planning period will be set at a assumed length of 40 years. The planning period is relevant to calculating the present worth of various control elements.

1.3.7 Useful Life

The useful life of a control element is the period during which the control element will operate without requiring replacement or substantial reconstruction to maintain design performance. Preventive and corrective maintenance are assumed when establishing the useful lives of the control element components.

1.4 Economic Parameters

The following parameters have been utilized as standard values in development of the basis of cost opinions.

1.4.1 Useful Life

Useful life is relevant to alternatives evaluation because of the extended planning period. Present worth calculations need to include structural replacement or rehabilitation and equipment replacement costs that would occur during the planning period (e.g., a storage tank with effluent pumps coming on line in 2029 would likely require pump replacement or major overhaul before 2057). Because of the intermittent operation of wet-weather facilities, traditional estimates of equipment useful life may be inappropriate.

1.4.2 Discount Rate

The discount rate utilized to calculate the present worth of control elements is assumed to be 2.875%, and is based on the Department of Interior Federal water resources planning discount rate for fiscal year 2017.

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1.4.3 Construction Cost Base Date

The base date, likely to be the current year, is a assumptions , and represents the date the opinion of cost is in terms of. The base date is 2016 as the base date for estimated construction costs.

1.4.4 Cost Inflation

Future Capital Costs

Future capital costs are derived with the assume inflation value of 3.0%.

Operations and Maintenance Cost Inflation

Base date (2016) O&M costs are inflated to the first year of operation and for subsequent years throughout the planning period. The initiation of operation will be assumed to occur on January 1 of the year following construction completion. The assumed O&M cost inflation is 3.0%.

1.4.5 Cost Indexes

Because the cost estimating sources were based on different dates and geographic locations, the cost estimates for the base year and base location were adjusted through cost indexes. Specifically, the Engineering News Record Construction Cost Index (ENRCCI) was used to adjust for the year of the cost estimate, and the 2008 RSMeans Location Factor (RSMeans) was used to adjust for the geographic location of the cost estimates. **Table 1.4.5-1** shows the cost indexes for the cost estimating sources. The base ENRCCI is 10338 and RSMeans factor is 99.8.

Table 1.4.5-1: Summary of Base Index Values for Technologies Cost Data

Technology	Cost Equation Data Base Index Values			
	ENRCCI Construction	RS Means Construction	ENRCCI O&M	RS Means O&M
Assumed Project Analysis	10338	99.8	10338	99.8
Green Stormwater Infrastructure	7966	115.2	8141	115.2
Private I/I Removal	8551	100.0	8551	100.0
Municipal I/I Removal	8551	100.0	8551	100.0
Conventional Tunnel	8551	100.0	8551	100.0
Tank Storage	8551	100.0	8551	100.0
Open Cut Pipe	7312	92.9	6771 (Detroit)	103.9 (Detroit)
Pump Station	8551	100.0	7939 (PWD)	115.2 (PWD)
			7966 (EPA)	100.0 (EPA)
Trenchless Technologies	8578	113.2	6771 (Detroit)	103.9 (Detroit)
Sewer Separation	8551	100.0	8551	100.0
Retention Treatment Basins	8551	100.0	8551	100.0
Vortex Separation	8551	100.0	8551	100.0
High-Rate Clarification	8551	100.0	8551	100.0
Screening	8551	100.0	8551	100.0
Disinfection	8551	100.0	8551	100.0

Note: The unit cost values in the subsequent appendices reflect unadjusted costs. The index values are used for adjustment of cost to the project analysis ENRCCI and RSMeans values.

2.0 COST ESTIMATING APPROACH

This section outlines the wet-weather controls that are included and the methodologies to be used to scale estimated capital costs to the sizes and complexities identified by the user.

2.1 Non-Construction Costs

Non-construction costs and economic parameters that impact the estimated total capital cost of a given control alternative are included.

Non-construction costs are assigned to the construction costs calculated for a control element. With the exception of land acquisition and easement costs which are determined by the user, each non-construction cost is calculated as a percent of the estimated construction cost either before or after other multipliers are applied.

2.1.1 Construction Contingency

Construction contingencies are added to take into account how far advanced a design has proceeded. This contingency takes into account any design development concerns based on the status and phase of the project. For the initial planning work that is being done, a 25 percent contingency is added to the construction cost, which already includes (implicitly), the contractor's overhead and mark-up. The construction cost with this contingency included will be referred to as the opinion of probable construction cost.

2.1.2 Project Contingency

Project contingency is added to the opinion of probable construction cost. This contingency typically ranges from 5 to 30% depending upon such things as the level of difficulty of the project, the volatility of the bidding climate for the project type, the level of complexity of the site conditions, and the type and stage of funding being required. The assumed project contingency in is 20%.

2.1.3 Capitalized Interest

Capitalized interest, or interest during construction, reflects interest payments on the amount borrowed (through bonds), payment of which is deferred during construction. The cost of capitalizing interest during construction based on the anticipated duration(s) of construction. For planning purposes, the annual draws on construction funding will be assumed to be straight line.

2.1.4 Land Acquisition and Easements/Rights-of-Way

Because of the specificity of local conditions, there is not a standard multiplier for land acquisition, easements and Rights-of-Way (ROW). Upon identifying preliminary routing (for relief or consolidation interceptors) or sites for control facilities, it may have been considered to overlay the potential routes and sites with existing easements and ROW to identify the need for new easements, ROW or parcels. The total estimated costs for land acquisition, easements and ROW are then included in the development of the basis of cost opinion for a given alternative.

2.1.5 Engineering and Implementation

Engineering and implementation costs are added as a percentage to the total of all costs described above. The value assumed is 20% of the total project costs, and is intended to address the following typical project costs:

- Permitting
- Engineering design
- Construction oversight /resident engineering
- Administration and program management
- Finance bonding costs
- Legal
- Geotechnical
- Survey
- Public participation.

2.1.6 Contractor's Overhead and Profit and Indirect Costs

Cost estimate sources presented are in two different levels of cost. Most cost sources are in terms of construction costs as defined above: contractor's bid cost including overhead and profit and indirect costs. However, a few cost sources assembled directly from materials, labor, and equipment estimates are in terms of direct construction costs, excluding contractor's overhead and profit and indirect costs. **Table 2.1.6** shows the breakdown between construction and direct construction.

Overhead and profit and indirect costs are applied to the cost sources based on direct construction costs. The assumed value for contractor's overhead and profit is 20%. The assumed value for contractor's indirect costs is 4%.

Table 2.1.6: Technology Cost Source Level of Cost

Technology Cost Curve/Cost Module	Direct Construction Cost (i.e. materials, labor, equipment)	Construction Cost Including Contractor's Overhead, Profit and Indirect Costs
Green Stormwater Infrastructure	X	
Trenchless Technologies	X	
Open Cut Pipe	X	
All Other Technologies		X

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2.2 Construction Cost Approach

2.2.1 Cost Scaling

Scaling of construction costs is based on a series of cost per facility size equations utilized for each of the structural control alternatives outlined in Section 2.3. Otherwise, costs are assembled from construction and O&M costs from smaller components (e.g. material cost of a particular type and size of pipe, energy cost for pumping at a specific total dynamic head, flow rate, duration and electrical rate, etc).

2.2.2 Cost Data Sources

A variety of construction cost estimate data sources were used. National wet-weather control facility costs of facilities in operation, as well as unit cost breakouts for such facilities (as they are available) were used extensively. These costs were updated for time and location.

Cost curve data sets were utilized from other wet weather programs (PWD, 2009). These cost curves were used for comparison purposes to verify the feasibility of the selected cost curve for a given technology. This combined knowledge base allowed for comparison of different cost estimation methodologies for each technology.

The United States Environmental Protection Agency (U.S. EPA) publications containing control facilities cost data and cost curves will be used as a secondary source of guidance. These cost estimating curves were compared to installed project data, and adjusted chronologically using ENRCCI Index values.

2.3 Cost Estimation Methodology

The following subsection outlines variables, assumptions, and methodologies used to estimate construction costs of various control technologies that were identified in Section 1.2.

2.3.1 Green Stormwater Infrastructure

Green Stormwater Infrastructure (GSI) or Land Based Stormwater Management (LBSM) costs are determined using unit-area estimates. Underlying those unit-area estimates are more precise engineering cost opinions based on real site plans representing a variety of technologies, land use types, sizes, and land ownership.

A range of stormwater management plans using different stormwater management techniques was selected. Engineering cost estimates were based on materials, labor, overhead, and profit using unit costs from RSMeans CostWorks (see example in **Table 2.3.1-1**). Costs were adjusted to represent construction taking place within Philadelphia with union labor rates in 2008 dollars and are considered construction costs with overhead, profit and without indirect costs.

Table 2.3.1-1: Example of Project Cost Estimate based on Quantities and Unit Costs

Category	Material	Units	Quantity	Unit Cost	Total Cost	Source*
Trees	Deciduous Tree	total	6	$385.00	$2,310.00	Means 32 93 4320 1600
	Bark Mulch	sq. yd	10.66	$6.15	$65.56	Means 32 91 1316 0100
	Geotextile Separation Fabric	sq. yd	10.67	$1.95	$20.80	Means 02620-300-0110
	Planting Backfill Mixture	cu. Yd	9.48	$29.50	$279.70	Means 31 05 1310 0700
	Hauling Backfill Mixture to Site	cu. Yd	9.48	$30.55	$289.66	Calculation
	Excavation	cu. Yd	10.67	$2.75	$29.31	Calculation
Porous Pavement	Pervious Asphalt	sq. yd	652.36	$20.90	$13,634.32	2X cost of traditional pavement
	AASHTO No. 57 Choker	cu. yd	18.12	$37.69	$682.94	Means 31 05 1610 0300
	AASHTO No. 2 Coarse Aggregate	sq. yd	652.36	$9.55	$6,230.04	Means 32 11 2323 0302
	Non-Woven Geotextile	sq. yd	784.36	$1.95	$1,529.50	Means 02620-300-0110
	Excavation	cu. Yd	217.88	$2.75	$598.84	Calculation
	Hauling Asphalt Materials to Site	cu. yd	163.2	$30.55	$4,985.76	Calculation
	Hauling for excavated soil	cu. Yd	217.88	$30.55	$6,656.17	Calculation
Pipe Trench Under Porous Pavement	24" Perf. Pipes	ft	774	$62.00	$47,988.00	Means 3311 1325 3070
	24" LF HDPE Header	ft	22	$62.00	$1,364.00	Means 3311 1325 3070
	Gravel	sq. yd	95.3	$15.40	$1,467.56	Means 32 11 2323 0300
	AASHTO No. 2 Coarse Aggregate	sq yd	91.21	$9.55	$871.06	Means 32 11 2323 0302
	Hauling Aggregate to Site	cu yd	91.21	$30.55	$2,786.47	Calculation
Inlet Structure	Reinforced Concrete Inlet Box	total	1	$4,800.00	$4,800.00	Means 334913-10-1000
	Excavation volume	cu. Yd	4.74	$2.75	$13.03	Calculation
	Hauling for excavated soil	cu. yd	4.74	$30.55	$144.83	Calculation
	Footing	each	1	$27.78	$27.78	Anecdotal
	Reinforced Concrete Top Unit	total	1	$440.00	$440.00	Means 33-49-1310-1300
	Heavy Duty Inlet Frame	total	1	$1,125.00	$1,125.00	Means 02630-110-1582
	AASHTO Coarse Aggregate Size No. 57	cu yd	0.67	$37.69	$25.13	Means 31 05 1610 0300
	Hauling Aggregate to Site	cu yd	0.67	$30.55	$20.37	Calculation
Outlet Structure	Cast Iron Manhole Frame and Cover	total	1	$505.00	$505.00	Means 33-44-1313-2100
	Precast Manhole Slab	total	1	$650.00	$650.00	Means 33-49-1310-1400
	Precast Reinforced Concrete Inlet Box	total	1	$4,800.00	$4,800.00	Means 334913-10-1000
	Cast Iron Trap	total	1	$550.00	$550.00	Means 22-13-1660-1160
	AASHTO Coarse Aggregate Size No. 57	cu yd	0.89	$37.69	$33.50	Means 31 05 1610 0300
	Hauling Aggregate to Site	cu yd	0.89	$30.55	$27.15	Calculation
Cleanout (Storm water piping)	Cast Iron Cleanout Housing	total	1	$880.00	$880.00	Means 22-05-7620-0280
	8" Dia. PVC Cleanout with Screw Plug	ft	0.75	$14.30	$10.73	Means 33-31-1325-2080
	8" Dia. PVC Spool Piece	ft	0.33	$14.30	$4.77	Means 33-31-1325-2080
Piping	12" Dia. PVC Pipe	ft	80	$23.50	$1,880.00	Means 33-31-1325-2160
	Redevelopment Cost				**$107,727**	

* Most unit costs are taken from R.S. Means Costworks Version 11.0, Building Construction Cost Data 2008. Some are based on local bid data or best engineering judgment. Some are calculations based on combinations of individual items and are too complex to describe in this table. (PWD, 2009)

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Direct construction costs were estimated using materials and labor quantities for the following two cases:

- The marginal construction cost (beyond the cost of traditional measures) to implement each LBSM approach assuming that redevelopment is already taking place.
- The full construction cost required to implement each LBSM approach by retrofitting traditional development on an existing site.

Green Stormwater Infrastructure Cost Variables

To calculate the construction cost of a green stormwater infrastructure or LBSM technology, the following variables are determined:

Impervious Area - For calculating the LBSM construction cost, the calculated impervious area (in acres) proposed for the LBSM technology alternative must be determined based on the alternative design.

Control Type - Next, the type of control is to be selected out of the five LBSM technologies: Bioretention, Green Roof, Porous Pavement, Street Trees, and Subsurface Infiltration.

Control Level - The third variable is the control level, either retrofit or redevelopment.

Based on the values, direct construction costs as well as operation and maintenance (O&M) costs are calculated. These values were utilized from unit costs per acre for each scenario . A summary of the LBSM unit costs is provided in **Table 2.3.1-6**. A summary of LBSM O&M costs is provided in **Table 2.3.1-14**.

Summary of Results

The results from the takeoffs of stormwater management plans are summarized in the following sections. Descriptions of the projects that are selected for the analysis are listed in **Table 2.3.1-2**. A list of the cost estimates that were calculated for direct construction costs are shown in **Table 2.3.1-3**. The estimates were summarized into five categories: bioretention, subsurface infiltration, green roof, porous pavement and street trees in **Table 2.3.1-4**. Each category was further broken down into a redevelopment and retrofit cost. Due to the small sample size costs for bioretention, subsurface infiltration and porous pavement do not appear to be significantly different. For the purpose of the study the pooled value for all controls was assigned to these three types.

Table 2.3.1-2: Project Descriptions and Characteristics

Project Name	BMP Type	Land Use	Lot Size (sq. ft.)	Pre Construction Impervious Cover (sq. ft.)	Post Construction Impervious Cover (sq. ft.)
Private (1)	Subsurface Infiltration	High Density Residential	23,760	21,701	23,760
47th and Grays Ferry Traffic Triangle	Bioretention	Street	6,835	19,318	19,318
Private (2)	Green Roof	High Density Mixed Use	30,593	0	23,012
Public (2)	Pervious Pavement and Detention	School	52,254	43,655	52,254
Private (3)	Subsurface Infiltration	School and Parking	371,239	107,530	121,384
Mill Creek Tree Trench	Subsurface Infiltration	Street	1,131	17,346	17,346
Private (4)	Green Roof and Pervious Pavement	High Density Residential	64,600	25,874	52,230
Private (5)	Subsurface Infiltration	Commercial	122,839	0	105,415
Public (4)	Bioretention	Parking	551,470	12,235	424,870
Public (5)	Subsurface Infiltration	School	95,738	81,218	29,053
Curb Extension	Bioretention	Street	190	3,508	3,358
Swale without Parking	Bioretention	Street	192	2,716	2,550
Swale with Parking	Bioretention	Street	192	2,429	2,263
Planter with parking	Bioretention	Street	175	922	862
Planter without parking	Bioretention	Street	99	1,147	1,067
Street Trees*	street trees	Street	43,560	43,560	43,000*

*Note: 30.2 trees per acre placed in 16 sq. ft. tree boxes.

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Table 2.3.1-3: Direct Construction Cost Estimates in 2008 Dollars

Project Name	BMP Type	Cost Estimates ($/impervious acre)		Actual Project Cost (PWD Projects)
		Redevelopment	Retrofit	($/acre)
Private (1)	Subsurface Infiltration	$150,000	$230,000	
47th and Grays Ferry Traffic Triangle	Bioretention	$72,000	$80,000	$150,000
Private (2)	Green Roof	$290,000	$570,000	
Public (2)	Pervious Pavement and Detention	$85,000	$128,000	
Private (3)	Subsurface Infiltration	$44,000	$79,000	
Mill Creek Tree Trench	Subsurface Infiltration	$100,000	$120,000	$170,000
Private (4a)	Green Roof	$200,000	$430,000	
Private (4b)	Pervious Pavement	$190,000	$410,000	
Private (5)	Subsurface Infiltration	$120,000	$170,000	
Public (4)	Bioretention	$150,000	$200,000	
Public (5)	Subsurface Infiltration	$200,000	$350,000	
Curb Extension	Bioretention	$50,000	$65,100	
Swale without Parking	Bioretention	$70,000	$90,000	
Swale with Parking	Bioretention	$80,000	$100,000	
Planter with parking	Bioretention	$130,000	$160,000	
Planter without parking	Bioretention	$80,000	$100,000	
Street Trees	street trees	$15,000	$18,000	

Table 2.3.1-4: Summary of Direct Construction Cost Estimates [ENRCCI 7966; RSMEAN 115.2]

Control	Type	Minimum Cost ($ / impervious acre)	Median Cost ($ / impervious acre)	Mean Cost ($ / impervious acre)	Max Cost ($ / impervious acre)
Bioretention	Retrofit	$65,000	$120,000	$160,000	$410,000
	Redevelopment	$44,000	$90,000	$110,000	$200,000
Subsurface Infiltration	Retrofit	$65,000	$120,000	$160,000	$410,000
	Redevelopment	$44,000	$90,000	$110,000	$200,000
Green Roof	Retrofit	$430,000	$500,000*	$500,000	$570,000
	Redevelopment	$200,000	$250,000*	$250,000	$290,000
Porous Pavement	Retrofit	$65,000	$120,000	$160,000	$410,000
	Redevelopment	$44,000	$90,000	$110,000	$200,000
Street Trees	Retrofit	$18,000	$18,000	$18,000	$18,000
	Redevelopment	$15,000	$15,000	$15,000	$15,000

*Note: Other cities have been experiencing costs in the range of $7-16 per square foot ($305,000 - $700,000 per impervious acre), with a typical range of $10-14 per square foot ($435,000 - $610,000 per impervious acre). A recent green roof at Temple-Ambler campus was approximately $11 per square foot ($480,000 per impervious acre). The least expensive green roofs in Chicago, which has the largest-scale program in the U.S., are on the order of $6-7 per square foot ($285,000 per impervious acre), and this may be a reasonable estimate of what can be achieved in the future with a large-scale program in Philadelphia.

Learning Curve Assumptions

Over the long term, the cost of low impact development techniques is expected to decline for a number of reasons. A list of estimated long-term reduced construction costs in shown in **Table 2.3.1-5** and summary statistics are shown in **Table 2.3.1-6**. The reductions shown in this table are credited to improvements in site layouts, a reduction in the cost for materials, reduction in design costs, and reductions in perceived risk as low impact development becomes the standard way of doing business. For purposes of the plan there was no assumption of learning curve cost assumptions utilized in the alternative cost analysis.

Better Site Design: Site designers are required to comply with Philadelphia's stormwater regulations today. However, design features needed to comply are often added as an afterthought, after the site layout has been determined. Designs are very dense and do not leave open space for stormwater management (or resident enjoyment). This forces stormwater management features into underground, infrastructure-intensive facilities. Over time, local engineers will adopt better site design techniques. In the estimates in **Table 2.3.1-5**, it is assumed that impervious area on each site is reduced by 20% compared to the actual designs submitted in recent years. A 20% reduction is reasonable; the Philadelphia stormwater regulations provide an incentive for a 20% reduction, and there is a precedent for this level of reduction in surrounding states.

Reductions in Material Cost: As low impact development techniques such as porous pavement and green roofs become the standard way of doing business, materials needed to build them will no longer be considered specialty materials. For example, the estimates in Table 2.3.1-5 assume that in the future porous pavement have the same unit cost as traditional pavement today.

Reductions in Design Cost: Because low impact development techniques are unfamiliar to many local engineers, design costs are currently high relative to total construction cost. Future design costs are assumed to be no more than a project of "typical complexity" on the ASCE engineering fee cost curve. This assumption does not affect the direct construction costs shown in **Table 2.3.1-5**.

Reductions in Perceived Risk: a relatively low contingency will be used for low impact development, assuming that contractors will perceive less risk over time as these techniques become the standard way of doing business. This assumption does not affect the direct construction costs shown **in Table 2.3.1-5**. A summary of the LBSM unit costs is provided in **Table 2.3.1-6**.

Table 2.3.1-5: Summary of Direct Construction Cost Estimates with Improved Development Practices and Economies of Scale in 2008 Dollars

Project Name	BMP Type	Cost Estimates ($/impervious acre)		Percent Reduction	
		Redevelopment	Retrofit	Redevelopment	Retrofit
Private (1)	Subsurface Infiltration	$110,000	$180,000	27%	24%
47th and Grays Ferry Traffic Triangle	Bioretention	$57,000	$64,000	20%	20%
Private (2)	Green Roof	$230,000	$460,000	20%	20%
Public (2)	Pervious Pavement	$66,000	$100,000	22%	22%
Private (3)	Subsurface Infiltration	$35,000	$63,000	20%	20%
Mill Creek Tree Trench	Subsurface Infiltration	$80,000	$100,000	19%	19%
Private (4a)	Green Roof	$160,000	$340,000	20%	20%
Private (4b)	Pervious Pavement	$120,000	$290,000	36%	27%
Private (5)	Subsurface Infiltration	$90,000	$130,000	20%	20%
Public (4)	Bioretention	$120,000	$160,000	20%	20%
Public (5)	Subsurface Infiltration	$160,000	$280,000	20%	20%
Curb Extension	Bioretention	$43,000	$52,000	20%	20%
Swale without Parking	Bioretention	$58,000	$74,000	20%	20%
Swale with Parking	Bioretention	$70,000	$80,000	20%	20%
Planter with parking	Bioretention	$100,000	$130,000	20%	20%
Planter without parking	Bioretention	$60,000	$79,000	20%	20%
Street Trees	street trees	$12,000	$15,000	20%	20%

The green roof cost estimate for improved development practices is based on the direct construction cost estimate with no improved practices/economies of scale.

Table 2.3.1-6: Summary Statistics of Direct Construction Cost Estimates with Improved Development Practices and Economies of Scale in 2008 Dollars

Control	Type	Minimum Cost ($ / impervious acre)	Median Cost ($ /impervious acre)	Mean Cost ($ / impervious acre)	Max Cost ($ / impervious acre)
Bioretention	Retrofit	$52,000	$100,000	$130,000	$290,000
	Redevelopment	$35,000	$80,000	$80,000	$160,000
Subsurface Infiltration	Retrofit	$52,000	$100,000	$130,000	$290,000
	Redevelopment	$35,000	$80,000	$80,000	$160,000
Green Roof	Retrofit	$340,000	$400,000	$400,000	$460,000
	Redevelopment	$160,000	$200,000	$200,000	$230,000
Porous Pavement	Retrofit	$52,000	$100,000	$130,000	$290,000
	Redevelopment	$35,000	$80,000	$80,000	$160,000
Street Trees	Retrofit	$15,000	$15,000	$15,000	$15,000
	Redevelopment	$12,000	$12,000	$12,000	$12,000

*Note: Based on anecdotal information, resulting costs of approximately $6-9 per square foot ($260,000 - $395,000 per impervious acre) are in line with the experience of the large-scale program in Chicago.

Public-Sector Cost Sharing Assumptions

For some land use types, it could be assumed that entities other than CRW assume a portion of the stormwater retrofit capital and O&M costs. For purposes of the plan there was no assumption of cost sharing utilized in the alternative cost analysis. Potential entities or project types that could share project costs are as follows:

- Schools
- Park and recreation facilities
- Other public lands - libraries, police, fire, health, etc.
- Street trees
- Sidewalk replacement programs
- Retrofit of vacant and abandoned lands
- Private lands affected by the stormwater ordinance and regulations

Operations & Maintenance Cost Analyses

- Operations and maintenance (O&M) costs were summarized into five categories, Porous Pavement, Subsurface Vault, Green Roofs, Bioretention, and Street Trees, for the selected stormwater management plans. For each category O&M costs were broken down into required operations and maintenance activities as described in the Philadelphia Stormwater Management Guidance Manual.
- Operations and maintenance activities, length and frequency were also estimated. The operations and maintenance labor costs associated with each design were determined from union contract agreements with the City of Philadelphia. The operations and maintenance costs

ED_005060A_00001812-00473

were marked up to cover the costs associated with overhead & profit, estimated at 25%. The labor rates that were used in the analysis are shown in **Table 2.3.1-7**. The equipment costs utilized in the analysis are presented in **Table 2.3.1-8**. All equipment costs are from RS Means Costworks 2008. Materials costs were assumed to be the 10% of the median marginal redevelopment cost (see **Table 2.3.1-6**) distributed over 25 years.

Table 2.3.1-7: Labor Rates

General Description	Class	Basic Hourly Rate	Fringe Benefits
Truck Driver	Journeyman Class II	$22.60	$11.37
Truck Driver	Journeyman Class III	$22.85	$11.37
Landscape Laborer	Class I	$17.13	$16.87
Landscape Laborer	Class II	$17.88	$16.87

Table 2.3.1-8: Equipment Costs

General Description	Units	Unit Cost
Rent Vacuum Truck, hazardous materials, 5000 gallons	per day	$335.00
Rented sewer/catch basin vacuum, 14 cy, 1500 gallon	per day	$485.00
Truck, pickup, 3/4-ton, 2-wheel drive	per day	$80.50

The O&M activity and schedule associated with porous pavement are included in **Table 2.3.1-9**.

Table 2.3.1-9: Porous Pavement O&M Activities

Activity	Schedule	Visits Per Year Per Impervious Acre	Hours Per Visit Per Impervious Acre	Total Hours Per Year per Impervious Acre
Vacuum porous asphalt or concrete surface with commercial cleaning unit (Pavement washing systems and compressed air units are not recommended)	Twice per Year	2	4	8
Clean out inlet structures within or draining to the subsurface bedding beneath porous surface	Twice per Year	2	4	8
Maintain records of all Inspections and maintenance activity	Ongoing	1	1	1

The O&M activity and schedule associated with subsurface infiltration are included in **Table 2.3.1-10**.

Table 2.3.1-10: Subsurface Infiltration O&M Activities

Activity	Schedule	Visits Per Year Per Impervious Acre	Hours Per Visit Per Impervious Acre	Total Hours Per Year per Impervious Acre
Regularly clean out gutters and catch basins to reduce sediment load to infiltration system. Clean intermediate sump boxes, replace filters, and otherwise clean pretreatment areas in directly connected systems	As needed	3	5	15
Inspect and clean as needed all components of and connections to subsurface infiltration systems	Twice per Year	2	3	6
Evaluate the drain-down town of the subsurface infiltration system to ensure the drain-down time of 24-72 hours	Twice per Year	2	1	2
Maintain records of all inspections and maintenance	Ongoing	1	1	1

The O&M activity and schedule associated with green roofs are included in **Table 2.3.1-11**.

Table 2.3.1-11: Green Roof O&M Activities

Activity	Schedule	Visits Per Year Per Impervious Acre	Hours Per Visit Per Impervious Acre	Total Hours Per Year per Impervious Acre
Roof drains should be cleared when soil substrate, vegetation, debris or other materials clog the drain inlet. Sources of sediment and debris may be identified and corrected	As needed	2	3	6
Plant material should be maintained to provide 90% plant cover. Weeding should be manual with no herbicides or pesticides used. Weeds should be removed regularly	As needed	2	8	16
Irrigation can be accomplished either through hand watering or automatic sprinkler system if necessary during the establishment period.	As needed	5	1	5
Growing medium should be inspected for evidence of erosion from wind or water. If erosion channels are evident, they can be stabilized with additional growth medium similar to the original material.	Quarterly	4	3	12
Inspect drain inlet pipe and containment system	Annually	1	4	4
Test growing medium for soluble nitrogen content. Fertilize as needed	Annually	1	1	1
Maintain a record of all inspections and maintenance activity	Ongoing	1	1	1

The O&M activity and schedule associated with bioretention are included in **Table 2.3.1-12**.

ED_005060A_00001812-00475

Table 2.3.1-12: Bioretention O&M Activities

Activity	Schedule	Visits Per Year Per Impervious Acre	Hours Per Visit Per Impervious Acre	Total Hours Per Year per Impervious Acre
Re-mulch void areas	As needed	1	0.5	0.5
Treat diseased trees and shrubs	As needed	1	0.5	0.5
Keep overflow free and clear of leaves	As needed	3	0.5	1.5
Inspect soil and repair eroded areas	Monthly	12	0.5	6
Remove litter and debris	Monthly	12	0.5	6
Clear leaves and debris from overflow	Monthly	12	0.5	6
Inspect trees and shrubs to evaluate health, replace if necessary	Twice per Year	2	1	2
Inspect underdrain cleanout	Twice per Year	2	2	4
Verify drained out time of system	Twice per Year	2	1	2
Add additional mulch	Annually	1	1	1
Inspect for sediment buildup, erosion, vegetative conditions, etc.	Annually	1	1	1
Maintain records of all inspections and maintenance activity	Ongoing	1	1	1

The O&M activity and schedule associated with street trees are included in **Table 2.3.1-13**.

Table 2.3.1-13: Street Trees O&M Activities

Activity	Schedule	Visits Per Year Per Impervious Acre	Hours Per Visit Per Impervious Acre	Total Hours Per Year per Impervious Acre
Treat diseased trees and shrubs	As needed	3	3	9
Remove litter and debris	Monthly	12	1	12
Inspect trees and shrubs to evaluate health	Twice per Year	2	3	6

A summary of annual operation and maintenance costs are listed in **Table 2.3.1-14**.

Table 2.3.1-14: Annual Operation & Maintenance Costs [ENRCCI 8141; RSMEAN 115.2]

Control	Annual O&M Costs ($/Imp. Acre/yr)
Porous Pavement	$2,400
Subsurface Infiltration	$2,900
Green Roof	$4,000
Bioretention	$3,100
Street Tree	$1,800

Personnel Estimates for Green Streets

Based on the assumptions presented in the operations and maintenance descriptions, each acre of impervious drainage area requires approximately 24 hours of labor per year. Street lengths and widths vary widely, but on average the street and two sidewalks on one block make up approximately 0.5 acres of impervious surfaces. Assuming each employee averages 1,600 hours of task work per year (excluding vacation, training), the following estimates are reached:

- 12 hours of labor are required per block of green streets per year.
- A 2-person crew can visit 266 blocks once per year, 133 blocks twice per year, or 66 blocks four times per year. In all cases, the crew would visit approximately 1 block per day.
- Streets and sidewalks make up 591 acres in the City's combined sewered areas. A program to mitigate a portion of these through green infrastructure would result in the following estimated personnel requirements:
  - 10% (59 acres): 1-2 employees
  - 25% (148 acres): 2-3 employees
  - 50% (296 acres): 4-5 employees
  - 75% (444 acres): 6-7 employees
  - 90% (532 acres): 8 employees

Life Cycle Assumptions

A literature study was conducted on lifespan assumptions for each of the five categories of stormwater management designs and results can be found in **Table 2.3.1-15**.

ED_005060A_00001812-00477

Table 2.3.1-15: Life Cycle Assumptions

Control	Lifespan (years)
Bioretention	25 [1]
Green Roofs	25 to 30 [1,2]
Subsurface Infiltration	25 [1]
Porous Pavement	25 [1]
Street Trees	25 to40 [1,2]

[1]Note: Econ Northwest, 2007

[2] Note: internal communications

Based on these results, green infrastructure is typically overhauled or replaced every 25-40 years. Based on this and assuming a comprehensive O&M program, it appears reasonable to assume that an overhaul will not be performed until the end of the LTCP planning horizon of 40 years. However, replacement costs are discussed in the following section in case they are needed.

Replacement Costs

Replacement cost is determined by assuming that most traditional stormwater infrastructure components do not need replacing based on CRW's existing infrastructure life cycle. Traditional components include inlets, manholes, diversion structures, and pipes and related materials (i.e. gravel and fill). Most green infrastructure components have a shorter lifecycle and may need to be replaced more often. These costs are weighted with a percentage to determine the extent of the components cost to the replacement for a given stormwater management technique. Trees and plants have definite lifecycles and are assumed to be replaced completely if used in a given technique. Components such as gravel and soil are assumed to be replaced to a lesser extent, because their functionality is longer lasting. Other specific components, such as porous pavement and green roof components are assumed to be replaced completely. **Table 2.3.1-16** is an example of how replacement costs are determined. The summary of estimated replacement costs for specific control techniques is summarized in **Table 2.3.1-17.**

Green Stormwater Infrastructure Construction Cost Updates

For the purposes of the City Beautiful H2O Program Plan, green stormwater infrastructure costs assumptions were updated based on more recent cost investigations. Philadelphia Water Department prepared the *2016 Pilot Program Report* [3] and included an evaluation of construction and maintenance costs for green stormwater infrastructure. The median construction cost derived from the analysis and adjusted to Harrisburg for 2016 equals $316,000 per impervious acre managed for all project types. For the purposes of the development of cost opinions for the City Beautiful H_2O Program Plan construction and project contingencies are included in this value. Green stormwater maintenance cost analysis from the PWD Pilot Report found a cost of $8,000 per impervious acre managed for all project types.

[3] Philadelphia Water Department, *Pilot Program Report,* 2016, which can be found at: http://phillywatersheds.org/doc/Year5_EAPCombinedAppendices_website.pdf Appendix B, Section 4 (Construction Cost) and Section 5 (Maintenance)

ED_005060A_00001812-00478

Table 2.3.1-16: Example Specific Material Replacement Costs

Material	Units	Quantity	Unit Cost	Total Cost	Replacement Cost % Of Original	Replacement Cost
Deciduous Tree	total	6	$385.00	$2,310.00	100%	$2,310
Bark Mulch	sq. yd.	10.7	$6.15	$65.56	100%	$66
Geotextile Separation Fabric	sq. yd.	10.7	$1.95	$20.80	100%	$21
Planting Backfill Mixture	cu. yd.	9.5	$29.50	$279.70	100%	$280
Hauling Backfill Mixture to Site	cu. yd.	9.5	$30.55	$289.66	100%	$290
Excavation	cu. yd.	10.7	$2.75	$29.31	100%	$29
Porous Pavement						
Pervious Asphalt	sq. yd.	652	$10.45	$6,817.16	100%	$6,817
AASHTO No. 57 Choker	cu. yd.	18	$37.69	$682.94	50%	$341
AASHTO No. 2 Coarse Aggregate	sq. yd.	652	$9.55	$6,230.04	50%	$3,115
Non-Woven Geotextile	sq. yd.	784	$1.95	$1,529.50	50%	$765
Excavation	cu. yd.	218	$2.75	$598.84	50%	$299
Hauling Asphalt Materials to Site	cu. yd.	163	$30.55	$4,985.76	100%	$4,986
Hauling for excavated soil	cu. yd.	218	$30.55	$6,656.17	50%	$3,328
Pipe Trench Under Porous Pavement						
24" Perf. Pipes	foot	774	$62.00	$47,988.00	0%	$0
24" LF HDPE Header	foot	22	$62.00	$1,364.00	0%	$0
Gravel	sq. yd.	95	$15.40	$1,467.56	0%	$0
AASHTO No. 2 Coarse Aggregate	sq. yd.	91.2	$9.55	$871.06	0%	$0
Hauling Aggregate to Site	cu yd.	91.2	$30.55	$2,786.47	0%	$0
Inlet Structure						
Reinforced Concrete Inlet Box	total	1	$4,800.00	$4,800.00	0%	$0
Excavation volume	cu. yd.	4.7	$2.75	$13.03	0%	$0
Hauling for excavated soil	cu. yd.	4.7	$30.55	$144.83	0%	$0
Footing	Each	1	$27.78	$27.78	0%	$0
Reinforced Concrete Top Unit	Total	1	$440.00	$440.00	0%	$0
Heavy Duty Inlet Frame	Total	1	$1,125.00	$1,125.00	0%	$0
Coarse Aggregate Size No. 57	cu yd.	0.67	$37.69	$25.13	0%	$0
Hauling Aggregate to Site	cu yd.	0.67	$30.55	$20.37	0%	$0

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Table 2.3.1-17: Replacement costs

Control	Median Cost ($ / Impervious Acre)
Bioretention	$35,000
Subsurface Infiltration	$35,000
Green Roof	$220,000
Porous Pavement	$35,000
Street Trees	$12,000

2.3.2 Municipal Inflow and Infiltration Reduction

The planning level estimation of rehabilitation costs of municipal sewer infrastructure in an effort to reduce inflow and infiltration (I/I). Rehabilitation costs are included for the following municipal I/I reduction measures. **Table 2.3.2-1** and **Table 2.3.2-2** summarize the Municipal I/I unit costs.

- Pipe Lining
- Pipe lining costs based on the following assumptions:
  - Type of lining (cured-in-place)
  - Pipe diameter (8-inch through 48-inch; see Table 2.3.2-1 for unit costs)
  - Pipe length (in linear feet)

The cost of pipe lining is given per linear foot of pipe installed. A assumed unit cost per linear foot, varying by pipe diameter, is assumed.

Manhole Rehabilitation

Manhole rehabilitation includes sealing manholes and installing water tight frames and covers. The cost varies based on the number of manholes to be rehabbed, which are multiplied by a assumed unit cost value ($2500 per manhole) to determine the total manhole rehabilitation cost.

Catch Basin Rehabilitation

Catch basin rehabilitation includes sealing-off the connection from a catch basin to a sanitary or combined sewer. Construction cost estimates are based upon the input of number of catch basins or storm inlets to be removed, with a assumed unit cost per rehabilitation to be applied ($600 per catch basin). This unit cost does not include the new pipe and surface restoration required to reroute the catch basin.

Service Lateral Spot Repair

Estimates of the cost to spot repair cost of municipal service laterals are also available. Existing laterals would be reconnected with street wyes replaced. Construction cost estimates are based upon the input of linear feet of laterals to be repaired, with a assumed unit cost to be applied ($350 per LF repaired). The unit cost value is configured for this assumed type of service lateral repair.

Table 2.3.2-1: Municipal Pipe Lining Unit Costs [ENRCCI 8551; RSMEAN 100]

Diameter (in)	CIPP Pipe Lining Unit Cost ($/LF)
8	$137
10	$159
12	$199
15	$258
18	$280
21	$318
24	$395
27	$476
30	$572
36	$706
42	$846
48	$985

Table 2.3.2-2: Municipal Pipe Lining Unit Costs [ENRCCI 8551; RSMEAN 100]

Technology	Assumed Unit Cost	Units
Manhole Rehabilitation	$2500	Per manhole
Catch Basin Rehabilitation	$600	Per catch basin
Service Lateral Pipe Repair	$350	Per LF of lateral repair

2.3.3 Private Inflow and Infiltration Removal

Municipal collection sewer rehabilitation could be evaluated to estimate the cost effectiveness of wet-weather flow reduction by reducing I/I from private sources. Calculations for estimating cost of these removal alternatives and include rehabilitation costs for the following private I/I reduction measures. **Table 2.3.3-1** summarizes the Private I/I unit costs.

ED_005060A_00001812-00481

Table 2.3.3-1: Private I/I Removal Unit Costs [ENRCCI 8551; RSMEAN 100]

Technology	Assumed Unit Cost	Units
Service Lateral Lining	$120	Per LF of lateral lining
Sump Pump Discharge Rerouting	$4700	Per sump pump rerouting
Footing Drain Disconnection	$8000	Per disconnection
Exterior Roof Leader Disconnection	$20	Per homeowner disconnection
	$70	Per municipality disconnection
Private Drain Disconnection	$600	Per drain disconnection

Service Lateral Lining

This work includes spot repairs to the service lateral from a house or other building to the sewer pipe. Construction cost estimates are based upon the input of the combined length (in LF) of service laterals which require lining, with a assumed unit cost per LF to be applied ($120 per LF). The unit cost value is configured for this assumed type of service lateral repair.

Sump Pump Discharge Rerouting

For existing homes or other establishments with a sump pump that discharges flow from footing drains (and possibly roof leaders) into the sanitary system, this work includes constructing a hard pipe from the sump pump through the basement wall to an adequate discharge location (work will conform to applicable plumbing codes and other municipal regulations). The estimate is based on the number of homes or other establishments for which this work will be performed, with a assumed unit cost per home to route sump pump discharge below grade to storm system ($4,700 per rerouting).

Footing Drain Disconnection

For existing homes or other establishments where footing drains (and possibly roof leaders) are tied into the interior sanitary plumbing, this work includes removing and replacing portions of the basement floor as needed to separate the interior plumbing so that footing drains are routed to new sump. This work also includes constructing a hard pipe form the sump pump through the basement wall to a curb drain system, or existing catch basin. The unit cost includes the homeowner's share of the curb drain system cost. The estimate is based on the number of homes or other establishments for which this work will be performed, with a assumed unit cost applied ($8,000 per disconnection).

Exterior Roof Leader Disconnect

For buildings where roof leaders are tied into the footing drains and make their way to the sanitary lateral, this work includes disconnecting (cutting) the down pipe and providing a discharge to the ground for homes or other establishments with an adequate discharge location and where local codes permit. The estimate is based on the estimated number of roof leaders to be disconnected, as well as distinguish the type of roof leader disconnection. The estimate is based on whether will be performed by the homeowner or municipality.

Private Drain Disconnection

This work includes sealing the connection from a driveway drain or other private storm drain to a sanitary sewer. It also includes re-routing the drain line to an existing storm outlet or constructing a new drain outlet. The estimate is based on the estimated number of drains to remove and the total length of new storm sewer required. Based on these assumptions, a assumed unit cost is applied ($600 per disconnection).

2.3.4 Sewer Separation

Sewer separation construction costs were based on three components: new sanitary sewer construction costs, sewer lateral construction costs, and streetscape reconstruction cost. Unit cost data is based construction bids and are considered construction costs with overhead, profit and indirect costs included. Data is summarized in **Table 2.3.4.1**.

Table 2.3.4.1: Sewer Separation Component Costs [ENRCCI: 8551; RSMeans: 115.2]

Component	Unit Cost	Units
New Sanitary Sewers	$1,700,000	$/mile
Lateral from new sewer to property	$6,000	$/lateral
Interior plumbing modifications - Residential	$6,000	$/lateral
Interior plumbing modifications - Non-Residential	$20,000	$/lateral
Concrete Street Base	$6	$/square foot
Asphalt Paving	$3	$/square foot
Concrete Sidewalk	$7	$/square foot
Concrete Curb	$26	$/foot

2.3.5 Open Cut Pipe

Open cut installation of gravity sewer pipe is included and construction cost estimates for open cut pipe require the following assumptions values:

- Pipe cross-section, either circular or a box section;
- The nominal size of the cross-section in terms of diameter for circular pipe or a specified box size of Circular pipe nominal diameters range between six and 108 inches. In addition to the nominal diameter, the pipe material must be selected (PVC, Class II, III, IV, and V concrete pipe, or ductile iron).
    - Box culverts range in size between four foot by eight foot and 12 foot by 12 foot. The orientation of the box is also a variable, either wide or tall dependent on the orientation of the longer side of the box. A "wide" box would have a longer horizontal orientation, while a "tall" box would have a longer vertical orientation. The orientation designation of a square box will have no effect on unit cost.
- The proposed length of the pipe in the street as well as the length of the pipe out of the street, both in linear feet.

ED_005060A_00001812-00483

- The average depth to the pipe invert in vertical feet. The maximum depth to invert is 24 vertical feet.
- The volume percentage of rock excavation to total excavation.
- The pavement type. Assumed values for eight inch bituminous pavement or 11.5 inch pavement.
- The estimate is based on the type of street restoration efforts: a partial street opening which equals the trench width plus one foot on either side of the trench, or a complete restoration equal to the entire street width.
- The number of manholes and their typical diameter.
- The number of utility crossings encountered in the street.
- The number of service laterals to be installed or restored.
- Any sidewalk or curb restoration anticipated, and several assumptions for this type of restoration if it is needed.
- Additional cost considerations including: railroad costs, stream crossing costs, additional force main costs, and miscellaneous.
- Finally, several open pipe construction conditions are estimated as a percentage of total construction cost. These conditions include dewatering requirements, flow maintenance requirements, and traffic maintenance requirements.

The total cost estimate for open cut is determined by summing numerous direct unit construction costs (e.g. pipe material costs, equipment and labor costs for soil excavation).

Open Cut cost data is considered to be direct construction costs excluding overhead and profit, and indirect costs, and are summarized in **Tables 2.3.5-1** through **2.3.5-14**. The base index values for all open cut pipe cost data is ENRCCI 7312 and RS Means 92.9.

Table 2.3.5-1: Pipe Material Unit Cost Values ($/LF) [ENRCCI 7312; RS MEANS 92.9]

Pipe Diameter (in)	Pipe Classification					
	CL II	CL III	CL IV	CL V	PVC	Ductile Iron
6	-	-	-	-	-	14.6
8	-	-	-	3.3	3.3	16.15
10	-	-	-	5.6	5.6	22
12	-	-	13	14	7.7	26.5
14	-	-	-	-	-	34.5
15	-	-	15	16	10.9	-
16	-	-	-	-	-	37.5
18	-	17	18	20	13.3	47
20	-	-	-	-	-	55
21	-	21	23	28	17.5	-
24	-	27	29	33	23.9	70.5
27	30	31	34	44	24.5	-
30	37	37	41	51	41.4	-
33	42	44	51	62	-	-
36	49	51	61	74	62.6	-
42	66	68	78	101	82.8	-
48	80	85	100	126	109.3	-
54	97	101	123	166	118.9	-
60	123	132	156	184	-	-
66	149	156	190	218	-	-
72	176	175	226	252	-	-
78	209	224	269	306	-	-
84	258	276	330	369	-	-
90	289	308	365	404	-	-
96	320	337	400	442	-	-
102	351	372	444	482	-	-
108	359	409	491	526	-	-

ED_005060A_00001812-00485

Table 2.3.5-2: Pipe Laying Unit Cost [ENRCCI 7312; RS MEANS 92.9]

Pipe Diameter (in)	Cost ($/LF)
0	0.00
6	6.70
8	6.70
10	6.70
12	7.70
15	8.80
18	9.90
21	12.30
24	13.30
27	15.40
30	17.60
33	19.70
36	20.70
42	25.50
48	27.60
54	28.70
60	32.90
66	35.10
72	37.20
78	40.00
84	42.00
90	45.00
96	47.00
102	49.00
108	52.00

Table 2.3.5-3: Box Culvert Unit Costs [ENRCCI 7312; RS MEANS 92.9]

Box Culvert Size	Material Cost ($/LF)	Laying Cost ($/LF)
8'x4'	$395	$23.00
8'x6'	$435	$27.00
8'x8'	$474	$31.00
10'x6'	$553	$30.00
10'x8'	$632	$35.00
10'x10'	$711	$42.00
12'x4'	$632	$27.00
12'x6'	$751	$33.00
12'x8'	$830	$40.00
12'x10'	$909	$49.00
12'x12'	$988	$60.00

Note: Reinforced Concrete Box Sewer per ASTM C 1433

Table 2.3.5-4: Trench Width Values [ENRCCI 7312; RS MEANS 92.9]

Pipe Diameter (in)	Range of Trench Depth		
	0' to 10'	11' to 16'	17' to 25'
6	2.5	2.5	2.5
8	2.5	2.5	3
10	2.5	2.5	3
12	2.5	2.5	3
15	3	3.5	3.5
18	3.5	4	4
21	4	4.5	4.5
24	4	4.5	4.5
27	4.5	5	5
30	4.5	5	5
33	5	5.5	5.5
36	5.5	6	6
42	6.5	6.5	6.5
48	7	7	7
54	7.5	7.5	7.5
60	8.5	8.5	8.5
66	9	9	9
72	9.5	9.5	9.5
78	10	10	10
84	10.5	10.5	10.5
90	11	11	11
96	12	12	12
102	12.5	12.5	12.5
108	13	13	13

ED_005060A_00001812-00487

Table 2.3.5-5: Trench Wall Support Unit Cost [ENRCCI 7312; RS MEANS 92.9]

Excavation Depth (ft)	Unit Cost ($/Bank SF)
5	0.06
6	0.06
7	0.06
8	0.06
9	0.06
10	0.06
11	0.06
12	0.06
13	0.06
14	0.06
15	0.06
16	33
17	33
18	33
19	33
20	33
21	33
22	33
23	33
24	33
25	33

Table 2.3.5-6: Trench Excavation Unit Costs ($/CY) [ENRCCI 7312; RS MEANS 92.9]

Depth (feet)	Trench Width (feet)																
	0	2.5	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
5	0	9	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	0	12	10	9	9	8	-	-	-	-	-	-	-	-	-	-	-
7	0	14	13	12	10	10	9	9	8	8	8	7	7	7	7	6	6
8	0	16	15	13	12	12	10	10	10	9	9	9	8	8	8	8	8
9	0	18	16	14	13	13	12	12	12	11	11	10	10	10	10	10	9
10	0	20	18	16	14	14	13	13	12	11	11	11	10	10	10	10	9
11	0	23	20	17	16	15	14	13	13	12	11	11	11	10	10	10	9
12	0	25	23	19	17	16	15	14	14	13	12	12	11	11	10	10	10
13	0	27	25	21	19	17	16	15	14	13	13	12	12	11	11	10	10
14	0	29	27	24	20	18	17	16	15	14	13	13	12	12	11	11	11
15	0	30	29	25	23	20	18	17	16	15	15	14	13	13	12	12	12
16	0	33	30	27	24	21	20	18	17	16	16	15	14	14	13	13	12
17	0	36	32	28	26	24	21	20	18	18	17	16	15	15	14	14	13
18	0	38	34	29	27	25	23	21	19	19	18	17	16	16	15	15	14
19	0	40	37	30	28	26	24	23	21	20	19	18	18	17	17	16	16
20	0	42	38	33	30	27	26	24	23	22	21	20	19	19	18	17	17
21	0	44	39	36	31	29	27	25	24	23	22	21	20	19	19	18	18
22	0	45	42	37	33	30	28	26	25	24	23	22	21	20	20	19	18
23	0	47	44	39	34	31	29	27	26	24	23	22	22	21	20	20	19
24	0	50	45	40	37	33	30	29	27	26	25	24	23	22	21	21	20
25	0	52	47	42	38	34	32	30	28	27	26	25	24	23	22	22	21

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Table 2.3.5-7: Street Opening Unit Costs
[ENRCCI 7312; RS MEANS 92.9]

Opening Width (feet)	Cost ($/LF)
2	0
4.5	3.3
5	4.4
5.5	4.4
6	5.6
6.5	6.7
7	6.7
7.5	7.7
8	8.8
8.5	8.8
9	9.9
10	11.0
11	12.1
12	13.2
13	14.3
14	15.4
15	16.5
16	17.6

Table 2.3.5-8: Pipe Tap Unit Cost [ENRCCI 7312; RS MEANS 92.9]

Pipe Diameter (inches)	Cost ($/unit)
8	160
10	165
12	170
15	186
18	191
21	202
24	213
27	234
30	245
33	266
36	292
42	340
48	388

Table 2.3.5-9: Additional Pipe Tap Costs ($/LF) [ENRCCI 7312; RS MEANS 92.9]

In Street?	Cost ($/LF)	Comment
No	38	Under Grass
Yes	65	Under Pavement -granular backfill. For CDF use pipe sheet.

Table 2.3.5-10: Manhole Unit Costs [ENRCCI 7312; RS MEANS 92.9]

Manhole Depth (feet)	MH Diameter (feet)									
	0	4	5	6	7	8	9	10	11	12
5	0	$800	$1,500	-	-	-	-	-	-	-
10	0	$1,100	$2,100	$3,300	$3,700	$5,900	$6,500	$6,700	$9,800	$12,000
15	0	$1,500	$2,600	$4,300	$4,900	$7,500	$8,300	$8,500	$12,500	$15,400
20	0	$1,800	$3,100	$5,300	$6,000	$9,000	$10,100	$10,200	$15,100	$18,700
25	0	$2,100	$3,700	$6,200	$7,100	$10,600	$11,900	$11,900	$17,800	$22,100

Table 2.3.5-11: Street Restoration Unit Cost [ENRCCI 7312; RS MEANS 92.9]

Name	Total Thickness (inches)	Cost ($/SY)	Description
8" Bit.	14	33	6" Stone, 6" Bit. Base, 2" Bit Surface
11.5" Phila. Spec.	17.5	43	Standard Philadelphia Street Section: 6" Stone, 8" Cement Base, 2" Bit. Base, 1.5" Bit Surface

Table 2.3.5-12: Curb and Sidewalk Restoration Unit Costs [ENRCCI 7312; RS MEANS 92.9]

Restoration Type	Unit Cost	Description
Curb Restoration ($/LF)	$17	Typical 4" Concrete with 4" of Stone
Sidewalk Restoration ($/SY)	$30	

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Table 2.3.5-13: Miscellaneous Installation and Restoration Costs Associated with Open Cut Pipe [ENRCCI 7312; RS MEANS 92.9]

Description	Units	Unit Cost
Select backfill unit cost	$/CY	54
Gravel Unit Cost	$/CY	23
Common Backfill Unit Cost	$/CY	15
Manhole Bottom and Lid Unit Cost	$/unit	960
Utility Crossing/Relocation Unit Cost	$/unit	1000
Clearing and Grubbing Unit Cost	$/acre	3200
Rock Excavation Unit Cost - in add to TEU	$/CY	60

Table 2.3.5-14: Miscellaneous Construction Cost Multipliers [ENRCCI 7312; RS MEANS 92.9]

Category	Added Cost
In Rock (Y/N)?	50.00%
Dewatering Required (Y/N)?	10.00%
Flow Maintenance Required (Y/N)?	5.00%
In Brownfields (Y/N)?	5.00%
Traffic Maintenance Required (Y/N)?	1.00%

Conveyance Pipe O&M Costs

Maintenance of open-cut and trenchless pipes are based upon the same data set, and the costs to maintain both conveyance means can be estimated in a similar manner. The reference for O&M of both is a 2003 Detroit Water and Sewer Department (DWSD) report titled Wastewater Master Plan Volume 4: Capital Improvements Program. This report analyzed operation and maintenance of the conveyance pipe in the DWSD system between 1992 and 1996, and utilized target maintenance frequency equations for three most important maintenance issues: pipe cleaning, root intrusion removal, and TV inspections. The report also provided an audit of O&M costs and assigned a maintenance unit cost in dollars per linear foot of pipe for each of the three maintenance issues. These values were updated for time and location withusing ENR CCI and RS Means index values respectively.

Similar to the pipe maintenance analysis, an additional analysis of O&M costs related to manhole cleaning was determined in the DWSD report. This value is reported in dollars per manhole per year.

The assumed configuration is based on the same units used in the DWSD report. **Table 2.3.5-15** contains open cut pipe O&M costs.

Table 2.3.5-15 Open Cut Pipe O&M Cost Data [ENRCCI 7312; RS MEANS 92.9]

Description	Units	Unit Cost
Detroit Conduit O&M	$/LF-yr	4.00
Detroit Manhole O&M	$/MH-yr	2.60
Detroit O&M ENRCCI		6,771.00
Detroit O&M Means		103.90

2.3.6 Pump Stations

For purposes of the basis of cost opinions, all pump stations were assumed to be constructed as stand-alone structures – not part of a larger treatment or storage facility.

Construction cost estimates including overhead and profit, and indirect costs for three different pump station types were utilized: custom built wet-well/dry well, submersible, and deep tunnel dewatering. Deep tunnel dewatering pump stations can be significantly deeper than typical pump stations and will be used to dewater CSO storage tunnels. Custom built wetwell/dry-well and submersible pump stations are typical wet weather pump types, and will be used for collection and interceptor transmission, pumping into and dewatering satellite treatment facilities, and pumping into and through treatment plants. Low, intermediate, and high cost curves were determined for custom built wet-well/dry well and submersible pump stations. The primary factor for selecting a cost curve range is total dynamic head (TDH). For the purposes of cost estimating, high cost custom built wet-well/dry well pump stations generally have a TDH greater than 70 feet, whereas high cost submersible pump stations generally have a TDH greater than 50 feet. A secondary factor for selecting a cost curve range is standby power. For the purposes of cost estimating, intermediate cost pump stations are generally shallower than high cost pump station and have standby power, whereas low cost pump stations are generally shallower and without standby power.

Pump station cost estimates are based on the following assumptions:

- Type of pump station including low, intermediate, and high cost range
- Required firm pumping capacity

In addition, cost multipliers for pump station facility components could be included which could add to typical pump station costs such as: bar screens, maintenance dewatering pumps, grit removal provisions, odor control, variable speed motors, and special building requirements for motors and electrical controls.

The custom built wet-well/dry-well and submersible pump station cost estimating curves were based on the 2006 text book reference Pumping Station Design (Third Edition). The deep tunnel dewatering pump station cost curve was based on a collection of costs for existing and proposed large capacity deep tunnel dewatering pump stations in the United Stated. These costs were in

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the form of bids and basis of design costs, and a power trendline was utilized through the cost data points.

Pump station construction cost data is included in **Figure 2.3.6-1**.

The design curves for pump stations were utilized from Jones et al. Pumping Station Design (3rd Ed.). Cost estimation curves from this publication were utilized from a range of pump station installations around the US, and classified as either a custom built wet-well/dry-well facilities (**Figure 2.3.6-1**) or submersible facilities (**Figure 2.3.6-2**).

From each of these classifications, a low, intermediate, and high cost curve was utilized to encapsulate the range of costs which can be encountered in different pump station applications.

The selection of which curve to use is dependent primarily on depth and secondarily on whether standby power is needed at the station. **Table 2.3.6-1** is a matrix for selecting low, intermediate or high cost curves. These curves represent construction costs including contractor's overhead and profit and indirect costs.

In addition, a cost estimation curve was provided for deep tunnel dewatering pump stations (**Figure 2.3.6-3**). This curve was utilized from project cost data of installed dewatering pump stations. (Note: **Figure 2.3.6-3** also displays two curves along with equations, utilized via the Pumping Station Design (3rd Ed.) method).

Table 2.3.6-1: Cost Curve Selection Matrix for Pump Stations [ENRCCI 8551; RS MEANS 100]

Cost Curve	Depth[1]	Standby Power[2]
High	Deep	Yes or No
Intermediate	Shallow	Yes
Low	Shallow	No

[1]Deep Depths: Submersible (>50' TDH) Custom-Built Wet Well-Dry Well (>70' TDH)

[2]Standby Power: Back-up generators or dual electrical supply

For custom-built wet well/dry well pumping stations, the selected curves are as follows:

High Cost Curve: y = 803,151x0.9002
Intermediate Cost Curve: y = 385,002x0.8941
Low Cost Curve: y = 182,255x0.8914

For submersible pumping stations, the selected curves are as follows:

High Cost Curve: y = 1,077,394x0.6158
Intermediate Cost Curve: y = 473,381x0.6910
Low Cost Curve: y = 207,992x0.7662

For deep tunnel dewatering pumping stations, the equation for the selected curve was:

y = 1,077,394x0.6158

For all pump station cost estimate equations, y equals construction cost in dollars, and x equals pump station capacity in MGD.

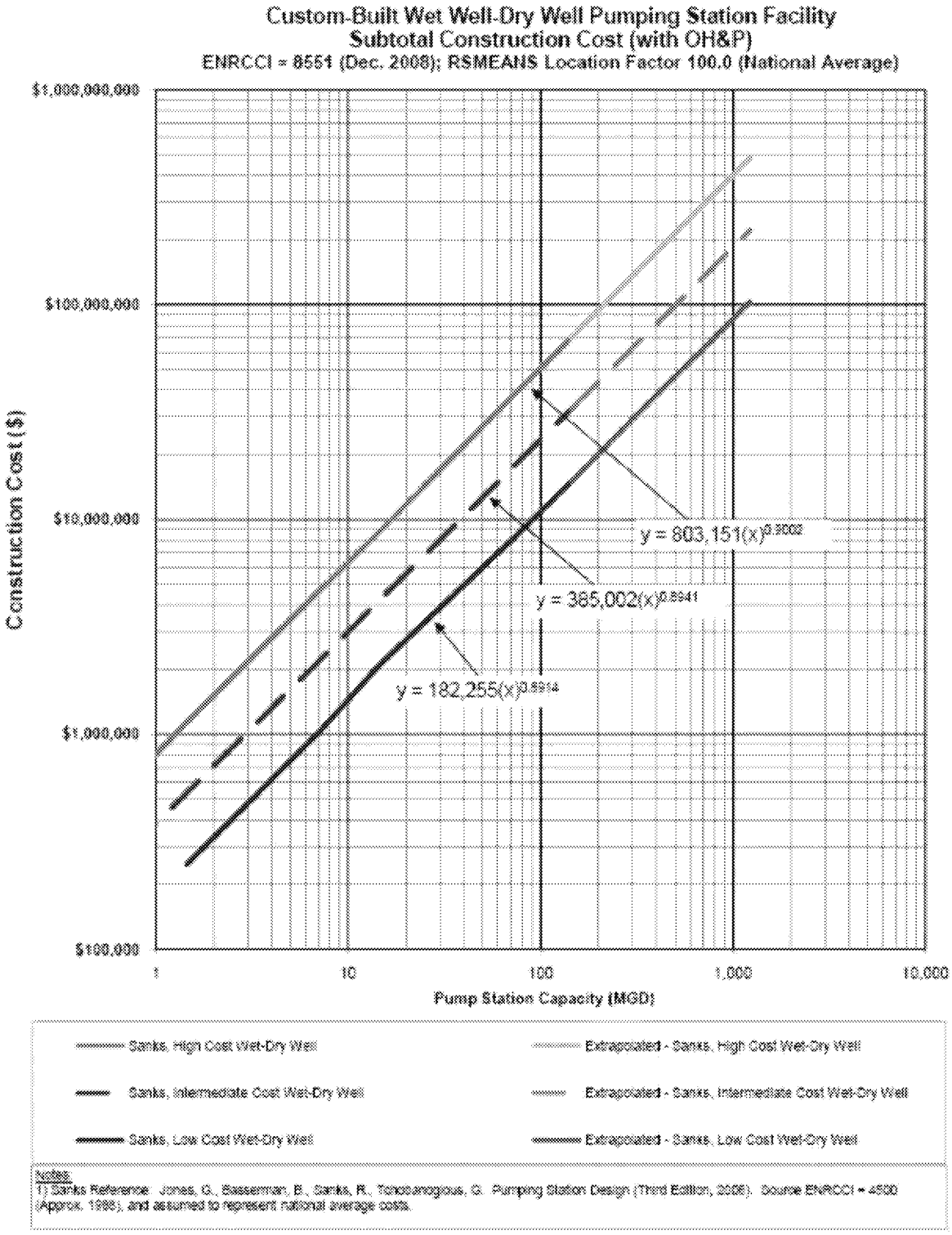

Figure 2.3.6-1: Custom-Built Wet-Well / Dry-Well Pump Station Curves [ENRCCI 8551; RS MEANS 100]

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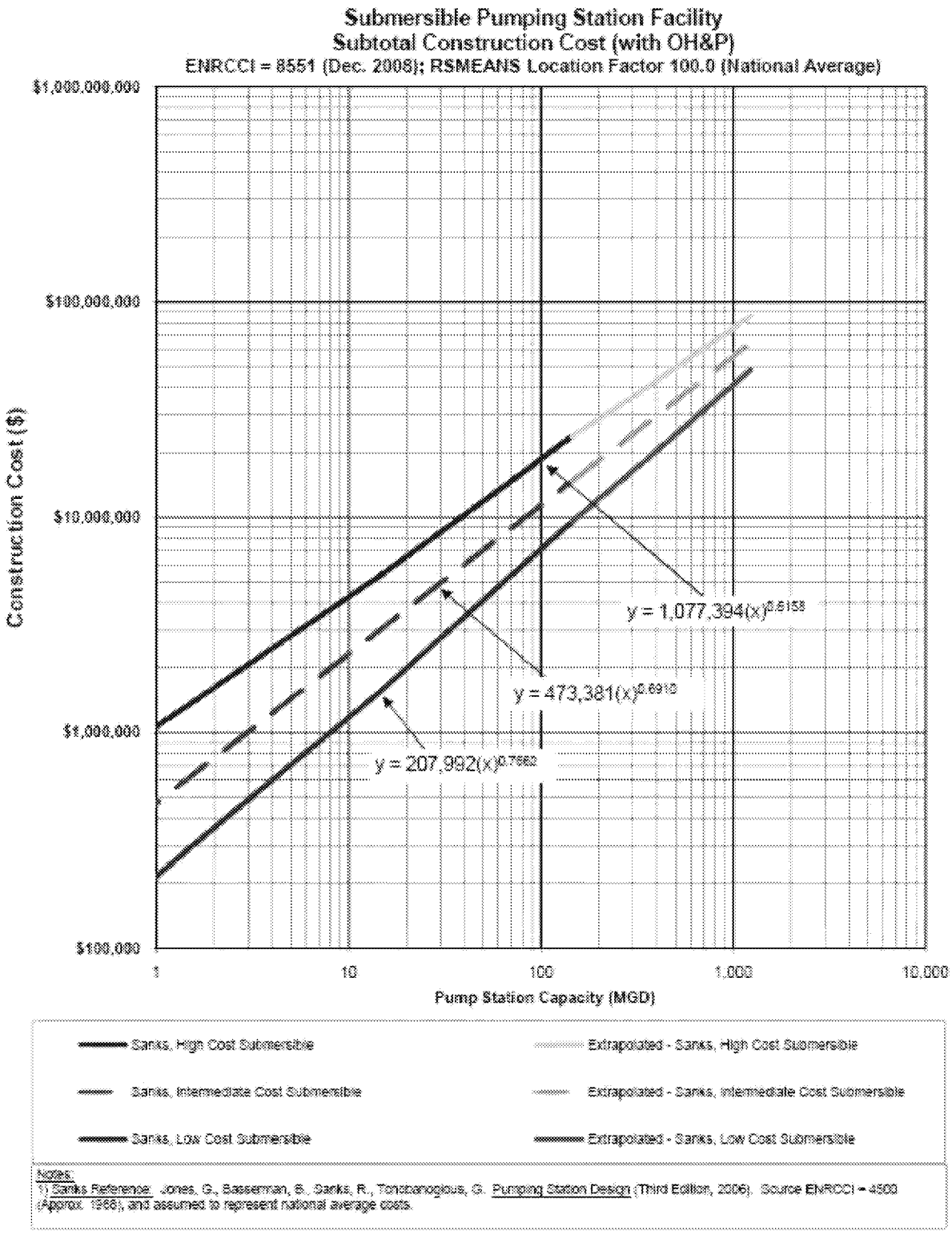

Figure 2.3.6-2: Submersible Pump Station Curves [ENRCCI 8551; RS MEANS 100]

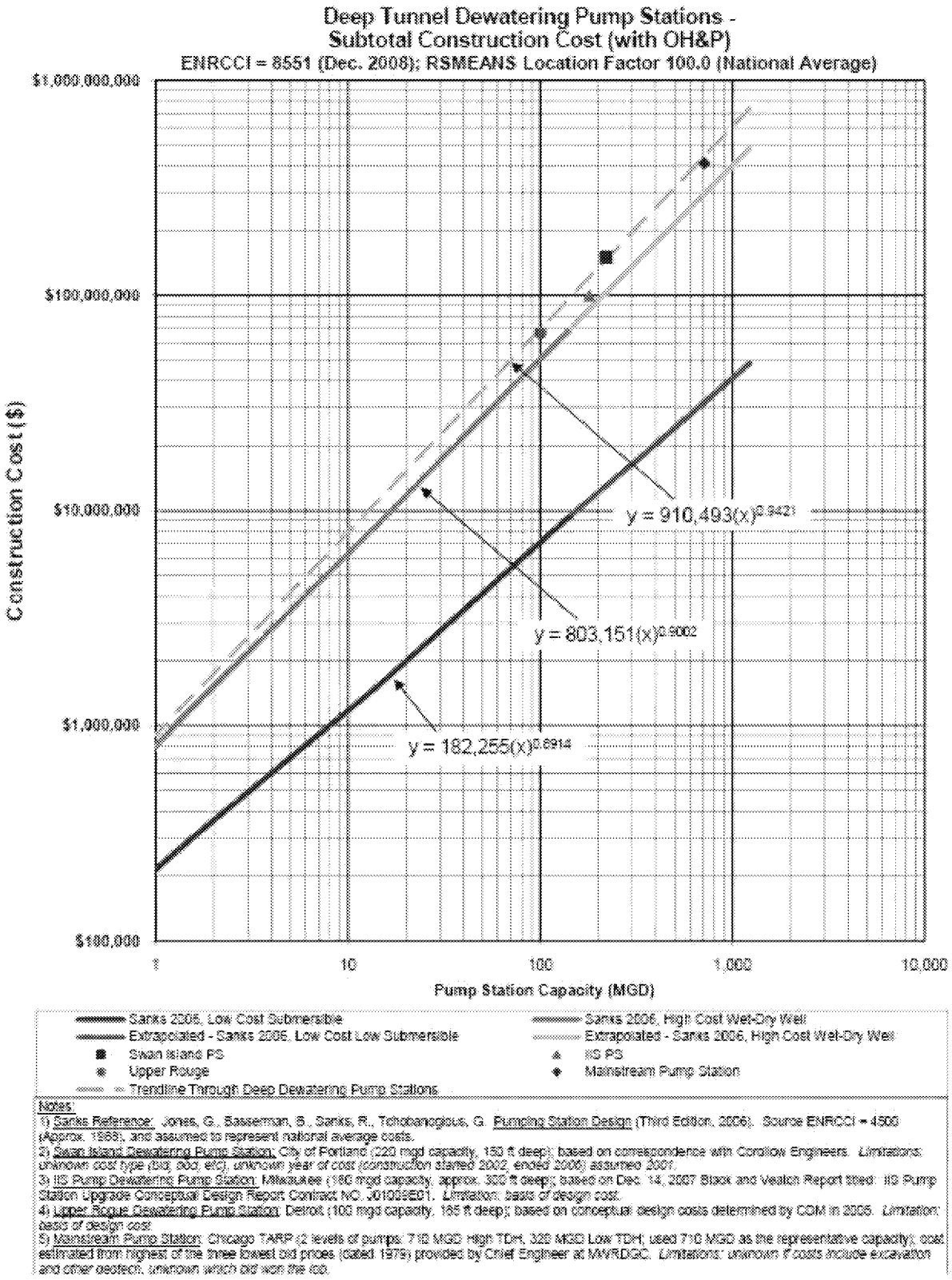

Figure 2.3.6-3: Deep Tunnel Dewatering Pump Station Curves [ENRCCI 8551; RS MEANS 100]

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Pump Station O&M Costs

Pump station O&M costs are calculated based on three cost components: energy costs, material costs and labor costs. Energy costs are calculated based upon assumptions values for the annual volume pumped (in mgd), the dynamic head (in feet), the "wire to water" efficiency, and electrical rate (in dollars per kilowatt-hour). The "wire to water" efficiency is the overall efficiency of the pump, motor and variable speed drive. This efficiency is the product of the efficiency percentages of these three components and is a percentage represented as a decimal value.

Three different options can be applied to calculate both material and labor costs for pump stations. The first method is derived from USEPA document 430/9-78-009, Innovative and Alternative Technology Assessment Manual dated February 1980. This document includes cost curves for both materials and labor annual cost as a function of wastewater flow (in mgd).

The second option for determining costs of pump station material and labor was derived from PWD cost data. Labor and material costs were calculated for each of 13 pumping stations based on materials purchased, annual maintenance man hours (including overtime hours) and an average hourly labor rate including fringe benefits applied from actual laborer salary data for calendar year 2007. Also applied to the labor costs is a site-specific work overhead percentage. The total annual labor and material costs were plotted individually against the rated pump station capacity (in mgd), and a linear line of best fit of these points determined the labor and materials cost equations.

Figure 2.6.3-4 summarizes the pump station O&M cost curves based on pump station capacity and compares the PWD costs to EPA O&M cost data.

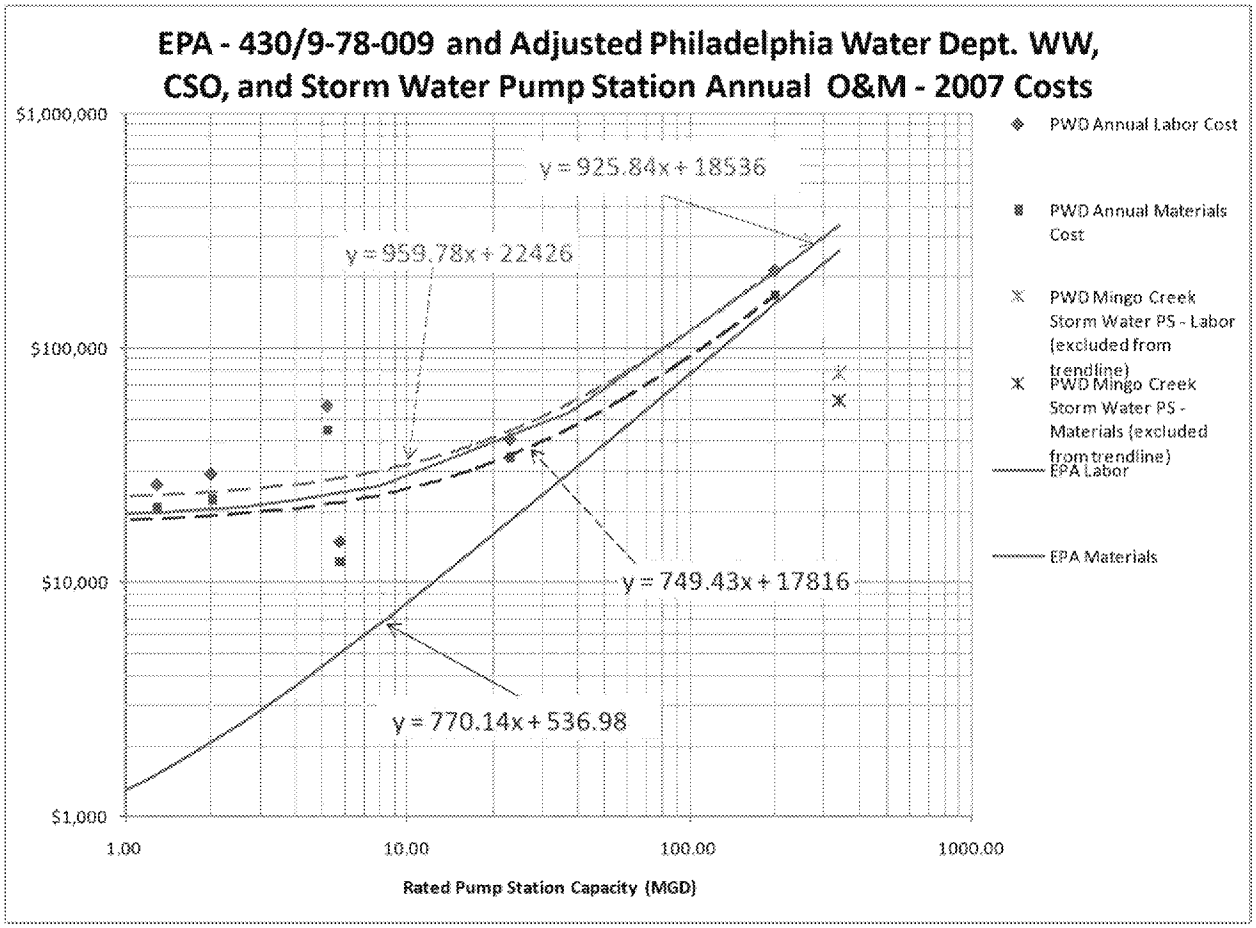

Figure 2.6.3-4 Pump Station Operations and Maintenance Costs [ENRCCI: 7939(PWD), 7966(EPA); RSMeans: 115.2 (PWD), 100.0 (EPA)]

2.3.7 Force Mains

There is not a separate control category for force mains, construction costs for force mains are to be calculated in the same manner as open-cut pipe, with the exception that the construction cost will assume installation of ductile iron pipe. Air release valves can be added as additional costs in the open-cut pipe cost estimate.

2.3.8 Short-Bore Tunnel (Trenchless)

Trenchless methods of pipeline construction can be superior to open cut methods, or the only option for special applications. Trenchless methods result in less surface disturbance, minimize pavement damage, and reduce utility conflicts, which is important when working in urban areas. Trenchless methods should be used when crossing highways, railroads, and other obstacles that are poorly suited for open cut methods. Trenchless methods might be less expensive than open cut methods depending on various factors including pipe depth, pipe diameter, distance between pits, geology, the bidding environment, etc. Trenchless methods can be used for pipe depths deeper than what is feasible for open cut methods.

Many trenchless methods exist; however, the two most applicable methods were included for cost estimating purposes: Microtunneling, and Pipe Jacking. These two methods work by

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pushing segments of pipe through the ground from a Jacking Pit. Microtunneling utilizes a micro-tunnel boring machine (MTBM) for advancement at the front of the pipe segments, whereas Pipe Jacking utilizes an open face. Pipe Jacking is typically a little less expensive, but because it utilizes an open face it should not be used below the groundwater table. Pipe Jacking is less favored than Microtunneling for diameters less than 48 inches and greater than 72 inches. For cost estimating purposes it is reasonable to not consider Pipe Jacking, and assume that Microtunneling will be used on all trenchless jobs. Both techniques require a Receiving Pit for retrieving equipment at the end of a pipe run. Significant cost savings can occur when two or more pipe runs share the same receiving or jacking pit.

Trenchless costs are sensitive to the geology at the pit locations and along the pipe run. For planning level cost estimation, basic geological conditions can be identified along the pipe run (e.g. soil, rock, and mixed), and in the pits (soil, rock). Mixed face conditions occur when both rock and soil conditions are experienced along the pipe run. Mixed face conditions should be avoided when possible, and will increase the uncertainty of the cost estimate. Steel pipe is recommended in mixed face conditions.

Construction cost estimates for pipelines constructed by trenchless methods based on the following:

- Pipeline
  - Method (Microtunneling or Pipe Jacking)
  - Nominal Pipe Size (ranging between 24 to 144 inches, but extreme minimum and maximum sizes are not feasible for all applications)
  - Pipe Material (RCP, HOBAS, Composite FRP, Steel)
  - Pipe Length (distance between pits)
  - Ground Type (Soil, Rock, Mixed)
- Jacking and Receiving Pits
  - Depth of Soil (i.e. depth from the ground surface to the bottom of excavation in soil)
  - Depth of Rock (i.e. depth from the bottom of excavation in soil to the bottom of excavation in rock)
  - Manhole at Pit (yes, or no)

Planning level trenchless unit costs are presented in **Tables 2.3.8-1** through **2.3.8-10** and are in terms of direct construction costs (i.e. materials, labor, and equipment), and do not include contractor's overhead and profit and indirect costs.

The total direct construction cost estimate for a trenchless pipeline is determined by the summation of the following cost groups: piping, pits, and manholes or just backfill. The piping costs listed by the soil group are complete and include the pipe material costs. Pit costs are determined by summing the Set Floor, Thrust Wall & Jacking Frames cost, cost per vertical foot in soil, and additional cost per vertical foot in rock. More specifically, costs per vertical foot are

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calculated separately for each depth group. When in rock, the cost per vertical foot in soil and additional cost in rock is summed together. The manhole costs per vertical foot are complete. If a manhole is not built the backfill cost per vertical foot should be used.

Trenchless tunneling costs ultimately depend on site specific and local geotechnical conditions, and other factors; the planning level unit costs presented in **Tables 2.3.8-1** through **2.3.8-10** represent optimum conditions and other assumptions:

- Planning level classifications of geotechnical soil conditions were used: soil, rock, mixed face.
- Ground improvement costs were not included.
- Production rates reflect work in urban streets with timely delivery of materials.
- Jacking and receiving pits were estimated using soldier piles and lagging for earth support.
- Rock was assumed to be below 15,000 psi compressive strength.
- Risk of boulders and manmade obstructions were not considered.
- Dewatering costs were excluded.

The planning level unit costs presented in **Tables 2.3.8-1** through **2.3.8-10** were based upon summing numerous direct unit construction costs (e.g. pipe material costs, equipment and labor costs for soil excavation). The logic for assembling the costs was based on engineering judgment and current industry practices. Unit cost sources and methods include:

- Labor Costs
  - Labor rates for Philadelphia.
  - Workman's compensation, liability insurance, and taxes were included in the labor rates.
  - Provisions for some overtime were included.
  - The following were excluded: stewards, surveyors, costs for off-shift, 10 hour shifts, and weekend work.
  - Crew size based on assumed collective bargaining coverage for this type of work.
- Equipment and operating costs represent compiled "owned" equipment rates for the Northeast area of the country.
- Material quotations were solicited from various vendors and represent budget estimates.

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Table 2.3.8-1 Microtunneling: Reinforced Concrete Non-Pressure Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining System: R. Concrete Non-Pressure Pipe			Soil				Rock				Mixed Ground			
	Pipe Internal Diameter	Pipe Materia Unit Cost	Short Range 150'-300'	Medium Range 300'-600'	Long Range 600'-1000'	Extra Long Range >1000'	Short Range 150'-300'	Medium Range 300'-600'	Long Range 600'-1000'	Extra Long Range >1000'	Short Range 150'-300'	Med Range 300'-600'	Long Range 600'-1000'	Extra Long Range >1000'
	(Inches)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)
	24	160	558	448	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	30	140	581	472	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	36	180	611	501	N/R	N/R	688	578	N/R	N/R	650	540	N/R	N/R
	42	200	715	580	553	511	772	637	610	568	744	609	582	540
	48	230	788	652	629	586	868	733	709	666	828	693	669	626
	54	270	971	792	752	699	1,095	917	877	824	1,033	855	815	762
	60	310	1,035	857	824	768	1,171	992	960	904	1,103	925	892	836
	66	360	1,159	956	919	855	1,305	1,103	1,066	1,002	1,232	1,030	993	929
	72	410	1,322	1,119	1,085	1,020	1,602	1,399	1,365	1,300	1,462	1,259	1,225	1,160
	78	480	1,451	1,242	1,211	1,142	1,754	1,536	1,504	1,436	1,603	1,389	1,358	1,289
	84	570	1,644	1,434	1,410	1,339	2,105	1,895	1,871	1,800	1,875	1,665	1,641	1,570
	90	630	1,962	1,712	1,682	1,597	2,333	2,083	2,053	1,969	2,148	1,898	1,868	1,783
	96	690	2,091	1,842	1,812	1,727	3,167	2,917	2,888	2,803	2,629	2,380	2,350	2,265
	108	950	2,711	2,619	2,416	2,380	3,638	3,545	3,342	3,306	3,175	3,082	2,879	2,843
	120	1,300	3,310	3,216	2,973	2,933	4,395	4,301	4,058	4,018	3,853	3,759	3,516	3,476
	144	2,060	4,344	4,294	4,032	3,998	5,680	5,630	5,367	5,333	5,012	4,962	4,700	4,666

Note: "N/R" indicates configurations which are not recommended for alternatives.

Table 2.3.8-2 Microtunneling: HOBAS GRP Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining system: HOBAS GRP Pipe			Soil				Rock				Mixed			
Pipe Internal Diameter	Pipe Material Unit Cost		Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'
(Inches)	($/LF)		($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)
24	198		618	508	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
30	264		686	577	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
36	345		771	661	N/R	N/R	847	738	N/R	N/R	809	700	N/R	N/R
42	420		928	793	766	724	986	850	823	781	957	822	795	753
48	476		1025	890	887	823	1106	971	947	904	1066	931	917	864
54	571		1261	1083	1044	990	1387	1208	1168	1115	1324	1146	1106	1053
60	635		1348	1170	1137	1081	1484	1305	1273	1217	1416	1238	1205	1149
66	745		1530	1327	1290	1226	1676	1473	1437	1373	1603	1400	1364	1300
72	810		1706	1502	1468	1403	1985	1782	1748	1683	1846	1642	1608	1543
78	900		1852	1642	1612	1543	2146	1937	1906	1837	1999	1790	1759	1690
84	1000		2051	1841	1817	1746	2512	2302	2278	2207	2282	2072	2048	1977

Note: "N/R" indicates configurations which are not recommended for alternatives.

Table 2.3.8-3 Microtunneling: Composite FRP Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining System: Composite FRP Pipe			Soil				Rock				Mixed			
	Pipe Internal Diameter	Pipe Material Unit Cost	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'
	(Inches)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)
	24	116	514	404	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	30	152	593	484	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	36	182	613	503	N/R	N/R	690	580	N/R	N/R	651	541	N/R	N/R
	42	223	738	603	576	534	795	660	633	591	766	631	604	562
	48	254	812	676	653	610	892	757	733	690	852	717	693	650
	54	314	1015	836	796	743	1139	961	921	868	1077	899	859	806
	60	346	1071	893	860	804	1207	1028	996	940	1139	960	928	872
	66	398	1197	994	957	893	1343	1141	1104	1040	1270	1067	1030	966
	72	434	1346	1143	1109	1044	1626	1423	1389	1324	1486	1283	1249	1184
	78	490	1461	1252	1221	1152	1764	1546	1514	1446	1612	1399	1367	1299
	84	522	1596	1386	1362	1291	2057	1847	1823	1752	1827	1617	1593	1522
	90	613	1945	1695	1665	1580	2316	2066	2036	1952	2130	1880	1850	1766
	96	672	2073	1824	1794	1709	3149	2899	2870	2785	2611	2362	2332	2247
	110	770	2531	2439	2236	2200	3458	3365	3162	3126	2994	2902	2699	2663

Note: "N/R" indicates configurations which are not recommended for alternatives.

Table 2.3.8-4 Microtunneling: Steel Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining system: Steel Pipe			Soil				Rock				Mixed			
Pipe Internal Diameter	Pipe Material Unit Cost		Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'
(inches)	($/LF)		($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)
24	124		544	434	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
30	136		559	449	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
36	148		575	465	N/R	N/R	651	541	N/R	N/R	613	503	N/R	N/R
42	172		681	546	518	477	738	603	576	534	710	575	547	506
48	198		748	612	589	546	828	693	670	627	788	653	630	587
54	248		939	761	721	668	1064	886	846	793	1002	824	784	731
60	299		1012	834	802	746	1148	970	938	881	1080	902	870	814
66	353		1138	935	898	834	1285	1082	1045	981	1212	1009	972	908
72	409		1304	1102	1068	1003	1585	1382	1348	1283	1445	1242	1208	1143
78	472		1424	1215	1184	1115	1718	1509	1478	1409	1571	1362	1331	1262
84	536		1587	1378	1353	1282	2048	1839	1814	1743	1818	1609	1584	1513
90	571		1877	1627	1597	1513	2248	1998	1969	1884	2063	1813	1783	1699
96	599		1971	1721	1692	1607	3047	2797	2767	2683	2509	2259	2230	2145
108	772		2447	2355	2152	2116	3374	3281	3079	3043	2911	2818	2616	2580
120	1033		3004	2910	2667	2627	4090	3996	3753	3713	3547	3453	3210	3170
144	1199		3430	3381	3118	3084	4766	4716	4474	4419	4098	4049	3796	3752

Note: "N/R" indicates configurations which are not recommended for alternatives.

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Table 2.3.8-5 Pipe Jacking: Reinforced Concrete Non-Pressure Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining system: Reinforced Concrete Non-Pressure Pipe			Soil				Rock				Mixed			
	Pipe Internal Diameter	Pipe Material Unit Cost	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'
	(inches)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)	($/Lf)
	24	160	530	420	N/R	N/R	663	525	N/R	N/R	N/R	N/R	N/R	N/R
	30	140	554	444	N/R	N/R	693	555	N/R	N/R	N/R	N/R	N/R	N/R
	36	180	583	473	N/R	N/R	729	591	N/R	N/R	N/R	N/R	N/R	N/R
	42	200	682	546	519	477	853	683	649	596	767	614	584	537
	48	230	747	611	588	544	934	764	735	680	840	687	662	612
	54	270	919	740	700	647	1149	925	875	809	1034	833	788	728
	60	310	979	800	768	711	1224	1000	960	889	1101	900	864	800
	66	360	1099	896	859	795	1374	1120	1074	994	1236	1008	966	894
	72	410	1123	1033	999	934	1404	1291	1249	1168	1263	1162	1124	1051
	78	480	1362	1151	1120	1051	1703	1439	1400	1314	1532	1295	1260	1182
	84	570	1531	1321	1296	1225	1914	1651	1620	1531	1722	1486	1458	1378
	90	630	1812	1562	1532	1447	2265	1953	1915	1809	2039	1757	1724	1628
	96	690	1926	1675	1645	1560	2408	2094	2056	1950	2167	1884	1851	1755
	108	950	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	120	1300	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	144	2060	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Note: "N/R" indicates configurations which are not recommended for alternatives.

Table 2.3.8-6 Pipe Jacking: Reinforced Concrete Non-Pressure Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining system: HOBAS GRP Pipe	Pipe Internal Diameter	Pipe Material Unit Cost	Soil				Rock				Mixed			
			Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'
	(Inches)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)
	24	198	590	480	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	30	264	659	549	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	36	345	743	633	N/R	N/R	929	791	N/R	N/R	836	712	N/R	N/R
	42	420	895	759	732	690	1119	949	915	863	1007	854	824	776
	48	476	984	849	825	782	1230	1061	1031	978	1107	955	928	880
	54	571	1210	1031	991	938	1513	1289	1239	1173	1361	1160	1115	1055
	60	635	1292	1113	1081	1024	1615	1391	1351	1280	1454	1252	1216	1152
	66	745	1470	1266	1229	1165	1838	1583	1536	1456	1654	1424	1383	1311
	72	810	1620	1416	1382	1317	2025	1770	1728	1646	1823	1593	1555	1482
	78	900	1762	1552	1521	1452	2203	1940	1901	1815	1982	1746	1711	1634
	84	1000	1938	1728	1703	1632	2423	2160	2129	2040	2180	1944	1916	1836

Note: "N/R" indicates configurations which are not recommended for alternatives.

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Table 2.3.8-7 Pipe Jacking: Composite FRP Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining System: Composite FRP Pipe			Soil				Rock				Mixed			
	Pipe Internal Diameter	Pipe Material Unit Cost	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'
	(inches)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)
	24	116	486	376	N/R	N/R	619	481	N/R	N/R	N/R	N/R	N/R	N/R
	30	152	566	456	N/R	N/R	705	567	N/R	N/R	N/R	N/R	N/R	N/R
	36	182	585	475	N/R	N/R	731	593	N/R	N/R	N/R	N/R	N/R	N/R
	42	223	705	569	542	500	875	705	671	619	790	637	606	559
	48	254	771	635	612	568	958	788	759	704	864	711	686	636
	54	314	963	784	744	691	1193	969	919	853	1078	877	832	772
	60	346	1015	836	804	747	1260	1036	996	925	1137	936	900	836
	66	398	1137	934	897	833	1412	1158	1112	1032	1274	1046	1004	932
	72	434	1147	1057	1023	958	1427	1315	1272	1191	1287	1186	1147	1074
	78	490	1372	1161	1130	1061	1712	1448	1410	1323	1542	1304	1270	1192
	84	522	1483	1273	1248	1177	1866	1603	1572	1483	1674	1438	1410	1330
	90	613	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	96	672	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	110	770	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Note: "N/R" indicates configurations which are not recommended for alternatives.

Table 2.3.8-8 Pipe Jacking: Steel Pipe Unit Costs [ENRCCI 8578; RS MEANS 113.2]

Lining System: Steel Pipe			Soil				Rock				Mixed			
	Pipe Internal Diameter	Pipe Material Unit Cost	Short Range 150'-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'	Short Range 150'-300'	Medium Range 300-600'	Long Range 600'-1000'	Extra Long Range >1000'	Short Range 150'-300'	Medium Range 300-600'	Long Range 600-1000'	Extra Long Range >1000'
	(Inches)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)	($/LF)
	24	124	532	422	N/R	N/R	665	528	N/R	N/R	599	475	N/R	N/R
	30	136	547	437	N/R	N/R	684	546	N/R	N/R	615	492	N/R	N/R
	36	148	562	452	N/R	N/R	703	565	N/R	N/R	632	509	N/R	N/R
	42	172	669	534	507	465	836	668	634	581	753	601	570	523
	48	198	707	571	548	505	884	714	685	631	795	642	617	568
	54	248	887	708	669	615	1109	885	836	769	998	797	753	692
	60	299	957	778	745	689	1196	973	931	861	1077	875	838	775
	66	353	1078	875	838	774	1348	1094	1048	968	1213	984	943	871
	72	409	1219	1015	981	916	1524	1269	1226	1145	1371	1142	1104	1031
	78	472	1334	1124	1093	1024	1668	1405	1366	1280	1501	1265	1230	1152
	84	536	1475	1265	1240	1168	1844	1581	1550	1460	1659	1423	1395	1314
	90	571	1727	1477	1447	1362	2159	1846	1809	1703	1943	1662	1628	1532
	96	599	1805	1555	1525	1440	2256	1944	1906	1800	2031	1749	1716	1620
	108	772	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	120	1033	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R
	144	1199	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R	N/R

Notes: "N/R" indicates configurations which are not recommended for alternatives.

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Table 2.3.8-9 Jacking Pit Unit Cost Values [ENRCCI 8578; RS MEANS 113.2]

Pipe Diameter Range (inch)	Jacking Pit Footprint - Length x Width (ft x ft)	Receiving Pit Footprint - Length x Width (ft x ft)	Set Floor, Thrust Wall & Jacking Frames (Receiving Pit Cost is 75% of Jacking Pit Cost)	Jacking Pit in Soil (Receiving Pit Cost is 75% of Jacking Pit Cost)					Additional Cost if Pit in Rock (Receiving Pit Cost is 75% of Jacking Pit Cost)				
				0-30' Deep ($/VF)	31-60' Deep ($/VF)	61-90' Deep ($/VF)	91-120' Deep ($/VF)	121-150' Deep ($/VF)	0-30' Deep ($/VF)	31-60' Deep ($/VF)	61-90' Deep ($/VF)	91-120' Deep ($/VF)	121-150' Deep ($/VF)
24 - 36	16 x 10	12 x 10	24,000	3,330	3,700	4,070	4,810	5,920	720	800	880	960	1,040
42 - 54	18 x 12	12 x 12	32,000	4,050	4,500	4,950	5,850	7,200	1,080	1,200	1,320	1,440	1,560
60 - 72	20 x 14	14 x 14	39,000	4,860	5,400	5,940	7,020	8,640	1,440	1,600	1,760	1,920	2,080
78 - 84	24 x 14	14 x 14	45,000	5,670	6,300	6,930	8,190	10,080	1,800	2,000	2,200	2,400	2,600
90 - 108	26 x 16	16 x 16	74,000	7,020	7,800	8,580	10,140	12,480	2,790	3,100	3,410	3,720	4,030
120 - 144	28 x 20	20 x 20	96,000	8,370	9,300	10,230	12,090	14,880	3,780	4,200	4,620	5,040	5,460

Table 2.3.8-10 Jacking Pit Manhole, Backfill & Bracing Removal Unit Cost Values [ENRCCI 8578; RS MEANS 113.2]

Pipe Diameter Range (inch)	Manhole, Backfill & Bracing Removal						Just Backfill				
	Manhole Diameter (ft)	0-30' Deep ($/VF)	31-60' Deep ($/VF)	61-90' Deep ($/VF)	91-120' Deep ($/VF)	121-150' Deep ($/VF)	0-30' Deep ($/VF)	31-60' Deep ($/VF)	61-90' Deep ($/VF)	91-120' Deep ($/VF)	121-150' Deep ($/VF)
24 - 36	6	1,627	1,350	1,485	1,755	2,025	675	750	825	975	1,125
42 - 54	8	2,350	1,800	1,980	2,340	2,700	900	1,000	1,100	1,300	1,500
60 - 72	10	3,517	2,450	2,695	3,185	3,675	1,125	1,250	1,375	1,625	1,875
78 - 84	12	4,633	3,300	3,630	4,290	4,950	1,350	1,500	1,650	1,950	2,250
90 - 108	16	6,608	4,675	5,143	6,078	7,013	1,688	1,875	2,063	2,438	2,813
120 - 144	20	8,833	6,000	6,600	7,800	9,000	2,250	2,500	2,750	3,250	3,750

General guidelines for using the trenchless unit costs include the following:

- Mixed face areas should be avoided if possible; tunneling at a deeper depth in rock is preferred.
- Tunneling in "mixed face" conditions if necessary, should be limited to steel pipe as the machine tends to deflect in the interface areas, thus stressing the joints on concrete or Hobas type pipes.
- Pipe runs with diameters less than 36 inches should be limited in length to less than 500 feet, due to the inability to remove intermediate jacking stations.
- Small diameter concrete or clay pipes should be limited to 400 feet.
- Hobas discourages pipes larger than 84 inches from being used for direct microtuneling or jacking as the bell / gasket bank will deform on the larger sizes.
- Diameters greater than 108 inches should not be "jacked" using open face machines, TBM's should be employed and segments should be considered.
- Shafts deeper than 30 feet to 50 feet should be constructed using circular caissons, which can ultimately be used as the permanent access.
- Tunneling in rock should be limited to machines 60 inches and above in diameter, this is due to face access for cutter head replacement and the limited power of the smaller machines.

2.3.9 Conventional Tunnel - Storage/Conveyance

The term Conventional Tunnel refers to large diameter tunnels created by tunnel boring machines (TBM) that are advanced from the TBM location, unlike Short-Bore Tunnels (Trenchless) that are advanced from the pit location.

Key components of a complete CSO storage tunnel alternative cost include cost estimates for Conventional Tunnels in Rock and Primary Tunnel components, and some Secondary Tunnel Alternative components. The following sections document the materials used to determine a complete CSO storage tunnel alternative cost.

The Primary Tunnel components include the following:

- Shafts
  - Work
  - Maintenance
  - Vent
  - Access
- CSO Tunnel Components

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- CSO vortex near surface structure
- CSO drop shaft structure
- Audits (tunnel connecting CSO drop shafts to the storage tunnel)

The Secondary Tunnel Alternative components include the following:

- New or modified CSO regulating structures
- Consolidation piping – near surface piping that directs flow from the CSO regulators to the CSO vortexing/drop structures
- Tunnel dewatering pump station

Supplemental Materials - Conventional Tunnel in Rock and Primary Tunnel Components

A tunnel costing spreadsheet was utilized to estimate the cost of conventional rock tunnels and primary tunnel components. The key assumptions used for determining a tunnel cost estimate include:

- Tunnel
  - Tunnel Inside Diameter
  - Tunnel Length
  - Lining Type (Cast in place, or Segmental)
  - Corrosion Protection Liner (Yes, or No)
- Shafts (numerous types)
  - Number of shafts
  - Shaft diameter
  - Depth in soil
  - Depth in rock
- CSO Tunnel Components
  - Design flowrate

It should be noted that there is no industry standard cost estimating tool for rock tunnel construction available at this time (i.e. equivalent of RS Means®, Mining Cost Services® etc.). This is due to the highly sensitive nature of the cost of tunneling relative to geology, depth, groundwater issues, the end use and application of the structures, among many other labor, finance and risk allocation issues. The result is that there is no uniform way of evaluating the cost across the industry.

Therefore, consideration of the implication of each factor on the tunneling method and related cost. As such, a reasonable planning level estimate of the potential tunnel cost can be derived if it

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is used within the ranges specified herein. For variations beyond these values, the assumptions will need to be revised.

The estimated cost is based on the assumption of using a tunnel boring machine (TBM) (open or shielded) as the tunneling method. The TBM deep tunnel drilling will be assumed to be in full rock face, which offers two choices of ground support, including temporary support plus cast in place (CIP) as well as Concrete Segmental lining. Most of the tunnel cost elements were based on a conventional tunnel in New York, detailed cost estimate for a conventional tunnel in St. Louis, MO, and general rule of thumb values for tunnel construction.

The formulas used to adjust the estimated cost of tunnel are empirical and in general vary by using power functions. The adjustment for diameter is considered to be proportional with tunnel diameter or linear function (power of 1) with the ratio of tunnel diameters. The adjustment for tunnel length is done based on a power function to account for the spread of the fixed cost items over the longer tunnel, meaning a gradual decrease in estimated cost per foot as the tunnel gets longer. Although these powers are variable and can be changed, they have been set to 0.3-0.25 for excavation and final lining, respectively. The values used are based on personal judgment of the overall trend in the adjustment curve.

Costs associated with site Mobilization/Demobilization are estimated based on the tunnel diameter and length. The length of the tail or starter tunnel in rock can be selected as needed and again a rule of thumb for this level of planning is to use a minimum of 10 times the tunnel excavated diameter to allow for assembly of the machine and its back up system. Cost per unit for hand mining of the starter/tail tunnel is calculated by the spreadsheet and the length is deducted from the length of the bored tunnel.

A short list of assumption behinds the conventional tunnel cost estimate is listed as follows:

- Construction of main tunnel to be performed by TBMs.
- Tunnel cost varies proportional to tunnel diameter.
- Tunnel cost will decrease with tunnel length within a certain range. The rate of decrease is estimated by using a power function (power of 0.25-0.3).
- Tunnel is in uniform ground. Mixed face conditions are not accounted for and it is recommended to choose the vertical alignment to stay within rock.
- Variation of rock types is acceptable.
- Tunneling is done with a circular profile and by a tunnel boring machine.
- Open hard rock TBMs will be used for excavation of rock while installing temporary support, and followed by CIP concrete lining. Alternatively, one pass system can be used with double shield machine and concrete segmental lining. Additional cost of tunneling is reflected in the cost per foot of segments.
- Access to the tunnel is through the work shaft and not portals.

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- No exceptional or extraordinary complications exist in the ground, normal variation of lithology and some structural features are included. Unusual conditions with high groundwater pressure, abnormal in situ stresses, extended area of fault zones, contaminated ground, encountering high volume of methane, etc. is not considered in the costs.
- Normal contracting practice with design-bid-build is assumed to be used for the project.
- Operations are based on 24 hour activities and full access to the site 7 days a week.
- Cost of tunneling comprises labor, equipment, and consumables, with 1/3 rule.
- Geographical impact is primarily in terms of labor cost, and can impact the 1/3 contribution of the labor.
- Shaft depths in the range of around 200 ft can be estimated based on unit price of excavation. Deeper shafts may require special provisions.
- Shaft diameters of 10-75 ft can be estimated based on unit prices, larger shafts may need special provisions.
- Excavation cost includes transportation of muck in the tunnel and off the site within reason. Additional cost of muck haulage to a long distance or special provisions of dump sites was not accounted for.

CSO vortex drop shaft costs were determined by using Sage Timberline software to estimate the cost of numerous structures, based on basis of design drawings, designed to handle specific flow rates.

Supplemental Materials - Secondary Tunnel Alternative Components

Cost estimates for new or modified CSO regulator structures were determined by using Sage Timberline software to estimate the cost of numerous structures, based on basis of design drawings, designed to handle specific flow rates.

Secondary Tunnel Alternative Structures Components

Consolidation piping was costed with unit costs from the open cut pipe cost assumptions. Deep CSO storage dewatering pump stations were costed with unit costs from the pump station cost curves. Specifically the deep tunnel dewatering pump station costing curve was used.

Supplemental Materials - CSO Storage Tunnel O&M Costs

Conventional CSO storage tunnel O&M was largely based on two WEFTEC 2007 Session 8 references:

- Murphy, S. Operations and Maintenance Requirements for Storage Tunnels and In-System Storage Facilities
- Sherrill, J. Fujita, G. Budget Development for Operations/Maintenance Requirements For CSO/SSO Control Facilities

These references provided a general framework to perform O&M cost estimates. Tunnel storage O&M activities were broken into two groups: event (operations), and non-event (maintenance). Non-event activities are maintenance activities on the tunnel, dewatering pump station, and associated structures, that occur when the tunnel is not being operated. Event activities are operations activities that occur immediately before a CSO storage event, while the tunnel is filling, and while the tunnel is being dewatered and flushed. Guidelines for estimating event and non-event labor hours were provided, along with a breakout of labor hours per labor classification. Guidelines for marking up labor hours to include training, vacation, and other benefits were included. In addition, estimates for materials and electrical costs were provided.

Several modifications to the cost estimating approach were performed. The primary consumer of electricity was the dewatering pump station, and was calculated directly. Additional cost markups for tunnel length and dewatering pump station capacity was included in the estimate.

The following variables were used to estimate an annual O&M cost:

- Estimates of annual event duration
- Labor rates for specific labor classifications
- Pump station electrical consumption
  - Annual Volume Pumped
  - Total Dynamic Head
  - Wire to Water Efficiency
  - Electrical Rate
- Tunnel Length
- Pump Station Capacity

2.3.10 Tank Storage

Off-line tank storage within the collection system can be used to reduce combined sewer overflows (CSOs) or sanitary sewer overflows (SSOs) by storing wet-weather flows. After an event, the stored combined sewage and flushed solids would be conveyed to the existing interceptor system (by gravity or pumping) for treatment at the treatment plant.

A costing curve for tank storage was utilized based on tank storage costing curves used for other CSO control programs around the nation, as well as cost data of completed storage tanks in varying CSO and SSO storage applications. The following items are included in the cost estimation equation for surface storage facilities:

- A below-grade, cast-in-place, covered storage tank between 0.1 and 30 MG of storage.
- Each tank includes an automated flushing system.
- Odor control is required.

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- A control building is required.

If pumping into the surface storage facility is required or if it must be dewatered via pumping, the pump station is to be provided in a separate structure, and its costs are accounted for separately. Dewatering pumping is required if gravity dewatering time exceeds 48 hours from the end of an event.

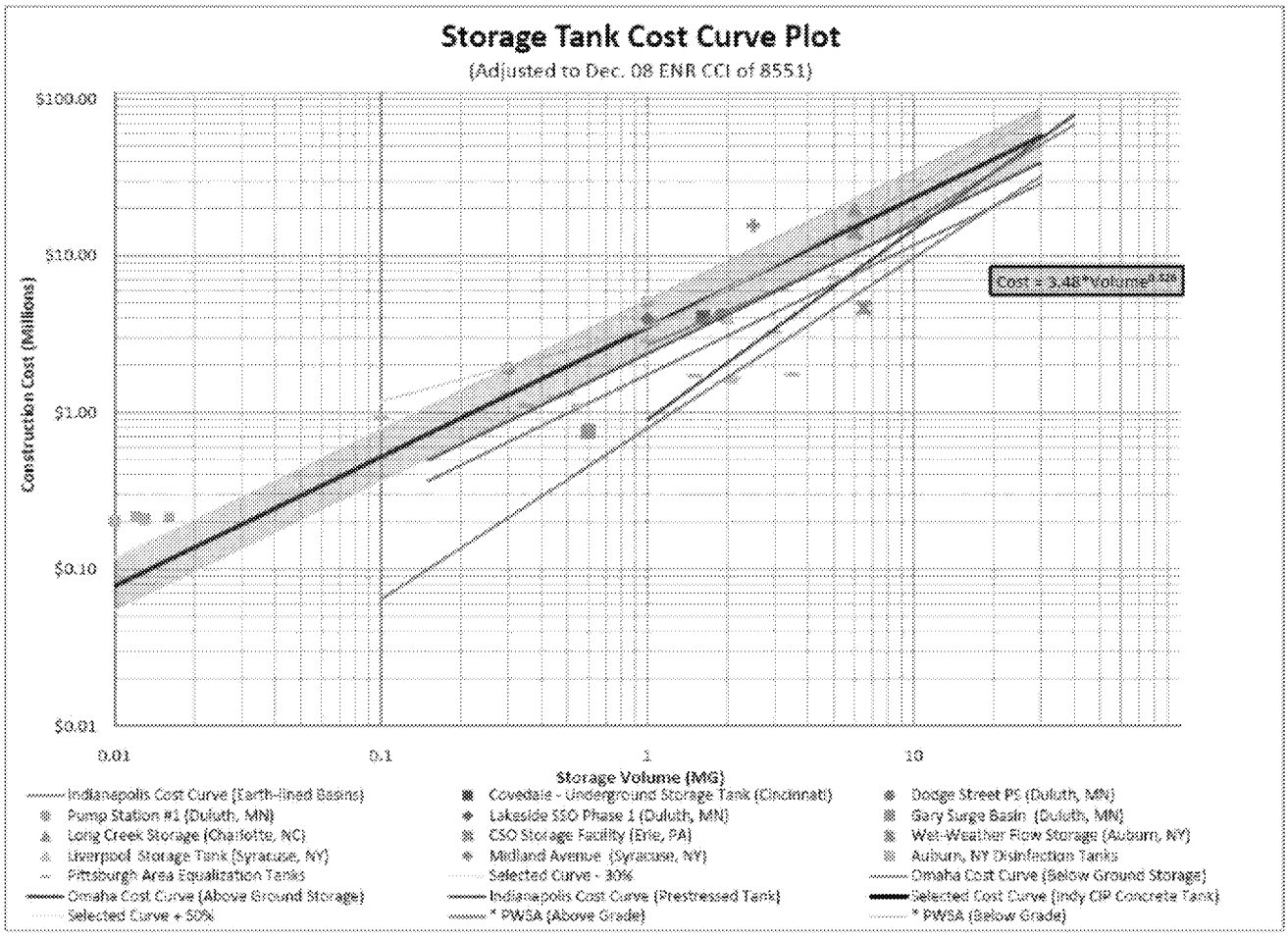
Conveyance from the existing collection system to the storage facility or from the facility to the interceptor will be accounted for separately.

Figure 2.3.10-1 displays the plot of the data used for determining the storage tank cost. The cost is based on the tank storage volume to calculate the initial facility cost. The equation for the storage tank costing curve is:

$y = 3.48x0.826$

Where y equals cost in million dollars and x equals the storage volume in MG

O&M Costs for CSO storage tanks were estimated based on the WEFTEC07 approach for CSO/SSO facility O&M. This methodology is used for Retention Treatment Basins as well.



* Source: PWSA *Basis of Cost for CSO Control Technologies* , March 2007

Figure 2.3.10-1 Storage Tank Cost Curve [ENRCCI 8551; RS MEANS 100]

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2.3.11 Screening

While screens serve as a pre-treatment device in several types of high rate treatment facilities, fine screens can also serve as a stand-alone CSO control measure with disinfection. With screen sizes ranging from 4 to 6 mm, these facilities can be very effective at removing floatables, including sanitary trash.

Screening facility costs are estimated as a standalone technology. However, since screening facilities are not designed to remove fecal solids, disinfection generally must be achieved via chlorination and dechlorination. Chlorination/dechlorination facilities are included as a separate control technology, and described further in Section 2.3.15 of this manual. For disinfection at screening facilities, the use of sodium hypochlorite for chlorination and sodium bisulfite for dechlorination will be the assumed assumptions. Any wastewater pumping required as part of the screening facility will be accounted for separately; Section 2.3.6 details pump station cost estimation.

The cost curve equation for screening was utilized from construction cost data provided by the PM, BC, and BPs, as well as cost curves from other CSO control programs around the nation. The curve is displayed in **Figure 2.311-1**. The equation of the selected curve for screening is: $y = 0.0834x^{0.843}$

- Where y equals construction cost in million dollars, and x equals treatment capacity in MGD

From the equation of the selected curve, the cost is based on the design flow rate in MGD.

O&M costs for screening facilities are estimated based on the WEFTEC07 approach for CSO/SSO facility O&M. An example O&M calculation for a screening facility is provided below. **Example Calculation for Determination of O&M Costs for Screening Facilities**

Notes: 1. *Input variables are highlighted in yellow*
2. *O&M Costs for chlorine disinfection are included*

	Annual "Task" Hours	Annual Staff Hours	Hourly Rate	Annual Costs
Annual Number of Non-Task Hours per Full-Time Employee	480			
Maintenance				
Supervisory Maintenance	80	104	$150	$15,600
Non-Supervisory Maintenance	1570	2041	$100	$204,100
Total:	1650	2145		$219,700
Annual Event Hours*	800			
Operations				
Supervisory Operations (0.6 hours/event hour)	480	624	$150	$93,600
Non-Supervisory Operations (3.6 hours/event hour)	2880	3744	$100	$374,400
Total:	3360	4368		$468,000
Non-Staff Resources ($70,000 / year)				$70,000
		Total Annual O&M Costs		**$757,000**

Source: Budget Development for Operations/Maintenance Requirements for CSO/SSO Control Facilities, WEFTEC 2007.
* Annual event hours include pre-event, treatment and post-event periods as defined in the WEFTEC source paper.

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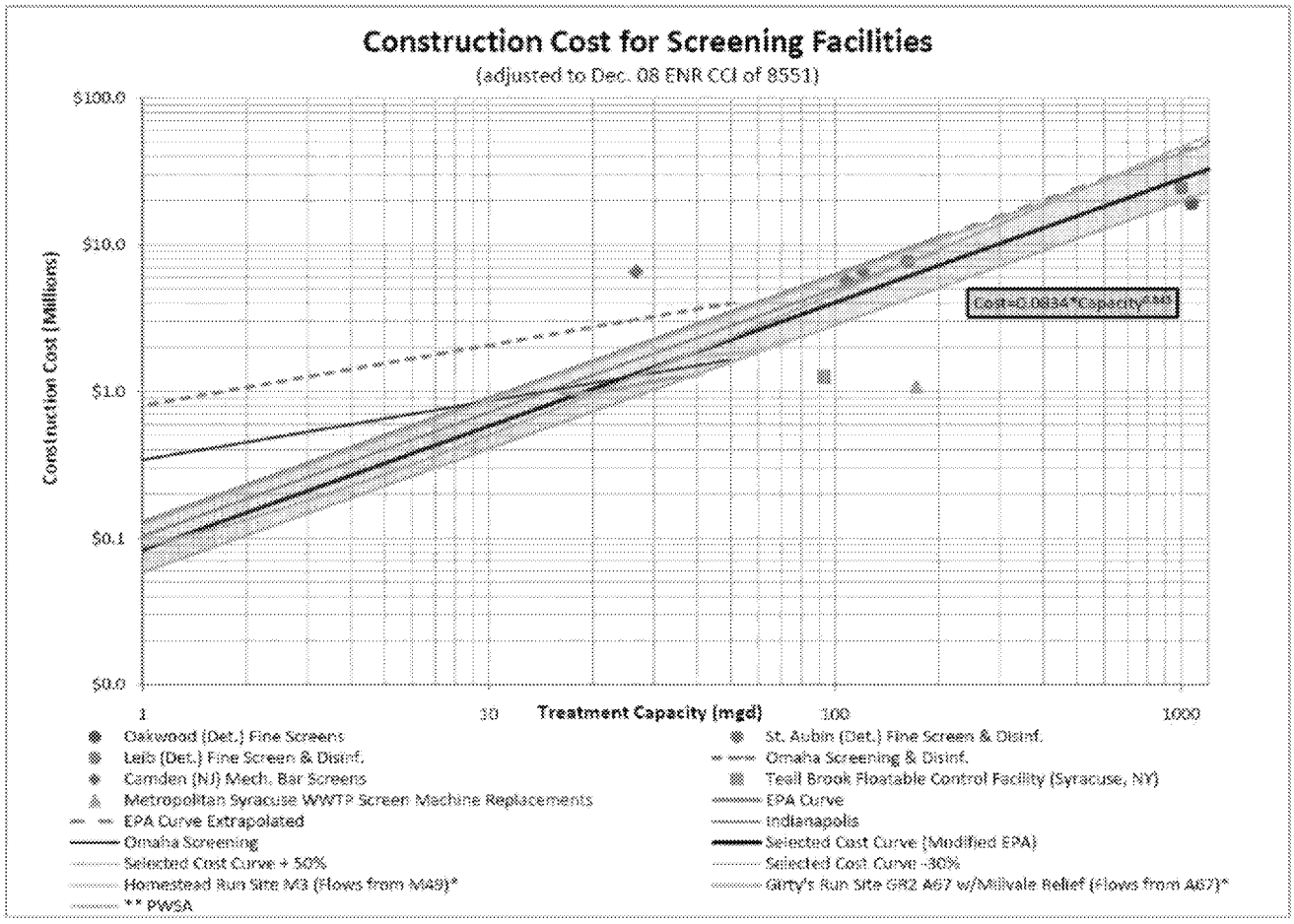

* Source: *ALCOSAN Overflow Control Facilities Alternatives* , August 2008

** From PWSA *Basis of Costs for CSO Control Technologies* , March 2007

Figure 2.3.11-1 Screening Facility Construction Cost Curve [ENRCCI 8551; RS MEANS 100]

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2.3.12 Vortex Separation

Vortex separator capital cost and operations and maintenance costs were assumed to be similar whether they are built at an existing water pollution control plant or at satellite locations.

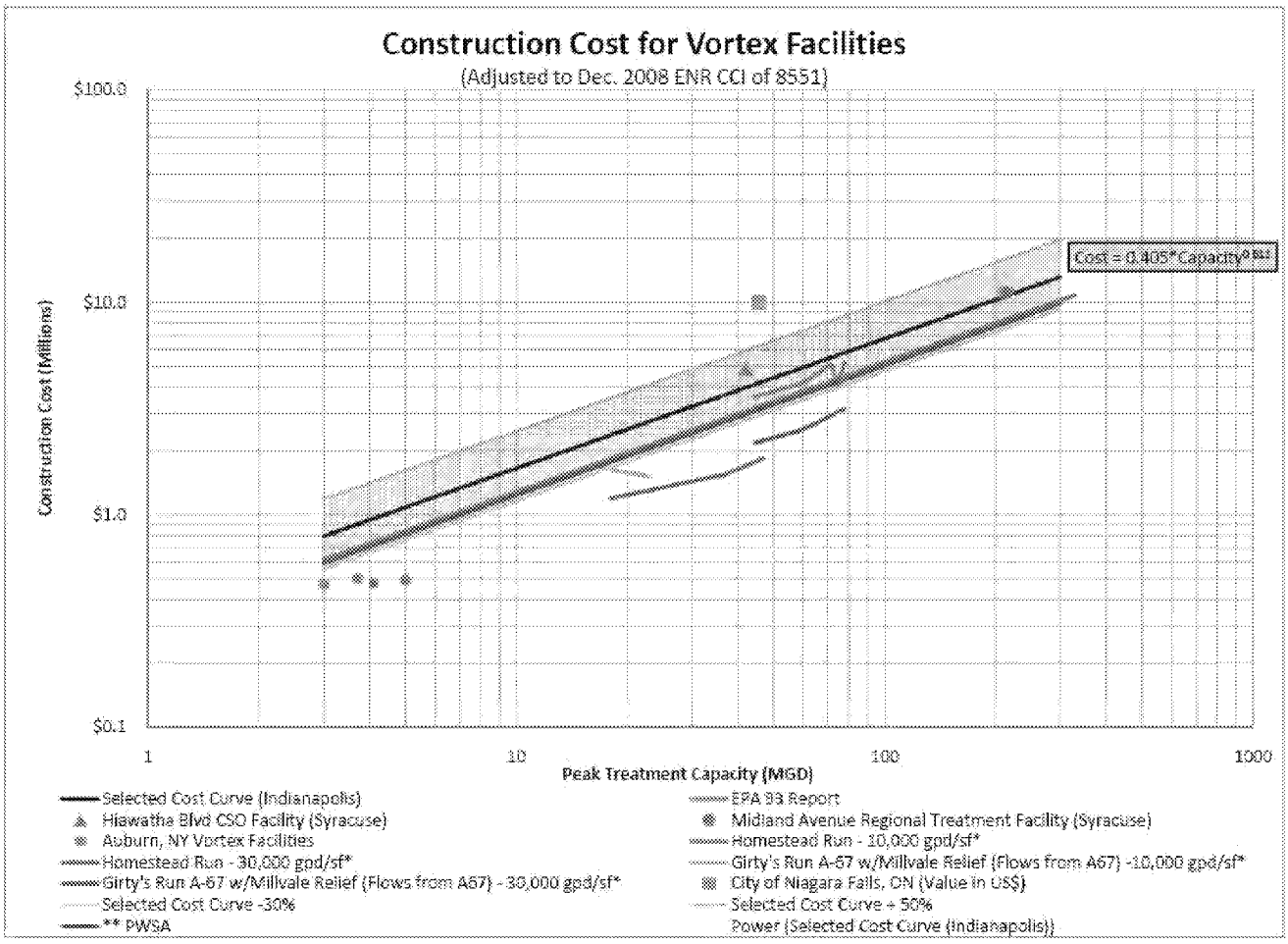
The construction cost curve equation for vortex separator facilities was utilized from the 1993 USEPA report Combined Sewer Overflow Control. It was compared to construction cost data provided by other CSO control programs around the nation. The equation of the selected curve for chlorination / dechlorination facilities, displayed in **Figure 2.3.12-1** is:

$$y = 0.105*x^{0.611}$$

Where y equals construction cost in million dollars, and x equals treatment capacity in MGD.

Vortex Separator O&M Costs

O&M Costs for vortex separator facilities were estimated based on the WEFTEC07 approach for CSO/SSO facility O&M. This methodology is used for Retention Treatment Basins as well.



* Source: ALCOSAN *Overflow Control Facilities Alternatives* , August 2008

** Source: PWSA *Basis of Cost for CSO Control Technologies*, March 2007

Figure 2.3.12-1 Vortex Separator Cost Curve based on Facility Volume [ENRCCI 8551; RS MEANS 100]

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2.3.13 Retention Treatment Basins

Retention treatment basins (RTBs) are satellite HRT facilities designed to provide screening, settling, skimming (with a fixed baffle) and disinfection of combined sewer flows before discharging to the receiving water. RTBs serve to capture combined sewage during small wet weather events and are gradually dewatered after the event for treatment at a wastewater treatment plant. In larger events, RTBs will begin to overflow and discharge treated effluent, but the captured volume left at the end of the event is also dewatered for treatment.

RTBs can be designed with a variety of screen types, disinfection methods and basin geometries. The surface loading rates can also vary but are typically higher than rates used for design of primary clarifiers. RTBs can be constructed above or below grade but typically require at least an above-grade process/control building. If pumping of the combined sewer flow is required, the pump station may be integral to the RTB facility or constructed as a separate structure.

For planning purposes, all RTBs will be assumed to be configured as described below. The RTB facilities are assumed to include:

- Coarse, mechanically cleaned bar screens at the headworks of the facility.
- Disinfection via chlorination using sodium hypochlorite with sodium bisulfite dechlorination. The basins are sized to achieve the design chlorine contact time at the design flow rate with no additional volume for pre-disinfection settling. Estimates for an assumed design contact time of 10 to 30 minutes at design flow.
- A settling/contact basin with flushing provisions. Assumed rectangular basin configuration with side water depths to approximately 20 ft.
- Captured volume including solids are dewatered to the interceptor.
- A fixed baffle located just upstream of the effluent weir to provide skimming.
- Provisions to dewater the facility to the interceptor system, including pumping if required.
- An option for an above or below ground facility, which will be covered with odor control.
- A building for screenings removal, chemical storage, electrical and process control.
- A basin divided into two parallel compartments just below grade, with an effluent weir and geometry based on a design surface overflow rate of 6,000 gallons per day (gpd)/square foot (sf).
- If pumping is required, it will be provided in a separate structure. Its costs will be accounted for separately.

Design factors include:

- Design flow rate
- Chlorine contact time

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Figure 2.3.13-1 displays the selected retention treatment basin facility cost estimating curve and equation, and is considered a construction cost with overhead, profit and indirect costs included.

Given the unique nature of RTBs, actual facility construction costs from around the country are a good source for developing planning level costs. In the mid to late 1990's, a number of retention treatment basins were constructed in Michigan as part of the Rouge River National Wet Weather Demonstration Project. Due to the readily available actual construction cost data for each of these RTBs, nine were selected to serve as the basis for deriving planning level construction costs.

The verified data was plotted with facility volume as the dependent variable. As a test of fit, a USEPA cost curve1 for tank storage capital costs was plotted to determine any fit with the RTB actual construction cost data. The EPA curve was used due to the similar structural configurations among tank storage and RTBs, and that this particular cost curve was based on a large, wide ranging data set. The curve was updated for time, and modified by a factor of 50% for a more complete fit with the verified data points. The resulting curve fit well enough to render it the selected curve for costing RTB capital costs. All verified points are displayed in **Figure 2.3.13-1** along with the selected costing curve. The cost equation from the selected curve is:

$y = 9.72x0.826$

Where y equals construction cost in million dollars, and x equals facility volume in MG

RTB O&M Costs

O&M cost estimates for RTBs were utilized based on the WEFTEC07 approach for CSO/SSO facility O&M. An example calculation is provided below, and **Figures 2.3.13-2** through **2.3.13-4** display supplemental estimate curves based on the WEFTEC approach.

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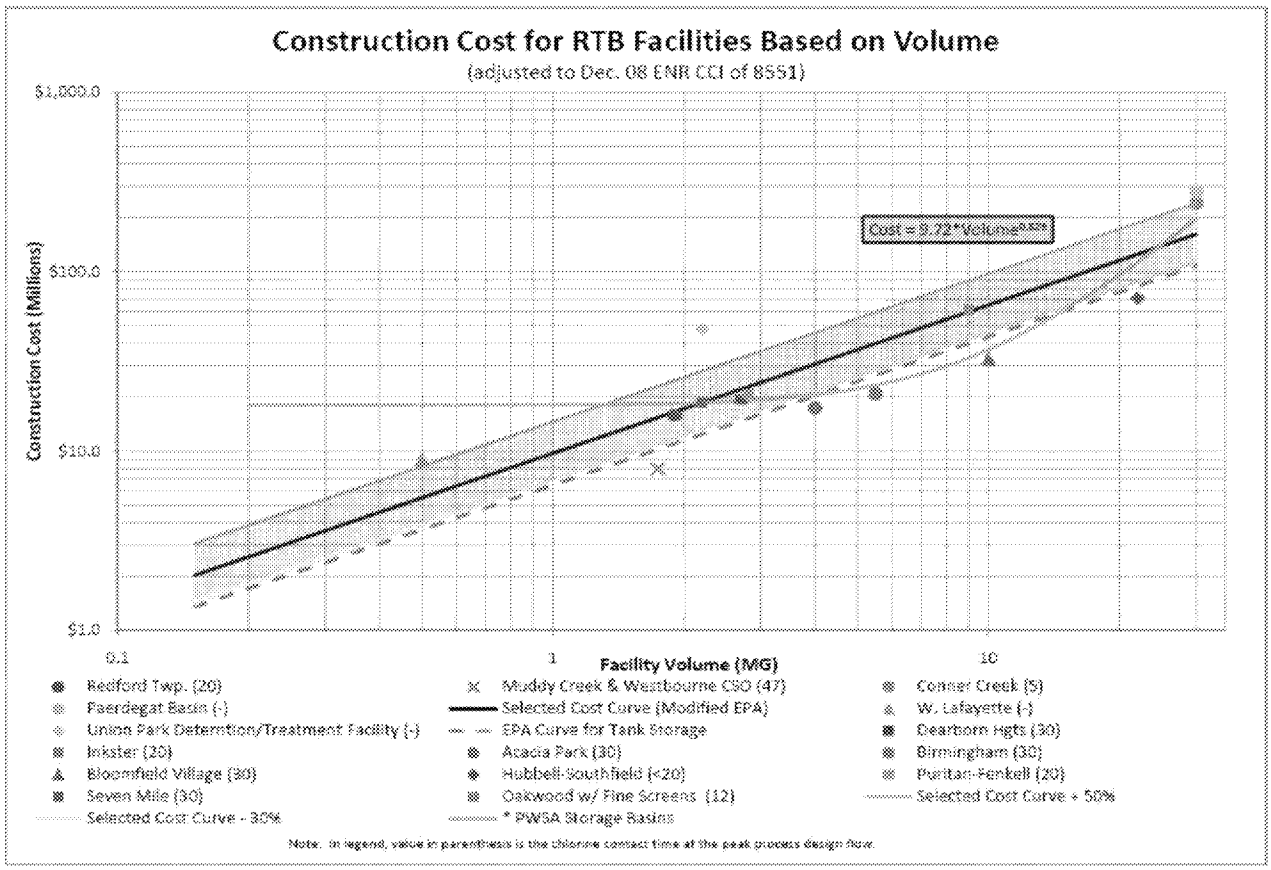

Figure 2.3.13-1 Retention Treatment Basin Cost Curve based on Facility Volume [ENRCCI 8551; RS MEANS 100]

Example Calculation for Determination of O&M Costs for Retention Treatment Basins

Note: Input variables are highlighted in yellow.

Peak Treatment Rate (MGD)	250
Design Chlorine Contact Time (minutes)	20
Basin Volume (MG)	3.47

	Annual "Task" Hours	Annual Staff Hours	Hourly Rate	Annual Costs	Notes
Annual Number of Non-Task Hours per Full-Time Employee	480				
Total Maintenance	2,319				See Figure 2.3.13-2 for curve & equation**
Supervisory Maintenance (15% of Total)	348	452	$89	$40,255	
Non-Supervisory Maintenance (85% of Total)	1,972	2,563	$54	$138,403	
Annual Event Hours*	1,400				
Total Operations	2,955				See Figure 2.3.13-3 for curve & equation**
Supervisory Operations (11% of total)	325	423	$92	$38,881	
Non-Supervisory Operations (89% of total)	2630	3,419	$63	$215,422	
Non-Staff Resources				$98,642	See Figure 2.3.13-3 for curve & equation**
	Total Annual O&M Costs			**$531,604**	

Source: Budget Development for Operations/Maintenance Requirements for CSO/SSO Control Facilities, WEFTEC 2007.

* Annual event hours include pre-event, treatment and post-event periods as defined in the WEFTEC source paper.

** Curves obtained from cited source.

Estimated Data Points from Reference

Basin Size (MG)	Annual Manhours
2.5	1400
3.75	2600
5	3300
7.5	4400
10	5300
12.5	5800
15	6400
20	7100
25	7800
30	8300
35	8700
40	9100

Assumed Straight-Line Extrapolation at Low End

Basin Size (MG)	Annual Manhours
0	500
2.5	1411

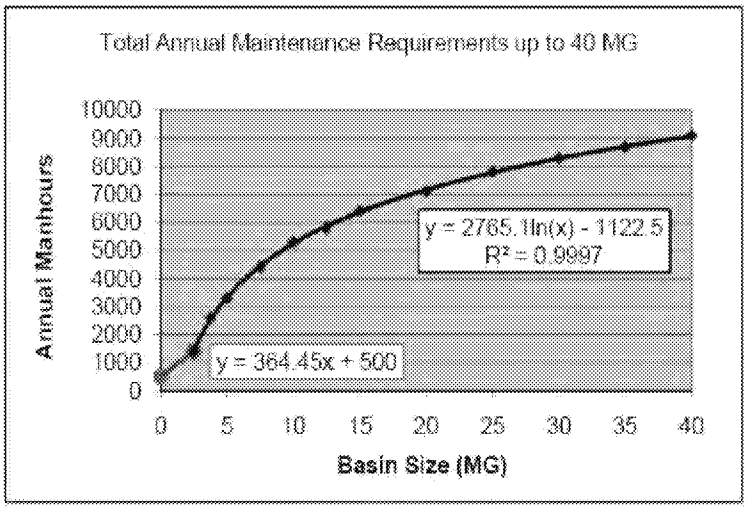

Figure 2.3.13-2: Typical Annual Maintenance Staff for RTBs [ENRCCI 8551; RS MEANS 100]

Estimated Data Points from Reference

Annual Event-Hrs	Annual Manhours
250	1000
500	1750
750	2250
1000	2550
1500	3050
2000	3300
2500	3700
3000	3800
3600	4050

Assumed Straight-Line Extrapolation at Low End

Annual Event-Hrs	Annual Manhours
0	0
250	979

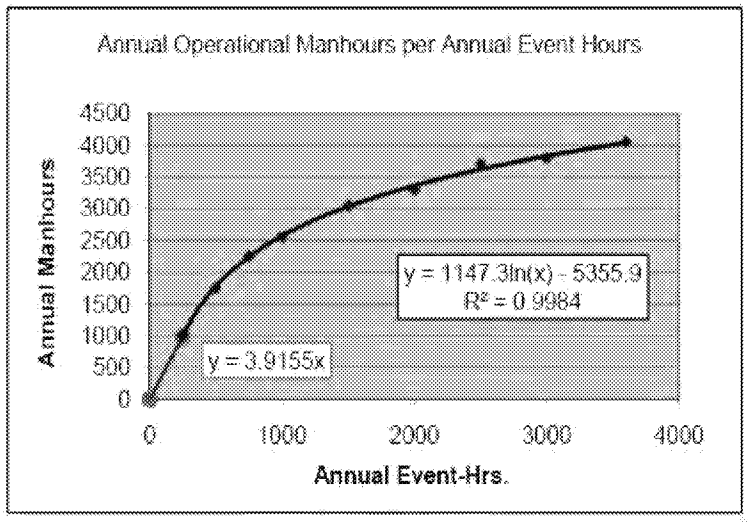

Figure 2.3.13-3: Typical Annual Staff Operation for RTBs [ENRCCI 8551; RS MEANS 100]

Estimated Data Points from Reference

Basin Size (MG)	Annual Non-Staff Resources ($)
2.5	$70,000
3.75	$110,000
5	$137,500
7.5	$175,000
10	$210,000
12.5	$235,000
15	$255,000
20	$290,000
25	$320,000
29	$340,000

Assumed Straight-Line Extrapolation at Low End

Basin Size (MG)	Annual Non-Staff Resources ($)
0	0
2.5	$62,585

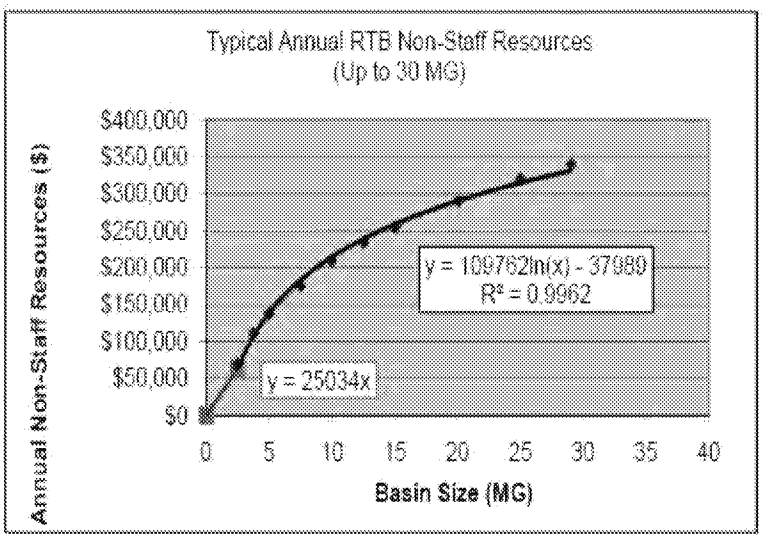

Figure 2.3.13-4: Typical Annual Non-Staff Resources for RTBs [ENRCCI 8551; RS MEANS 100]

Table 2.3.13-1: Miscellaneous RTB Construction Cost Multipliers [ENRCCI 8551; RS MEANS 100]

Description	Units	Value
Foundation Cost Multiplier	%	15%
Sitework Cost Multiplier	%	6%
Dewatering Multiplier	%	2%
Dechlorination Multiplier	%	3%

Table 2.3.13-2: RTB Design Assumptions [ENRCCI 8551; RS MEANS 100]

Description	Value
Overflow Rate	6000 gpd/sf
Footprint Area Multiplier	125%
Basin Freeboard	4 feet

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2.3.14 High Rate Clarification

High rate clarification capital cost and operation and maintenance costs were assumed to be similar whether they are built at an existing water pollution control plant or at satellite locations.

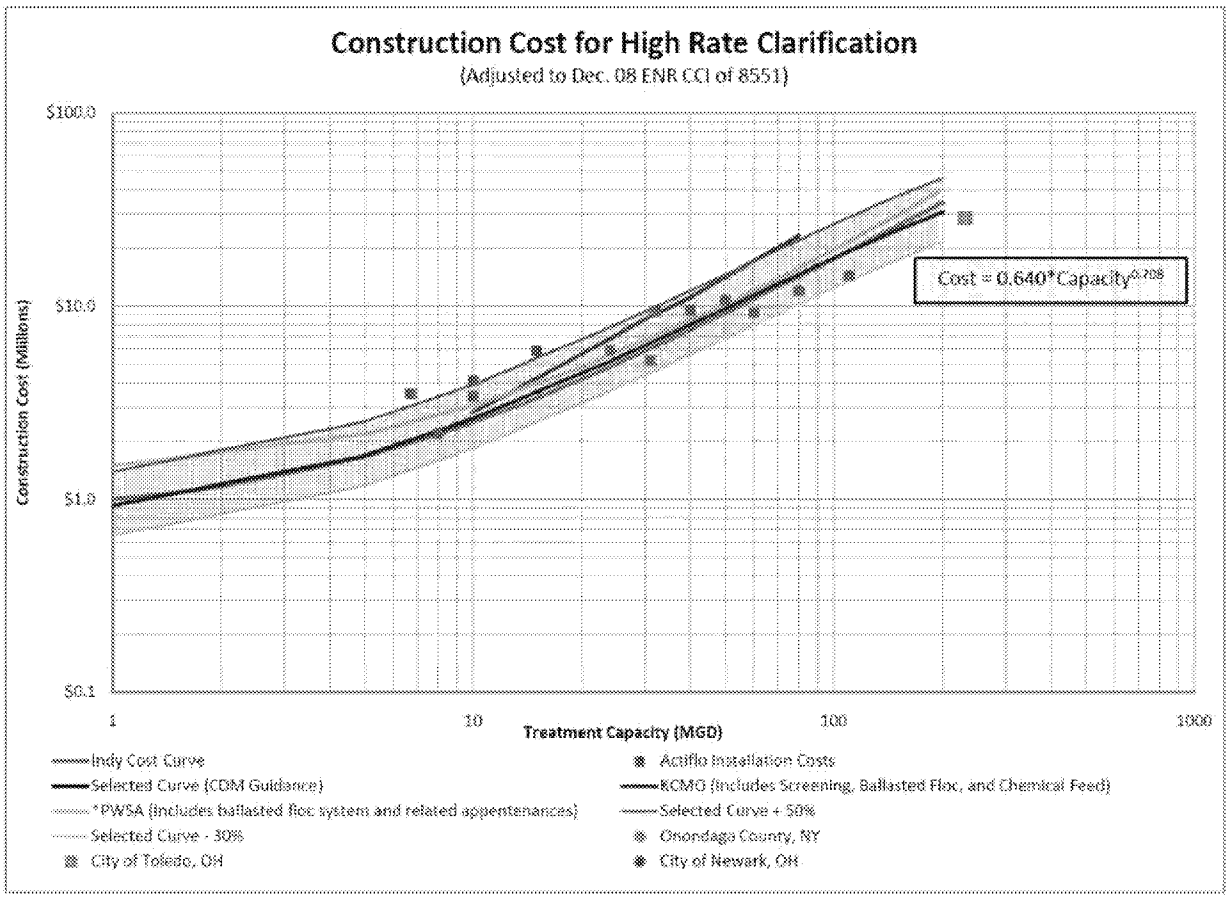
The construction cost curve equation for high rate clarification facilities was utilized from the 1993 USEPA report Combined Sewer Overflow Control. It was compared to construction cost data provided by other CSO control programs around the nation. The equation of the selected curve for chlorination / dechlorination facilities, displayed in **Figure 2.3.14-1** is:

$$y = 0.640*x^{0.708}$$

Where y equals construction cost in million dollars, and x equals treatment capacity in MGD.

High Rate Clarification O&M Costs

O&M Costs for high rate clarification were estimated based on the WEFTEC07 approach for CSO/SSO facility O&M. This methodology is used for Retention Treatment Basins as well.



*Source: PWSA *Basis of Cost for CSO Control Technologies*, March 2007

Figure 2.3.14-1: High Rate Clarification Construction Cost Curve [ENRCCI 8551; RS MEANS 100]

2.3.15 Disinfection

Disinfection is assumed to be a component of all high rate treatment (HRT) facilities. All costs for disinfection (including contact tanks or conduits) will be included in the cost estimates for applicable alternatives, with sizing scaled to appropriate design flows.

As a assumed assumption, the equipment and appurtenance costs for chlorination using sodium hypochlorite and dechlorination using sodium bisulfite. However, it is recognized that UV disinfection may be a viable alternative for HRC, and an option to select UV disinfection is included.

The cost is based on a disinfection type and the design flow rate for the disinfection alternative.

Figure 2.3.15-1 displays the selected disinfection cost estimating curve and equation.

Chlorination/Dechlorination Construction Costs

The construction cost curve equation for chlorination / dechlorination facilities was utilized from the 1993 USEPA report Combined Sewer Overflow Control. It was compared to construction cost data provided by other CSO control programs around the nation. The equation of the selected curve for chlorination / dechlorination facilities, displayed in **Figure 2.3.15-1** is:

$$y = 0.223*x^{0.464}$$

Where y equals construction cost in million dollars, and x equals treatment capacity in MGD.

Ultraviolet Disinfection Construction Costs

The cost curve equation for UV disinfection facilities was utilized from the City of Indianapolis CSO Control Cost Estimating Procedures Memo which modified a chlorination cost curve found in the 1993 USEPA report Combined Sewer Overflow Control. It was compared to cost curves from other CSO control programs around the nation. The equation of the selected curve for ultraviolet disinfection, displayed in **Figure 2.3.15-2** is:

$$y = 0.719*x + 0.540$$

Where y equals construction cost in million dollars, and x equals treatment capacity in MGD

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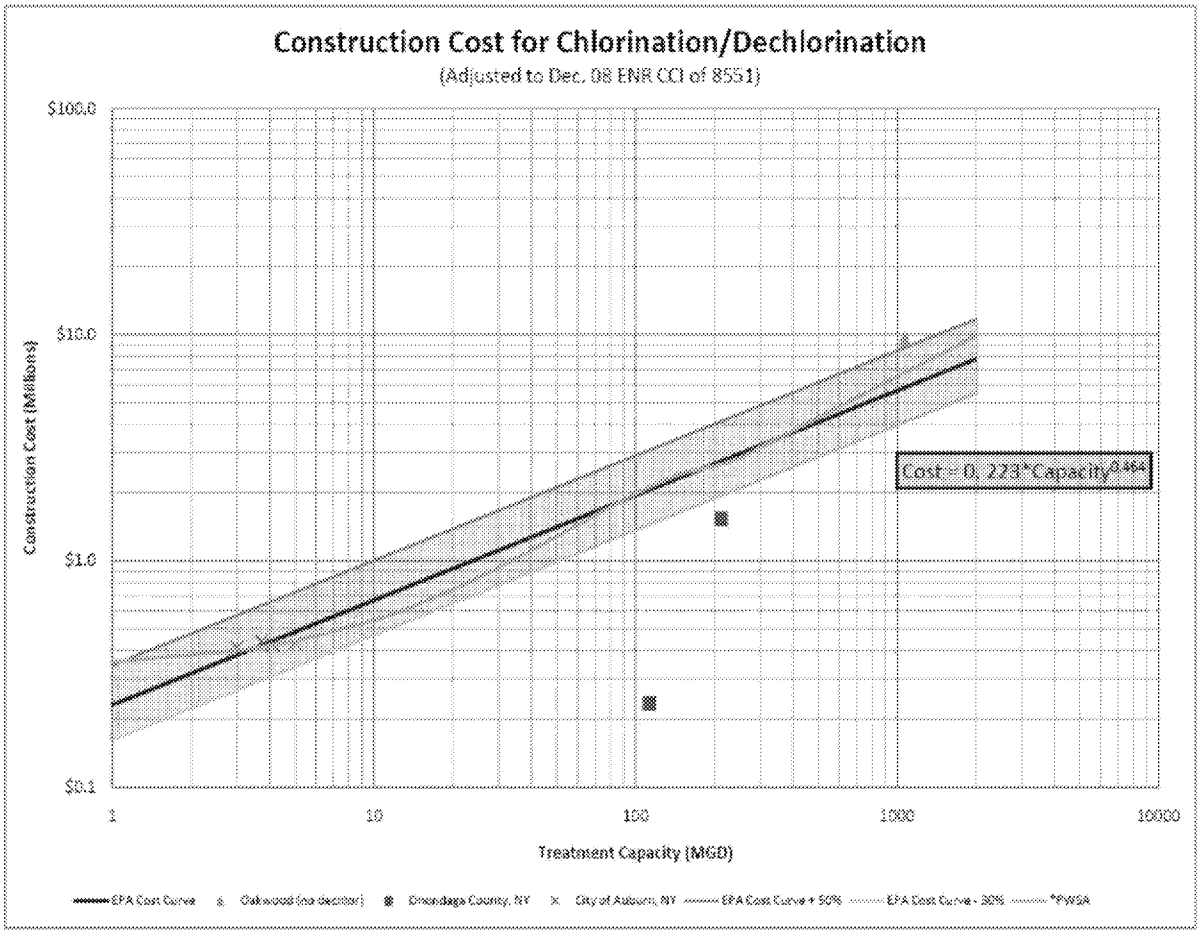

* Source: PWSA *Basis of Cost for CSO Control Technologies* , March 2007

Figure 2.3.15-1: Chlorination / Dechlorination Construction Cost Curve [ENRCCI 8551; RS MEANS 100]

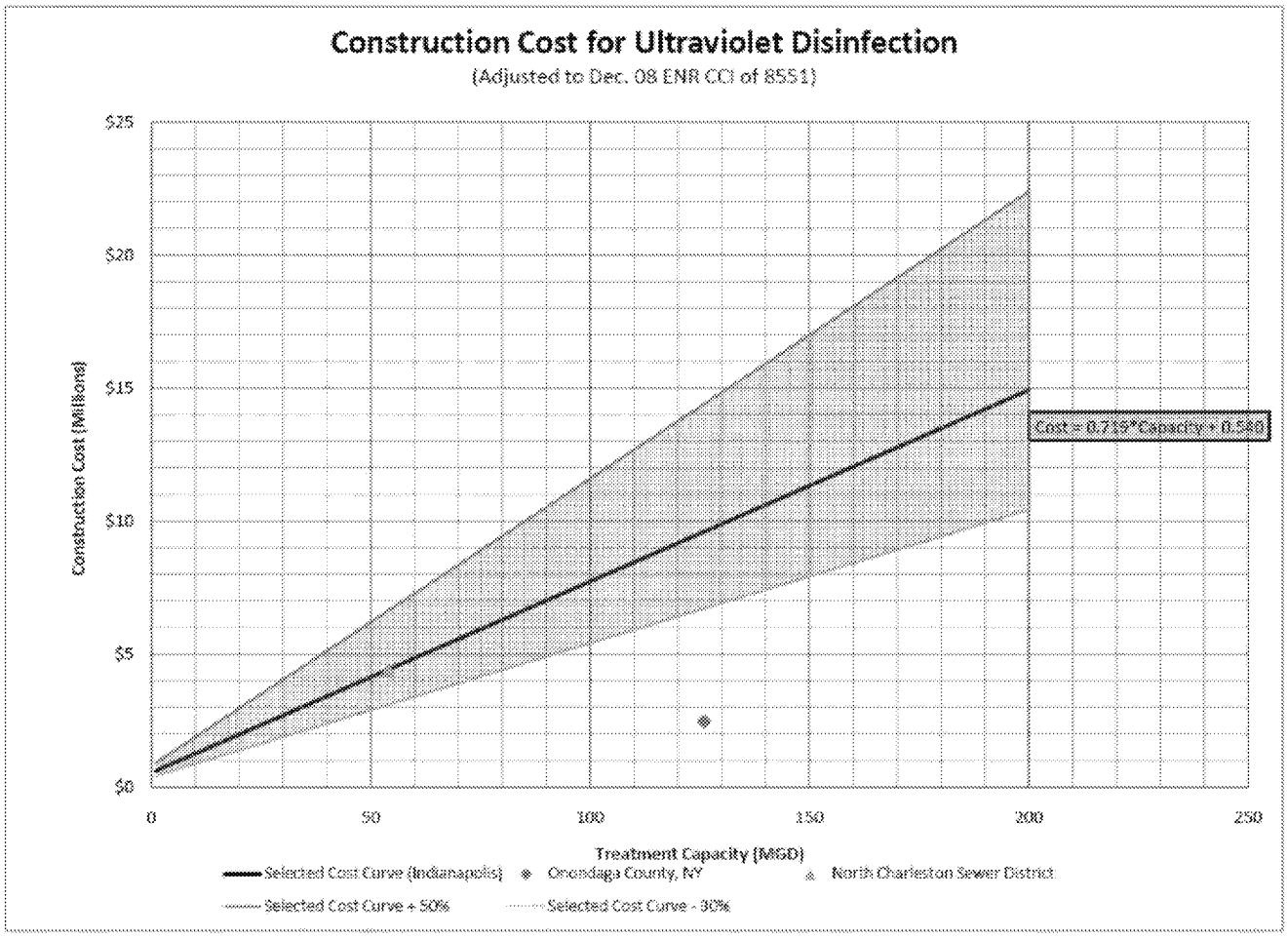

Figure 2.3.15-2: Construction Cost Curve for Ultraviolet (UV) Disinfection [ENRCCI 8551; RS MEANS 100]

Chlorination/Dechlorination & Ultraviolet Disinfection O&M Costs

Disinfection facility O&M cost equations are provided for both ultraviolet disinfection and chlorination/dechlorination facilities. These equations were utilized from the City of Indianapolis CSO Program[4], and are based on USEPA curves adjusted to the proper ENRCCI value.

O&M costs for chlorination / dechlorination facilities were derived from the City of Indianapolis CSO Control Cost Estimating Procedures Memo which modified a chlorination cost curve found in the 1993 USEPA report Combined Sewer Overflow Control. The curve was updated to a base period of December 2008.

The resulting cost curve, displayed in **Figure 2.3.15-2**, is:

$$y = (\text{Current ENRCCI}/6635) * 12.531 * x^{0.614}$$

[4] Cost Estimating Procedures for Raw Sewage Overflow Control Alternatives Evaluation. City of Indianapolis, September 2003.

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Where y equals construction cost in $Thousands, and x equals facility capacity in MGD.

O&M costs for UV disinfection facilities were derived from the City of Indianapolis CSO Control Cost Estimating Procedures Memo which modified a chlorination cost curve found in the 1993 USEPA report Combined Sewer Overflow Control. The curve was updated to a base period of December 2008. The resulting cost curve, displayed in **Figure 2.3.15-3**, is:

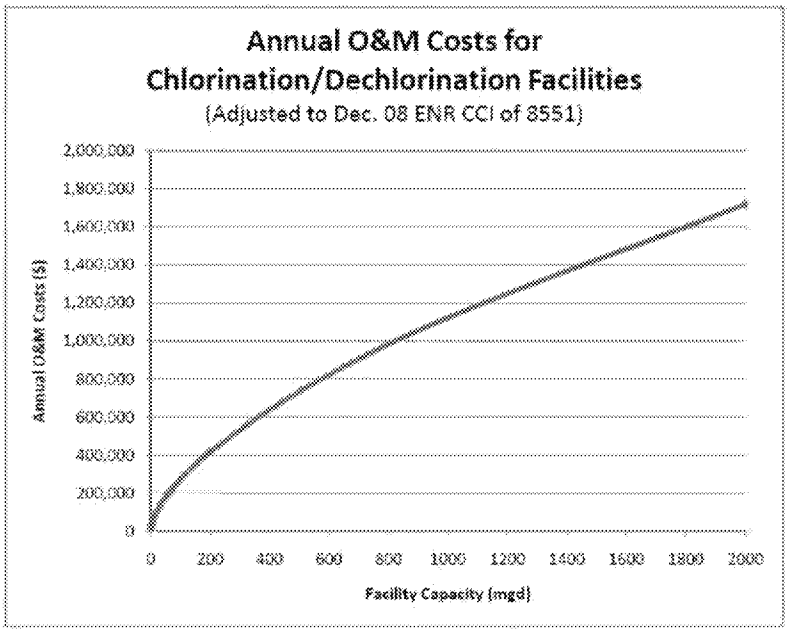
y = (Current ENRCCI/6635) * 5475 * x

Where y equals construction cost in dollars, and x equals facility capacity in MGD.

Base ENRCCI: 8,551

Cost Table for New CSO Chlorination/Dechlorination Disinfection Treatment Facilities

Facility Capacity (mgd)	Annual O&M Cost ($)
1	16,149
2	24,716
5	42,383
10	66,266
15	85,167
20	101,622
30	130,348
40	155,631
50	178,370
60	199,498
70	219,303
80	238,040
90	255,893
100	272,994
120	305,331
140	335,642
160	364,320
180	391,643
200	417,817
500	733,366
1000	1,122,419
2000	1,718,000



The cost table above is based on the following conditions:

1. Annual O&M costs are derived from the USEPA construction cost curves using the current ENRCCI, which is an acceptable estimate between a range of 1 and 2000 mgd.
2. Curve defined by the equation below is based on the use of sodium hypochlorite and sodium bisulfite.

Annual O&M Cost Equation:

Cost ($Thousands) = (Current ENRCCI / 6635) * 12.531 * $Q^{0.414}$

*6,635 was the ENRCCI from March 2003

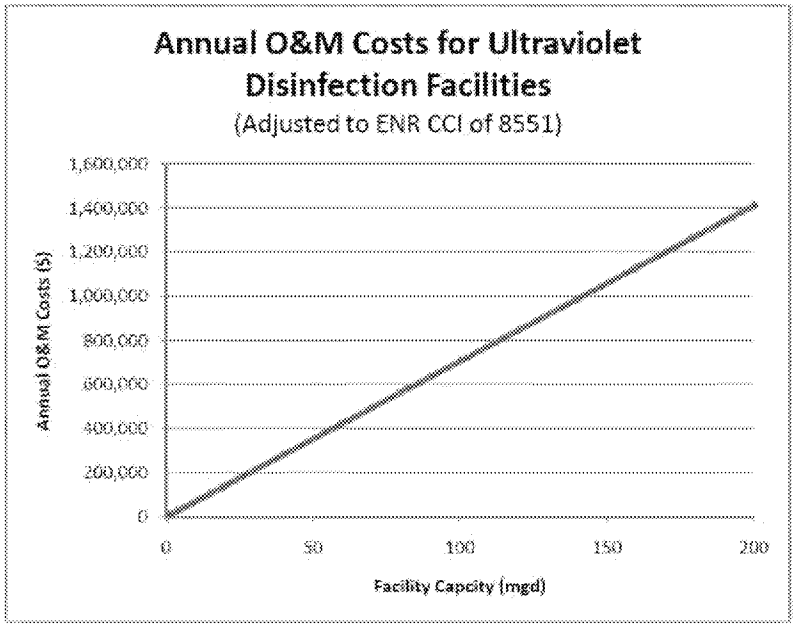
*Q = Facility Capacity (mgd)

Source: USEPA Cost Curves as Reported in Indianapolis CSO Control Cost Estimating Procedures Memo

Figure 2.3.15-3: O&M Cost Curve for Chlorination / Dechlorination Facilities [ENRCCI 8551; RS MEANS 100]

Base ENRCCI: 8,551

Cost Table for New CSO UV Disinfection Treatment Facilities	
Facility Capacity (mgd)	Annual O&M Cost ($)
1	7,056
2	14,112
5	35,280
10	70,560
15	105,840
20	141,120
30	211,681
40	282,241
50	352,801
60	423,361
70	493,922
80	564,482
90	635,042
100	705,602
120	846,723
140	987,843
160	1,128,964
180	1,270,084
200	1,411,205



The cost table above is based on the following conditions:

1. Annual O&M is estimated between a range of 1 and 100 mgd based on recent author references (Cotton et al.) as cited in Indianapolis CSO Program documentation.

Annual O&M Cost Equation:

Cost ($M) = (Current ENRCCI / 6635) * 5475 * Q

*6,635 was the ENRCCI from March 2005

*Q = Facility Capacity (mgd)

Figure 2.3.15-4 O&M Cost Curve for Ultraviolet (UV) Disinfection [ENRCCI 8551; RS MEANS 100]

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3.0 LIFECYCLE COSTS

3.1 Introduction to Lifecycle Costs

The plan will be evaluating alternative control elements (e.g., storage vs. satellite treatment) and control alternatives. Control alternatives are arrays of control elements (e.g., a relief interceptor and one 5-mg storage tank at the bottom of the sewershed vs. two 2-mg tanks along the existing interceptor) to provide the same level of watershed-wide wet-weather control.

The various control elements and control alternatives will be compared economically based on comparative life cycle costs. Lifecycle costs are the total costs of building, operating and maintaining a control element for the planning period of the WWP.

3.2 Planning Period and Temporal Framework

Construction end dates and construction duration periods for each control implemented are utilized to determine planning and implementation periods.

3.3 Present Worth Analysis

Lifecycle costs of alternative control elements will be compared based on their respective present worth. The calculation of present worth of control elements is based on the specified parameters.

Present worth is the value, expressed in present dollars of the capital costs and the stream of future O&M costs generated by a control element. Calculating the present worth of alternative control elements allows for comparisons between various mixes of capital and O&M costs over the planning period.

For analysis of alternatives, the City Beautiful H_2O Program Plan describes costs and benefits derived using current year capital costs inflated to the mid-point of construction at the assumed capital costs inflation rate and then deflated back to current year using the discount factor. O&M costs are inflated to the years of implementation and the inflated stream of costs is discounted back to the current year. If applicable, replacement costs are inflated to the replacement year and then discounted back.

3.4 Replacement Costs

Because of the long planning period, mechanical equipment and depending on the initiation of operation, potentially structural facilities will be at the ends of their respective useful lives prior to the end of the planning period. Therefore, replacement costs for equipment or structural facilities requiring replacement or substantial rehabilitation prior to 2057 must be included in the present worth analysis.

A replacement cost and a renewal/replacement frequency for applicable equipment in an alternative. Calculation of the present value of these replacement costs is determined using the assumption values and the assumed planning period.

4.0 References

The Association for the Advancement of Cost Engineering. 2005. Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries (AACE International Recommended Practice No. 18R-97).

Center for Watershed Protection. 2007. Urban Subwatershed Restoration Manual No. 3 Urban Stormwater Retrofit Practices Version 1.0. Ellicott City, Maryland.

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Philadelphia Water Department. 2016. Pilot Program Report, Appendix B. Philadelphia Water Department. http://phillywatersheds.org/doc/Year5_EAPCombinedAppendices_website.pdf

United States Environmental Protection Agency. 1993. Combined Sewer Overflow Control (625/R-93/007).

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Appendix C – Public Participation Documents

The enclosed digital copy of the entire Program Plan includes electronic versions of the following supporting documents related to the public engagement and participation activities, developed during the public draft comment period:

Bill Inserts

2018-01-22 February Bill Insert.pdf
2018-02-16 March Bill Insert.pdf

Community Group Meetings

2018-03-19 Community Group Meetings.xlsx

Companion Document

2018-03-01 Program Plan Summary_PDFX2.pdf

Door Hanger

2018-02-01 Public Meeting Doorhanger 2.pdf
February 12 email stats.csv

Emails

February 12 email to media outlets.msg
February 12 Email to Stakeholders.msg
February 12 email.png
February 15 email stats.csv
February 15 email.png
February 28 email stats.csv
February 28 email.png
March 1 Chamber of Commerce Email.msg
March 5 email stats.csv
March 5 thank you email.png

Impervious Surface Meetings

2017-11-13 CBH2O Impervious Surface Property Owner Meeting Invitation.docx
Top 50 Impervious Area For Final Submission.xlsx

Media Outreach

Draft City Beautiful H2O Program Plan.msg
Feb 12 PA Environmental Digest.pdf
February 12 PennLive.pdf
February 12 TheBurg.pdf
February 15 PennLive.pdf
February 16 TheBurg Podcast.pdf
February 27 ABC 27 Story.pdf
March 12 PennLive Story.pdf
Media Outlets List.xlsx

Public Comments

01 - 2018-03-13 Public Comments Compiled.xlsx
02 - Bellevue Park Association Letter of Support.pdf
03 - Choose Clean Water Stormwater Joint Letter 03122018.pdf
2018-02-21 Public Meeting 2 Public Comments.pdf

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CAPITAL REGION WATER

2018-03-13 Online Form Public Comments FINAL.csv
Camp Curtin Neighbors United Public Comment.pdf
Public Meeting 3 Public Comments.pdf

Public Meetings

February 15 Photo 2.jpg
February 15 Photo.jpg
February 21 Photo.jpg
March 1 Photo.jpg
Sign In Sheets.pdf

Social Media

Facebook Ad for February 15 Meeting.png
Facebook Ad for February 15 Results.png
Facebook Ad for February 21 Meeting.png
Facebook Ad for February 21 Results.png
Facebook Ad for March 1 Event.png
Facebook Ad for March 1 Results.png
February 12 Facebook Post.png
February 12 Nextdoor Post.png
February 12 Twitter Post 2.png
February 15 Twitter Post.png
February 15 Twitter Post2.png
February 17 Twitter Post.png
February 20 Nextdoor Post.png
February 20 Twitter Post.png
February 27 Twitter Post.png
March 1 Facebook Post.png
March 1 Twitter Post.png
March 12 Facebook Post.png
March 12 Nextdoor Post.png
March 6 Facebook Post.png
March 6 Twitter Post.png
Twitter Post February 12.png
Twitter Post March 12.png

Stakeholder Meetings

2017-06-26 CBH2O Stakeholder Committee Invitation FINAL.docx
2017-07-17 CBH2O Stakeholder Meeting.pptx
2017-08-23 CBH2O Stakeholder Meeting.pptx
2017-11-07 CBH2O Stakeholder Meeting.pptx
2018-02-23 CBH2O Stakeholder Meeting.pptx
2018-03-20 Stakeholder Meetings Tracking.xlsx

Website

Website Image.png