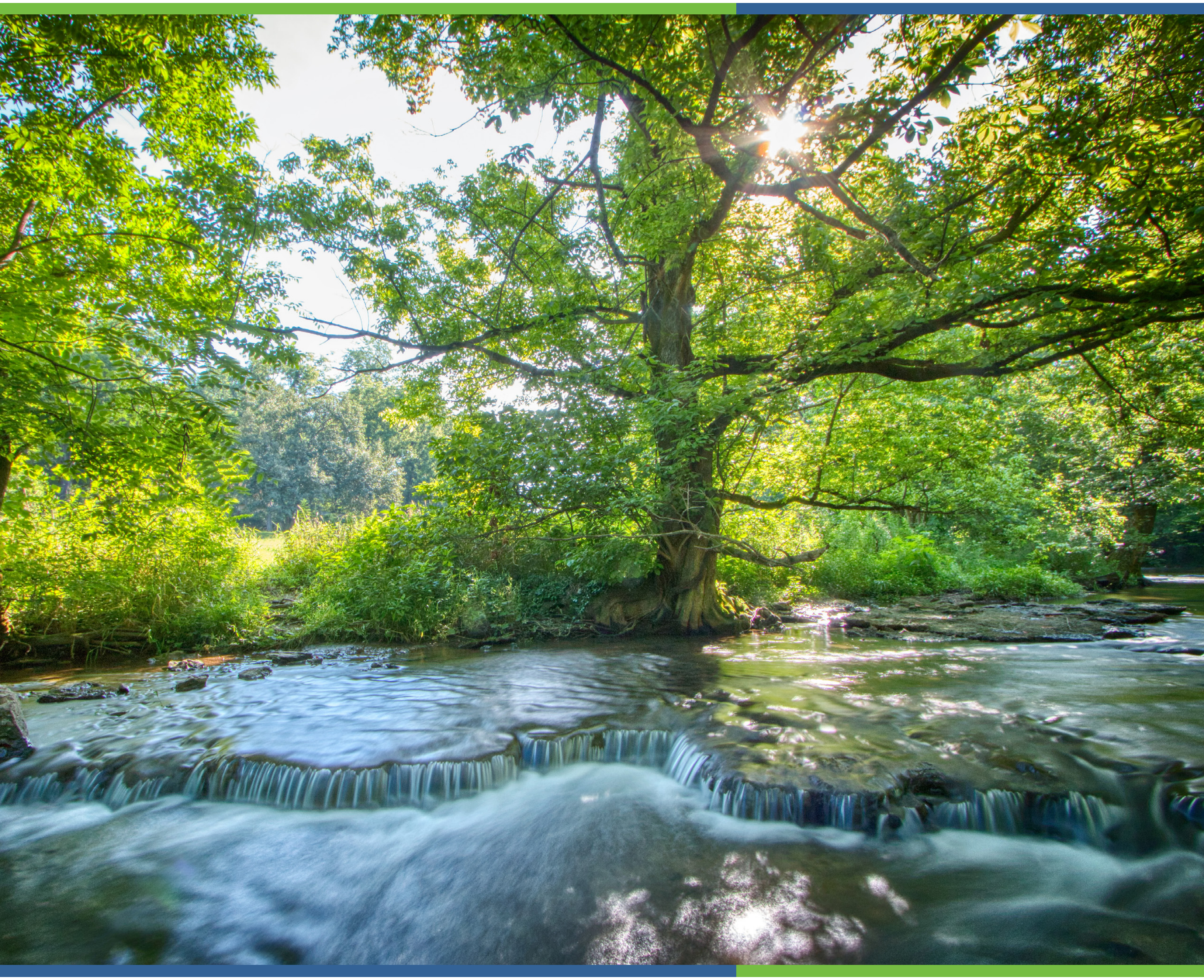
Louisville and Jefferson County
Metropolitan Sewer District

FINAL CSO LONG-TERM CONTROL PLAN

2021 Modification
April 2021, Volume 2 of 3



PROJECT WIN
Waterway Improvements Now

msd
Safe, clean waterways

APRIL 30, 2021

2021 IOAP MODIFICATION

EXECUTIVE SUMMARY

METROPOLITAN SEWER DISTRICT

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDIXES

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SECTION ES: INTRODUCTION

In August 2005, the Louisville and Jefferson County Metropolitan Sewer District (MSD) entered into a Consent Decree with the Commonwealth of Kentucky by and through its Environmental and Public Protection Cabinet (Cabinet), as Plaintiff, and the United States of America, on behalf of the United States Environmental Protection Agency (EPA), as Plaintiff-Intervener. The first amendment to the Consent Decree became official in April 2009 (hereafter referred to as the ACD). The ACD requires MSD to "eliminate SSOs and Unauthorized Discharges from MSD's SSS, CSS and WWTPs, and to address discharges from MSD's CSO locations identified in its Morris Forman Water Quality Treatment Center (WQTC) Kentucky Pollutant Discharge Elimination System (KPDES) permit."

Recognizing the long-term nature of the IOAP, MSD committed to an approach of adaptive management, intending to make mid-course corrections as more information is learned about the performance of projects and the related response in the sewerage systems. Adaptive Management offers MSD an opportunity to continue collecting more data to recalibrate and revalidate its hydraulic model. As projects are completed and system improvements come on-line, MSD's model is updated to reflect current conditions. In some cases, the level of control for a particular location has already been met based upon flow monitoring data and modeling.

Based on the need to spend nearly $1 billion over the next 5 years, MSD is requesting a time extension for completion of the remaining ACD responsibilities. Much of the spending forecasted for the 5-Year CIP is required for new priorities not known when the ACD was executed. MSD remains committed to completing all projects, and requests additional time to construct the remaining mandated projects in order to allow MSD to continue to invest in its infrastructure.

After more than a year of discussion and exchange of extensive information, the parties agreed to a second ACD, the purpose of which is to extend some of the existing Final Sanitary Sewer Discharge Plan (SSDP) and Final Long-Term Control Plan (LTCP) milestones to enable MSD to prioritize significant additional environmentally beneficial spending.

Under the Second ACD, MSD is requesting a time extension for completion of the remaining SSDP projects in order to facilitate construction of: 1) improvements at the Morris Forman (WQTC) required to meet permit conditions and mitigate combined sewer overflows (CSOs); 2) improvements at the Paddy's Run Pump Station required to mitigate CSOs and enhance the reliability of public safety; 3) rehabilitation of MSD"s most critical interceptors; and 4) a focus on asset management for MSD's existing wastewater assets. A summary of the Second ACD requirements is provided in Table ES.0.1-1.

Table ES.0.1-1 Summary of Second ACD Provisions

SECOND ACD COMPONENT	IOAP/SECOND ACD CRITERIA	COMPLIANCE MEASURES
Integrated Overflow Abatement Plan (IOAP) Modification **Volume 1**	Reporting Frequency (Volume 1, Chapter 1)	• Semi-Annual and Annual Reporting
	Specific Remedy Projects (Volume 1, Chapter 4)	• Construct Morris Forman New Biosolids Facility by December 31, 2030 • Construct Paddy's Run Pump Station Capacity Upgrade by December 31, 2026

SECOND ACD COMPONENT	IOAP/SECOND ACD CRITERIA	COMPLIANCE MEASURES
	Critical Interceptors Program (Volume 1, Chapter 4)	• Complete rehabilitation and replacement work for nine critical interceptors: 1) Large Diameter Interceptor Rehabilitation Program, 2) Broadway Interceptor; 3) Western Outfall, 4) Rudd Avenue Sewer, 5) I-64 & Grinstead Interceptor, 6) Harrod's Creek Force Main, 8) Buechel Branch, and 9) Prospect Area Sewers totaling approximately $70 million during FY21 through FY25 for completion by December 31, 2026.
	Asset Management Program (Volume 1, Chapter 4)	• Submit Strategic Asset Management Plan no later than June 30, 2021 • Complete an average of $25 million per year of work for asset management projects • Document spending of $125M for asset management projects during FY21-FY25 • Document spending of $125M for asset management projects during FY26-FY30 • Document spending of $125M for asset management projects during FY31-FY35
Final LTCP Modification **Volume 2**	Waterway Protection Tunnel (Volume 2, Chapter 4, Executive Summary Table ES1.1-3)	• Substantial Completion to be achieved no later than December 31, 2022 for the remaining LTCP project
	System-Wide Modeled Level of Control for CSOs (Volume 2, Chapter 4)	• Achieve modeled system-wide 85% or greater capture or elimination of CSS volume
Final SSDP Modification **Volume 3**	Remaining SSDP Projects (Volume 3, Chapter 4, Executive Summary Table ES1.1-5)	• Substantial Completion of seven SSDP projects no later than December 31, 2025 (Idlewood In-Line Storage, Kavanaugh Road PS Improvements, Raintree & Marian PS Eliminations Phase 1, Monticello PS Elimination, Cinderella PS Elimination, Leven PS Elimination, and Gunpowder PS In-Line Storage).
		• Substantial Completion of six SSDP projects no later than December 31, 2030 (Bardstown Road PS Improvements, Dell Rd & Charlane Parkway interceptor, Raintree & Marian PS Elimination Phase 2, Middle Fork Relief Interceptor & PS, Sutherland Rd Interceptor, and Mellwood System Improvements).
		• Substantial Completion of three SSDP projects no later than December 31, 2035 (Little Cedar Creek Interceptor, Goose Creek Interceptor, and Camp Taylor Rd Improvements Phase 4).

ES.1.1. CONSENT DECREE CURRENT STATE

Since 2005, pursuant to the Consent Decree and subsequent ACD, MSD has spent nearly $0.9 billion (of the $1.2 billion ACD/IOAP total) for mitigating combined sewer overflows (CSOs) and eliminating sanitary sewer overflows (SSOs) and unauthorized discharges. This section provides an update on MSD's progress related to the IOAP, Final SSDP, and Final LTCP requirements.

ES.1.1.1. IOAP PROGRESS

The programmatic IOAP requirements are summarized in Table ES.1.1-1 along with the progress MSD has made through December 31, 2020.

Table ES.1.1-1 Summary of IOAP Program

REQUIREMENT	PROGRESS
Engage Stakeholders	MSD's community input, outreach and notification program were approved and is ongoing. In 2006, MSD initiated a Wet Weather Team Stakeholder Group which is still in existence and active today. Details regarding this Group are provided in Volume 1, Chapter 3.
	MSD exceeded the original commitments made to the community by spending 35% more for community benefits including: expanded system monitoring and rain gauge networks to improve model calibration and discharge reporting; increased system storage capacity over original commitments by 25%; increased sanitary pump station capacity over original commitments by 50%; and improved community engagement and created neighborhood green spaces. Details regarding this investment are provided in Volume 2, Chapter 4.
Plumbing Modification Program	Since the program's inception, MSD has completed over 17,992 projects totaling approximately $21.7 million dollars. The countywide program is now available to all MSD customers experiencing basement backups. MSD will pay up to $4,000 per residence for plumbing modifications. Generally, installations average about $2,500.
Supplemental Environmental Projects	MSD certified completion of all required supplemental environmental projects.
Consent Decree Reporting	MSD submitted 60 quarterly Consent Decree reports and 15 Annual Consent Decree reports. Reports are available to the public on MSD's Project WIN website.
Interim and Final LTCP	MSD completed all Interim projects and has completed 24 of 25 of the Final LTCP projects. Refer to section ES.1.1.2
Interim and Final SSDP	MSD completed all Interim SSDP projects and has completed 41 of the 57 Final SSDP projects. Refer to section ES.1.1.3

ES.1.1.2. IMPROVED OHIO RIVER & BEARGRASS CREEK WATER QUALITY

Although not required by the Presumption Approach, water quality sampling and modeling (described in Volume 1, Chapter 5) supports that both Beargrass Creek and the Ohio River would be in compliance with existing water quality standards if all background loads were removed. The measured reductions of Beargrass Creek and ORSANCO Ohio River bacteria levels during wet weather compared to pre-construction support the environmental and health benefits of IOAP implementation.

The general water quality trend since 2000 has demonstrated an improvement for bacteria trends. MSD received ORSANCO sampling data on the Ohio River indicating significant reductions in median fecal coliform levels downstream of Louisville, Kentucky (refer to Figure ES.1.1-1). Graphical representation of wet weather sampling performed by MSD along Beargrass Creek is provided in Figure ES.1.1-2.

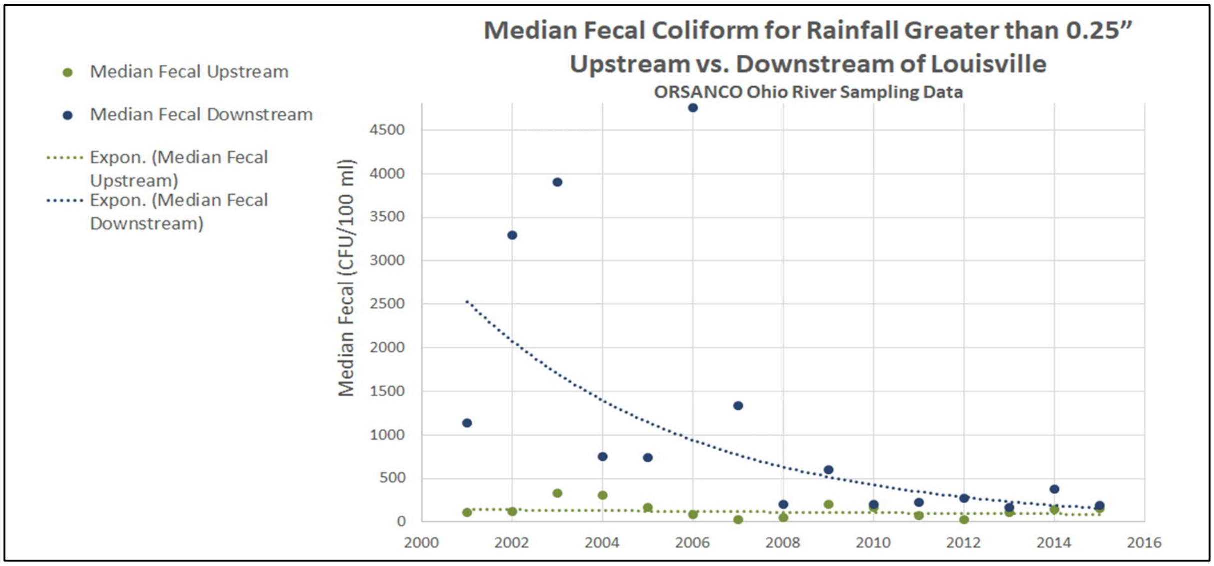

Figure ES.1.1-1 Ohio River Bacteria Trends as Published by ORSANCO in 2018

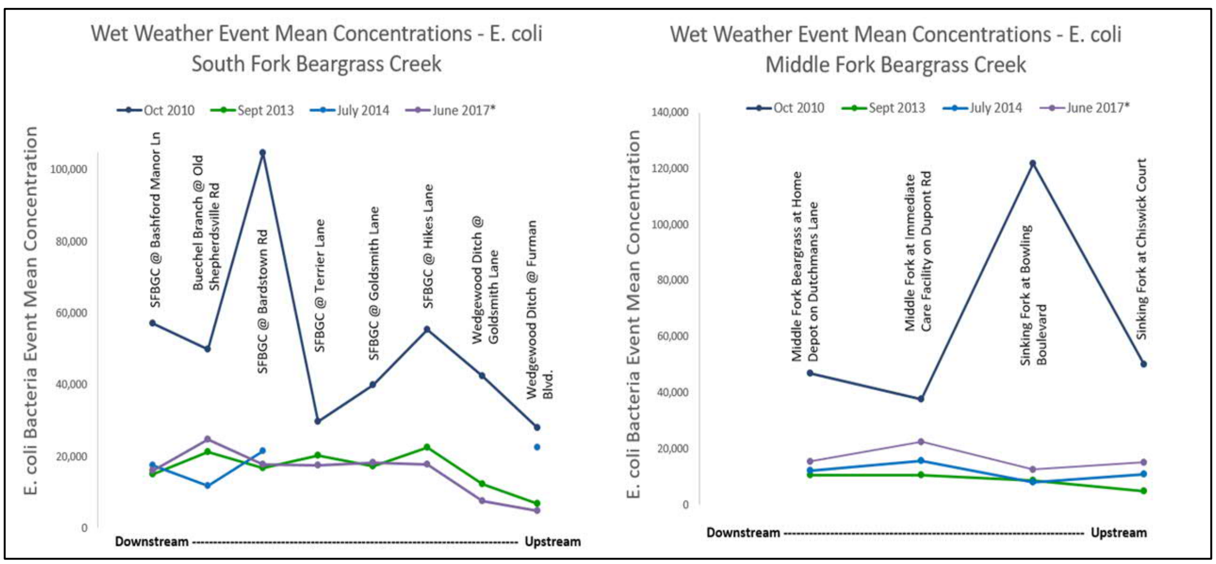

Figure ES.1.1-2 Beargrass Creek Bacteria Trends as Published by Louisville MSD

ES.1.1.3. FINAL LTCP PROGRESS

The IOAP requirements related to CSOs are summarized in Table ES.1.1-2 along with the progress MSD has made through December 31, 2020.

Table ES.1.1-2 Summary of Final LTCP Program

REQUIREMENT	ACCOMPLISHMENT
Construct 25 LTCP projects	MSD certified completion of 24 CSO LTCP projects to-date, reducing overflows to local waterways by approximately 5 billion gallons per Typical Year. The Waterway Protection Tunnel remains under construction and is scheduled to be completed December 31, 2022. The CSOs that have been mitigated through the LTCP projects are listed in Table ES.1.1-3
Construct 19 green infrastructure demonstration projects	MSD completed all green infrastructure demonstration projects as well the other green infrastructure program elements, totaling nearly $40 million for an incremental system benefit. Details regarding these projects are provided in Volume 2, Chapters 3 and 4.
Achieve 85%or greater capture throughout the combined sewer system (CSS)	The IOAP projects, when fully implemented, are modeled to achieve 95 percent capture of the wet weather combined sewage generated in the service area, which greatly exceeds EPA's Presumption Approach requirement of 85 percent. Compliance with the 85 percent capture will be achieved with completion of the Wateway Protection Tunnel. MSD expects to achieve 95 percent modeled performed by December 31, 2026 upon completion of the Morris Forman WQTC Sedimentation Basin Rehabilitation Project per the State Agreed Order Number 150220 Corrective Action Plan.
Nine Minimum Controls (NMC) Program	MSD's NMC Plan was submitted and approved by Regulators. MSD continues to implement its NMC Program. Through December 2020, MSD constructed 126 MG of system storage. The Phase 1 Real Time Control (RTC) Program provided a total of 41.05 MG of this storage. The rest of the storage volume was attributed to the basins listed in Volume 2, Chapter 4, Table 4.1-6. By December 2022, the Waterway Protection Tunnel will provide an additional 52 MG of system storage. Upon completion of the LTCP, MSD will have 178 MG of total storage available to better manage wet weather.

MSD has certified completion of 24 Final LTCP projects. The projects are listed in order of completion in Table ES.1.1-3 located at the end of the chapter.

Table ES.1.1-3 CSO Mitigations by Projects Completed under the LTCP Program
Table is located at the end of the Executive Summary

The remaining Final LTCP project is the Waterway Protection Tunnel as summarized in Table ES.1.1-4. This work will be substantially complete no later than December 31, 2022 per the Second ACD.

Table ES.1.1-4 Remaining LTCP Project

2021 FINAL LTCP PROJECT & IOAP PROJECT ID	2012 LTCP PROJECT	ESTIMATED REMAINING COST[1]	SECOND ACD DEAD-LINE[2]	CSOS MITIGATED & LEVEL OF CONTROL
Waterway Protection Tunnel Suite L_OR_MF_020_S_09B_B_A_8 L_MI_MF_127_M_09B_B_A_8 L_SO_MF_083_M_09B_B_A_8 L_OR_MF_155_M_09B_B_B_4	Story Ave. & Main St. Storage Basin I-64 and Grinstead CSO Basin Lexington Rd. and Payne St. Storage Basin 13th St & Rowan St Storage Basin	$64,437,300	12/31/2022	8 overflows per TY for CSO 020, 022, 023, 050, 051, 052, 053, 054, 055, 056, 150, 155 4 overflows per TY for CSOs 125, 126, 127, 166 0 overflows per TY for CSOs 082, 084, 118, 119, 120, 121,141, 153

[1]This table only shows the remaining forecasted project costs and does not include the total estimated cost at completion of the projects. [2]Consent Decree Completion date represents Substantial Completion of construction.

ES.1.1.4. FINAL SSDP PROGRESS

MSD is required to construct SSDP projects to eliminate sewer overflows (SSOs) for the 2-year, 5-year, or 10-year storm event. The level of control (LOC) storm event was selected for each modeled SSO location. The LOC selection and modeling referenced herein was performed in accordance with the approved IOAP, as required by the Amended Consent Decree. The IOAP requirements related to SSOs are summarized in Table ES.1.1-5 along with the progress MSD has made through December 31, 2020. Detailed information regarding the SSDP projects is provided in Volume 3.

Table ES.1.1-5 Summary of Final SSDP Program

REQUIREMENT	PROGRESS
Construct 57 SSDP projects of varying scopes to eliminate SSOs including six projects noted in the Interim SSDP	MSD certified completion of 41 (SSDP) projects through December 2020, that have eliminated 307 SSO occurrences. These locations are noted in Table ES.1.1-6.
For the 2-year storm, eliminate 100% modeled SSO volume and 100% modeled overflow locations	For the 2-year storm, eliminated 82% modeled SSO volume and 67% modeled overflow locations
For the 5-year storm, eliminate 13% modeled SSO volume and 35% modeled overflow locations	For the 5-year storm, eliminated 72% modeled SSO volume and 45% modeled overflow locations
For the 10-year storm, eliminate 10% modeled SSO volume and 18% modeled overflow locations	For the 10-year storm, eliminated 54% modeled SSO volume and 37% modeled overflow locations
Comprehensive Performance Evaluation-Composite Correction Plan (CPE-CCP) projects	Each of the small WQTCs that had SSOs in their watersheds were eliminated as part of MSD's long-term strategic plan to eliminate small WQTCs in its service area. The Jeffersontown WQTC was eliminated in 2015. Expansion of the Derek R. Guthrie WQTC to 60 MGD average day and 300 MGD peak day (for short durations) was completed in 2018 and the State approved is rerating in 2020. Similarly, expansion of the Floyd's Fork WQTC to 6.5 MGD was completed in 2012. The Hite Creek WQTC is under construction to expand its capacity to 9 MGD ADF and 24 MGD peak flow. Construction is scheduled for completion in FY22.
Capacity, Maintenance, Operation, and Management (CMOM) Program	MSD's CMOM Self-Assessment Program was submitted and approved in 2006. MSD continues to implement CMOM related capital projects.
Sewer Overflow Response Program (SORP)	MSD's SORP was submitted and approved in 2006. MSD completely revised the SORP in 2011. Final approval of the updated SORP document was received February 21, 2012. Modifications were made to the document in 2016 to reflect the elimination of the Jeffersontown WQTC and were approved on July 21, 2017. A new format was presented for the SORP in 2020 to reflect the software configuration.
Sewer Capacity Assurance Program (SCAP)	MSD's SCAP was submitted and approved in 2006. MSD submitted a revised SCAP dated November 2014 to EPA and KDEP on December 9, 2014. MSD received a letter approving that plan and acknowledging the November 2014 document superseded the 2008 SCAP on February 5, 2015

MSD certified completion of 41 SSO SSDP projects to-date and eliminated 87% of the SSOs identified in the SSDP (refer to Table ES.1.1-6 at the end of the chapter). Twelve of the projects were certified complete 1 year or more ahead of schedule. In addition, MSD has completed the 6 Interim SSDP projects listed in the ACD. More detailed regarding the Interim SSDP projects are provided in Volume 3, Chapter 1, Section 1.3.4.

Table ES.1.1-6 SSO Eliminations Under SSDP and other Programs
Table located at the end of the Executive Summary

The remaining SSDP projects are listed in Table ES.1.1-7 along with the Second ACD revised compliance dates. Although MSD is requesting a time extension through 2035, seven of the 16 remaining SSDP projects will be substantially complete by December 31, 2025. Six projects will be completed through 2030 and the remaining three projects will be completed through 2035. MSD desires to retain flexibility with scheduling this work to balance known and unknown critical capital needs.

Table ES.1.1-7 Remaining SSDP Projects

IOAP PROJECT ID		REMAINING SSDP PROJECT	ESTIMATED COST	SECOND ACD COMPLETION DATE[1]	LEVEL OF CONTROL STORM EVENT
1	S_JT_JT_NB03_M_01_C	Raintree & Marian Ct Phase 1	$125,000	12/31/2025	2-Year
2	S_CC_CC_70158_M_09A_C	Idlewood Inline Storage	$4,807,400	12/31/2025	2-Year
3	S_JT_JT_NB04_M_01_A	Monticello PS Elimination	$464,000	12/31/2025	10-Year
4	S_HC_HC_MSD1085_S_03_A	Kavanaugh Road Pump Station	$4,300,000	12/31/2025	10-Year
5	S_PO_WC_PC10_M_01_C	Leven Pump Station Elimination	$720,000	12/31/2025	2-Year
6	S_PO_WC_PC04_M_01_C	Cinderella PS Elimination	$1,500,000	12/31/2025	2-Year
7	S_HC_HN_NB02_S_09A_C_B	Gunpowder Pump Station ILS	$800,000	12/31/2025	2-Year
8	S_CC_CC_67997_M_01_C	Little Cedar Creek Interceptor	$2,400,000	12/31/2025	2-Year
9	S_CC_CC_MSD1025_S_03_B	Bardstown Road PS	$3,400,000	12/31/2030	5-Year
10	S_JT_JT_NB03_M_01_C	Raintree & Marian Ct Phase 2	$1,800,000	12/31/2030	2-Year
11	S_JT_JT_NB02_M_01_C	Dell Road & Charlaine Pkwy Int.	$8,800,000	12/31/2030	2-Year
12	S_MISF_MF_NB01_M_01_C_A1	Middle Fork Relief Interceptor, Wet Weather Storage, & Diversion Phase 2: Upper Middle Fork PS & Interceptor	$86,408,000	12/31/2030	2-Year
13	S_OR_MF_NB01_M_01_B	Mellwood System Improvements & PS Eliminations Phase 2: Mockingbird Valley PS	$2,516,100	12/31/2030	5-Year
14	S_SD_MF_NB05_M_01_A	Sutherland Interceptor	$1,065,300	12/31/2030	10-Year
15	S_SF_MF_30917_M_09_A	Camp Taylor Improvements Phase 4: Offline Storage	$23,972,300	12/31/2035	10-Year

IOAP PROJECT ID		REMAINING SSDP PROJECT	ESTIMATED COST	SECOND ACD COMPLETION DATE[1]	LEVEL OF CONTROL STORM EVENT
16	S_MI_MF_NB04_M_03_B	Goose Creek PS Improvements & Wet Weather Storage Phase 2 – Goose Creek PS Improvements	$6,978,600	12/31/2035	2-Year
Remaining Costs for SSDP Projects			**$150,056,700**		

[1]Consent Decree Completion date represents Substantial Completion of construction. The Lucas Lane Project Minor Modification was submitted in February 2021 indicating refined hydraulic modeling has demonstrated the LOC is currently met without further investment.

ES.1.1.5. MODELED SSO VOLUME AND LOCATIONS

When the CD was lodged, MSD had an estimated 218 modeled SSOs occurrences. The CD/ACD required MSD to eliminate all SSOs for the 2-year storm event. SSO occurrences are required to be reduced to a level of control for the 5-year and 10-year storm events. Under the Final SSDP MSD is required to eliminate 197 modeled SSO occurrences. A forecast of the number of modeled SSOs per the revised Second ACD compliance dates is presented in Table ES.1.1-8.

Table ES.1.1-8 Modeled Performance of SSO Occurrences

CLOUDBURST STORM EVENT	2007 NUMBER OF MODELED SSOS	2020 NUMBER OF MODELED SSOS	2025 NUMBER OF MODELED SSOS	2035 NUMBER OF MODELED SSOS	NUMBER OF MODELED SSOS AT REQUIRED LEVEL OF CONTROL
2-Year Cloudburst Storm Event	197	65	55	0	0
5-Year Cloudburst Storm Event	211	117	109	75	137
10-Year Cloudburst Storm Event	218	137	129	108	178

Sixteen (16) SSDP projects remain to be completed and these projects will eliminate 65 remaining SSOs occurrences during the 2-year storm event. When all SSDP projects are completed no later than 2035, MSD will have eliminated a total of 197 SSO occurrences for the 2-year storm. The remaining SSDP projects and SSO locations are noted in Table ES.1.1-7.

The series of graphs shown below demonstrates MSD's progress with eliminating the SSOs identified in the Final SSDP. Figure ES.1.1-3 shows the forecasted elimination schedule based upon the Level of Control agreed upon in the ACD reflecting the Final SSDP time extension associated with the Second ACD. Separate lines are shown on the graph for each cloudburst storm event level of control. This information shows the general trend to reduce 2-year storm event SSOs from nearly 200 to 0 upon completion of the Final SSDP. Similarly, the 5-year storm SSOs were agreed to be reduced from nearly 210 overflows to approximately 140 SSO occurrences; and the 10-year storm event SSOs were agreed to be reduced from approximately 220 overflows to approximately 180 SSO occurrences.

Figure ES.1.1-3 SSO Eliminations Over Time Based on Level of Control

MSD modeled the system improvements constructed through August 2020 and those forecasted to be built with the remaining SSDP projects (through 2035). The resulting modeled system performance with respect to SSO eliminations is shown in Figure ES.1.1-4. The scope of work for several of the constructed SSDP projects was revised which subsequently achieved a higher level of control and greater environmental benefit.

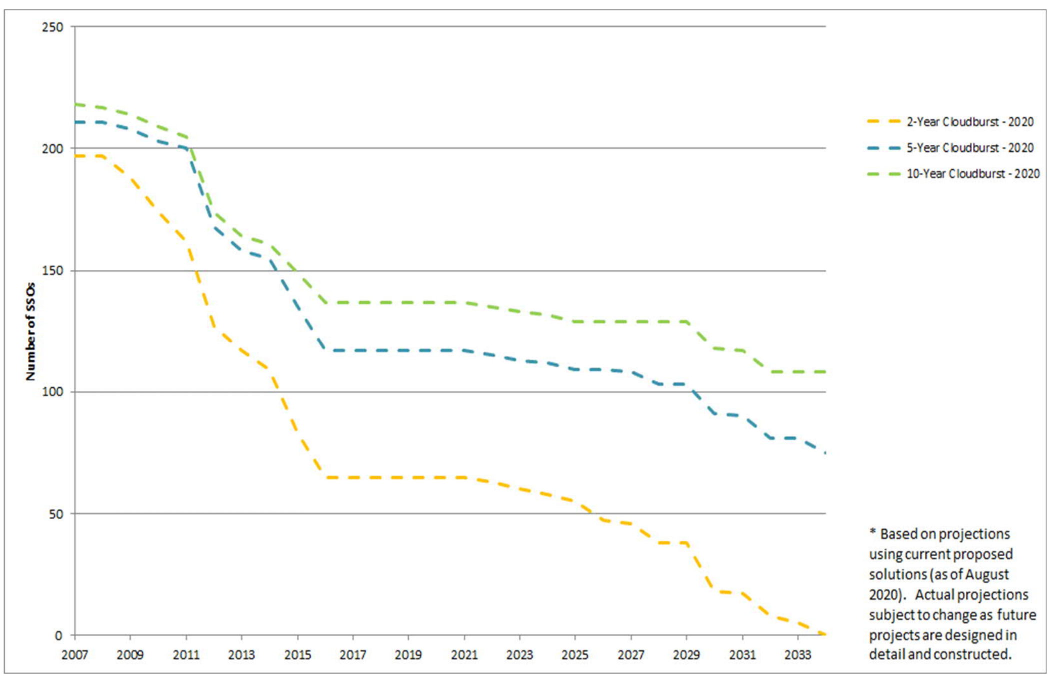

Figure ES.1.1-4 SSO Eliminations Over Time Based on Model Projections

For example, the modeled performance results at the conclusion of the Final SSDP indicates MSD will reduce the 2-year storm event SSOs from approximately 200 to 0 occurrences; 5-year storm event SSOs from approximately 210 to 75 occurrences ; and 10-year storm event SSOs from approximately 220 to 110 occurrences.

Figure ES.1.1-5 shows the comparison of SSO eliminations based upon both level of control and model predictions. The line representing the 2-year storm event is the same as the level of control shown in Figure ES.1.1-3 and Figure ES.1.1-4. However, the lines for the 5-year and 10-year storm events are lower than those in Figure ES.1.1-3 – indicating fewer SSOs are occurring compared to the IOAP/ACD requirements.

Figure ES.1.1-5 SSO Eliminations Based on Level of Control and Model Projections

MSD's investments have resulted with 65 fewer SSOs during 5-year storm events and 70 fewer SSOs during 10-year storm events as compared to the agreed upon ACD level of control. This represents **an additional 30% reduction of SSO occurrences during larger storm events than was agreed upon with the IOAP/ACD**.

In addition to having fewer SSO occurrences during larger storms, MSD has already achieved (through August 2020) a better performance than originally envisioned with the IOAP/ACD. Figure ES.1.1-6 presents a graphical depiction of the forecast for eliminating the SSOs as envisioned during 2012. All three lines showing each level of control storm (2-year, 5-year, and 10-year) indicate MSD achieved SSO eliminations faster than anticipated. For example, the original 2012 forecast that was incorporated into the IOAP/ACD estimated approximately 77 SSOs occurring for the 2-year storm event during 2020. Whereas, both the level of control line and modeled performance line in Figure ES.1.1-6 indicate MSD has already reduced SSOs to approximately 65 occurrences for the 2-year storm.

The difference for the 5-year and 10-year storm events are more pronounced. The 2020 values indicate the 2012 forecast estimated 169 SSO occurrences for the 5-year event vs. the modeled performance for the completed SSDP projects of 117 SSO occurrences. In 2012, it was assumed by 2020 MSD would have reduced the 10-year storm SSOs to 195 occurrences as compared to the 2020 modeled performance of 165 occurrences. This data suggests **MSD is achieving SSO eliminations and subsequent environmental benefits at a higher rate than required in the IOAP/ACD**.

Figure ES.1.1-6 SSO Eliminations Compared to Original Compliance Schedule

ES.1.2. MSD'S CHANGED CIRCUMSTANCES SINCE ACD LODGING

Major investments in other infrastructure rehabilitation, renewal, and replacement were limited as capital and operating spending increased to meet ACD requirements. The result of deferred investment on infrastructure renewal and replacement is that MSD now must confront a rapidly aging system of pipes, pumps, treatment plants, and flood control systems in urgent need of rehabilitation if those existing assets are to continue protecting public health and safety.

MSD's changed circumstances have resulted in critical reprioritization of needs for MSD's infrastructure, as contemplated by USEPA's 2012 Integrated Planning Framework and the passage of the Water Infrastructure Improvement Act. **These changed circumstances have added approximately $1B** to MSD's Capital Improvement Program (CIP), including $700M to the 5-year CIP as summarized in Table ES.1.2-1. A summary of each changed circumstance is provided herein.

Table ES.1.2-1 Projects Necessary to Address Changed Circumstances

MSD BUDGET ID	PROJECT	ESTIMATED COST AT COMPLETION	ESTIMATED COST IN 5-YEAR CIP
H09133	Waterway Protection Tunnel Extension – *Estimated cost represents the additional cost only. The total project cost = $151,788,400*	$30,000,000	$55,000,000
Multiple	Morris Forman WQTC Lightning Strike Repair[1]	$50,000,000	$0
Multiple	Morris Forman WQTC Corrective Action Plan	$171,771,000	$96,018,900
D18116	Morris Forman WQTC Biosolids Facility Replacement[2]	$197,800,000	$175,072,800
F21084,85	USACE FPS Reliability Improvements Program	$58,664,300	$58,664,300
F18515	Paddy's Run Pump Station Capacity Upgrade	$115,000,000	$115,000,000
Multiple	Critical Interceptor Rehabilitation Program	$70,000,000	$70,000,000
Multiple	Wastewater System Asset Management Program	$375,000,000	$125,000,000
		$1,068,235,500	**$694,756,000**

[1]All funds have already been paid for this changed circumstance. [2]Approximately $175M is forecasted to be spent during the 5-year CIP with the remaining $23M to be spent in the 6th year (FY26).

ES.1.2.1. MORRIS FORMAN WQTC LIGHTNING STRIKE OUTAGE

In April 2015, the Morris Forman WQTC experienced a catastrophic mechanical failure due to a lightning strike. As a result, there was significant damage to the primary treatment, secondary treatment, and electrical systems. The damaged infrastructure subsequently contributed to permit exceedances in the effluent for Biological oxygen Demand (BOD) and Total Suspended Solids (TSS). MSD invested $50M to repair the damage to the Morris Forman WQTC. These costs are not included in in the Estimated Cost for the 5-Year CIP because additional capital funds are not required to complete the repairs. However, it is important to realize that MSD was required to defer other Asset Management needs in order to fund this unforeseen $50M effort.

ES.1.2.2. WATERWAY PROTECTION TUNNEL UPGRADES

The Waterway Protection Tunnel is comprised of four projects consolidated from the 2009 LTCP to help control CSOs and other unauthorized discharges from MSD's sewer system. When completed, the approximate 55 million gallon storage facility will accommodate wet weather flows within the project area to limit the number of overflows to eight (8) times in a Typical Year for the Downtown area, zero (0) times in a Typical Year for the Irish Hill area, and four (4) times in a Typical Year for the Grinstead Road area. The Waterway Protection Tunnel project comprises the largest component of the remaining LTCP projects with $55M worth of work to be completed in FY21-FY25. The completion date for the tunnel was extended to December 31, 2022 (from December 31, 2020) with the Second Amendment to the Consent Decree.

In June 2018, MSD decided to extend the tunnel approximately 7,800 linear feet east to the I-64 & Grinstead CSO Basin project location to eliminate the need for this basin. A new retrieval/drop shaft was constructed at the I-64 & Grinstead location to collect flows from the nearby CSO locations. The necessary change order resulted in a price adjustment of over $30M and extended the contractor's schedule by 156 days. In addition to the tunnel extension, MSD's contractor was granted additional time for differing site conditions (35 days). MSD's contractors experienced issues with the tunnel crown at STA 102, 108 and 162. Through December 31, 2020, MSD granted 48 days for these issues, but MSD expects further notices regarding these issues. These delays do not represent all delays associated with the project. MSD's contractors provided a revised substantially complete date of September 4, 2021. However, MSD believes they are approximately 27 days behind that schedule. For example, the contractor encountered issues with the first tunnel concrete lining pours in the bifurcation.

In addition to the delays explained above, MSD's contractor requested 73 days for weather related delays; delays related to the delivery of the tunnel boring machine; and delays associated with relocations. However, MSD is disputing these days. Finally, to date, there are approximately 99 days of delay that are unaccounted for by MSD's contractor.

ES.1.2.3. MORRIS FORMAN WQTC CORRECTIVE ACTION PLAN

MSD has agreed to spend an additional $175M to reduce effluent BOD and TSS and take measures to prevent another catastrophic failure at the Morris Forman WQTC. MSD entered into an Agreed Order with the Kentucky Energy and Environment Cabinet (KDEP) and agreed to complete the $175M Corrective Action Plan (CAP) for mitigating permit non-compliance.

MSD has been working on the Morris Forman WQTC CAP projects since 2015. Many of the projects completed from 2015 – 2020 were related to providing redundancy for critical units/systems or improving the plant's resilience to avoid a similar fate. The complete list of CAP projects is provided in Table ES.1.2-2. As shown, MSD has completed several of these projects and all remaining projects are in-progress. This information is provided for informational purposes to demonstrate the level of investment MSD is making to improving the Morris Forman WQTC. This work is not part of the Second ACD.

Table ES.1.2-2 Morris Forman WQTC Corrective Action Plan

MSD BUDGET ID	PROJECT	ESTIMATED COST AT COMPLETION	ESTIMATED COST IN 5-YEAR CIP
H14108	Morris Forman WQTC Rubbertown Flow Sampling	$50,500	$0
D15022	Morris Forman WQTC MEB Leak Repair	$373,000	$0
F14179	Morris Forman WQTC Wet Cake Pump	$984,500	$0
D15127	Morris Forman WQTC Process Water Line	$365,500	$0
F13013	Morris Forman WQTC Condenser Upgrades	$395,200	$0
D15017	Morris Forman WQTC Centrifuge Electrical Controls	$1,091,900	$0
F14183	Morris Forman WQTC FEPS Generator	$3,275,500	$0
D18359	Morris Forman WQTC Delta Transformer	$98,500	$0
D18360	Morris Forman WQTC Air Dryer	$39,500	$0
D18362	Morris Forman WQTC FEPS Substation	$596,800	$0
F13016	Morris Forman WQTC High Yard Electrical Mod	$7,396,900	$0
F13023	Morris Forman WQTC Headworks Replacement	$14,940,600	$0
F09510	Morris Forman WQTC OGA Plants 1 and 2	$7,306,600	$0
D19044	Morris Forman WQTC Primary Sludge Pump Comp	$83,500	$0
D20249	District-Wide Biosolids Master Plan	$250,000	$0
F14182	Morris Forman WQTC FEPS Pump & Motor Repair	$450,000	$0

MSD BUDGET ID	PROJECT	ESTIMATED COST AT COMPLETION	ESTIMATED COST IN 5-YEAR CIP
D15020	Morris Forman WQTC Cake Pump Phase 2	$1,802,400	$0
D19227	Morris Forman WQTC Primary Sludge Line	$762,800	$0
D19237	Morris Forman WQTC Arc Flash Update	$102,700	$0
D19307	Morris Forman WQTC FEPS VFD Replacement	$813,200	$319,400
D20167	Morris Forman WQTC East Headworks HVAC	$101,900	$97,600
D20228	Morris Forman WQTC Centrifuge Rehabilitation	$1,100,000	$388,000
D18130	Morris Forman WQTC FEPS MCC Replacement	$500,000	$500,000
D20291/84	Derek R. Guthrie WQTC Dewatering Facility	$47,282,200	$34,324,300
D20285	Morris Forman WQTC LG Dryer Replacements	$49,305,200	$23,388,500
D19045	Morris Forman WQTC Sodium Hypochlorite Relocation	$3,471,000	$4,447,000
D17042	Morris Forman WQTC Sedimentation Basin Rehab	$32,514,000	$32,554,100
	Total	**$175,453,900**	**$95,042,900**

- The primary driver for the Morris Forman WQTC CAP is related to MSD's inability to process solids which led to permit exceedances for TSS and BOD. MSD initiated actions to expedite permit compliance. MSD offloaded regional biosolids from the Morris Forman WQTC by constructing a new dewatering facility at the Derek R. Guthrie WQTC. Dewatered biosolids are transported from the Derek R. Guthrie WQTC to the landfill. In addition to reducing the loading and stress on the Morris Forman WQTC, MSD expedited a project to construct two state-of-the-art dryers to replace the four broken and non-repairable dryers that completely failed in 2019.
- The Morris Forman WQTC CAP also includes a project to rehabilitate the four primary sedimentation basins. The WQTC is limited to a max wet weather flow of 240 MGD due to capacity constraints with the sedimentation basins. Each rectangular basin is approximately 275 feet long, 70 feet wide, 17 feet deep, was designed with a capacity of nearly 90 MGD for a total treatment capacity of 360 MGD. The Primary Sedimentation Basins were originally constructed in the 1950s. Most equipment serving the basins has exceeded the expected service life, and equipment performance has become unreliable. The timing for implementing this project is dependent upon Ohio River elevations and the associated impact on the sedimentation basins. MSD anticipates being able to rehabilitate one basin per year upon completion of the design phase of this project.
- Treating ≈330 MGD of wet weather flows will reduce potential discharges from the Main Diversion Structure (CSOs 210, 211, 016) and the Southwest Pump Station (CSOs 015 and 191). This will reduce the level of pollutants discharged into the Ohio River. This project is required in order for the plant to meet the total wet weather treatment capacity identified in the Final LTCP.

ES.1.2.4. MORRIS FORMAN WQTC BIOSOLIDS

In 2015, the Morris Forman WQTC began receiving higher solids loading from sewer discharges received from local distilleries. These loadings increased the level of TSS processed through the solids management system. This increase coupled with the substantial grit loading in the combined sewer system served to sandblast the centrifuges and dryers in use at the Morris Forman WQTC, which led to an accelerated level of deterioration for the biosolids equipment.

The Morris Forman WQTC is not able to consistently meet effluent permit limits for BOD and TSS due to outdated and aging biosolids processes and increased pollutant loading received from regional distilleries. MSD is proposing to invest $197.8M to replace the existing biosolids processing system with a modern facility. This project will provide MSD with the ability to fully comply with permit limits, thereby reducing the level of pollutants discharged into the Ohio River. Details regarding this project are provided in Volume 1, Chapter 4, Section 4.7.

ES.1.2.5. USACE FLOOD PUMP STATION IMPROVEMENTS

In 2018-2019, MSD partnered with United States Army Corps of Engineers (USACE) to complete the Preliminary Feasibility Study for the Ohio River Flood Protection System (ORFPS). The study identified projects needed to ensure flood protection levels meet today's standards. USACE has indicated federal funds may be available to address reliability improvements. However, capacity upgrades and back-up power needs are not eligible for USACE funding. The USACE will fund and lead the reliability improvement projects. MSD anticipates having a cost-share responsibility of approximately $58.7M but will have limited input regarding the timing of when the work is performed. USACE initially stated design will advance in FY21 with construction to begin in FY23.

ES.1.2.6. PADDY'S RUN PUMP STATION REPLACEMENT

The original station remains in operation. Additional capacity is needed to support operation of the Bells Lane Facility and to direct flow to the MFWQTC. Constructed in 1953 by USACE, the Paddy's Run Pump Station is beyond its useful life and critical infrastructure to replace. In addition to providing regional flood protection along the Ohio River, the station uniquely assists with wet weather treatment. When the Ohio River flood stage exceeds 58 feet on the lower gage, MSD relies on Paddy's Run Station to pump 50 MGD from the Bells Lane Wet Weather Treatment Facility. Without the station in operation, flow would discharge untreated through CSO 015, resulting in combined sewage ponding in upstream residential areas, including streets, basements, and first floors, before ultimately discharging to the Ohio River. This $115M project will protect the public from flooding and will prevent unauthorized discharges of combined sewage. Details regarding this project are provided in Volume 1, Chapter 4, Section 4.7.

ES.1.2.7. CRITICAL INTERCEPTOR REHABILITATION PROJECTS

MSD continues to experience an increased occurrence of critical sewer interceptor failures. Since most of the interceptors were constructed in the same era, the timing and rate for failures is not anticipated to lessen. For example, the Ohio River Interceptor was constructed 1958-1960. In August 2018, hydrogen sulfide corrosion caused a failure at the intersection of 4th and Main Streets. This was a catastrophic failure impacting multiple businesses and residents. Repair of this failure cost nearly $20M. MSD must proactively address similar interceptors having a risk score of 20 or higher. As such, $70M of critical sewer projects have been incorporated into to the 5-Year CIP as noted in Table ES.1.2-3. Details regarding these sewers are provided in Volume 1, Chapter 4, Section 4.7.

Table ES.1.2-3 Summary of Critical Interceptor Program

MSD BUDGET ID	CRITICAL INTERCEPTOR PROJECTS	ESTIMATED FY21-FY25 SPENDING
E17053	Buechel Trunk Sewer Rehabilitation	$3,000,000
A20280	Harrods Creek Force Main Repair	$8,400,000
H16075	Prospect Phase II Area Sewers Rehabilitation	$3,000,000
A19208	Broadway Interceptor Infrastructure Rehabilitation	$10,000,000
H18503	I-64 and Grinstead Infrastructure Rehabilitation	$16,000,000
A20244	Large Diameter Sewer Rehabilitation	$8,300,000
H21019	Rudd Ave Sewer Infrastructure Rehabilitation	$2,300,000
H20147	Western Outfall Infrastructure Rehabilitation	$16,000,000
H16074	Nightingale Sewer Rehabilitation	$3,000,000
	Total	**$70,000,000**

ES.1.2.8. ASSET MANAGEMENT PROGRAM

As MSD implemented the ACD and constructed new assets to mitigate unauthorized discharges, investment was diverted from management of existing assets. The level of underinvestment for Asset Management over the past 10 years has led to accelerated deterioration for multiple critical assets. If these conditions were present when the Consent Decree, ACD, and IOAP were being developed, these projects would likely have been addressed at that time. Under the Second ACD, MSD has agreed to invest an average of $25M per year for 15 years, for a total of $375M. MSD will report annually on the projects completed, in-progress, and forecasted for the next fiscal year under this program. If MSD does not satisfy the $125M spending amount during each 5-year period, the Second ACD stipulates penalties based upon the level of underperformance. Refer to Volume 1, Chapter 4, Section 4.7 for more information related to the Asset Management Program.

ES.1.2.9. CHANGED FINANCIAL CONDITIONS

MSD has experienced changed financial conditions since the ACD was executed, including the following:

- **Debt Profile**: In addition to the changed conditions with critical asset risks, financial risks have also surfaced. MSD's Board's authority to raise rates is limited to 6.9% annually. MSD's overall debt currently exceeds $2 billion as MSD continues to borrow faster than paying off debt each year. Today, MSD's debt profile has reached the point of a potential downgrade from the rating agencies. A downgrade would jeopardize MSD's ability to finance projects and would result with higher financing costs.
- **COVID19 Impact:** The COVID19 pandemic is impacting MSD's operating and capital budgets. The impacts so far have been less than initially feared but MSD continues to experience revenue reductions, delayed supplier deliveries, and volatility in the short-term municipal debt market. Revenue reductions are a direct result of rate payers not being able to pay their utility bills due to job loss and other COVID19 impacts. A few capital projects were extended into FY21 because equipment manufacturers were not able to build and ship equipment due to shortages of materials/labor attributed to the COVID19 pandemic. So far, these impacts are

not being experienced on Consent Decree projects. Finally, the pandemic brought extreme volatility in the short-term municipal debt market due to the social and economic realities. MSD is working closely with the commercial paper dealers to maintain its program. The length of the pandemic could shift investor's concerns to credit quality as municipal revenues and cash flows become impacted. MSD is moving forward with its planned 2020A Revenue Bond to refund outstanding commercial paper and notes. MSD is prepared for additional disclosure and conversation with investors to provide reassurance that MSD does not have prolonged credit concerns.

Due to these changes circumstances, the Cabinet, EPA and MSD have agreed to enter into a Second Amendment to the Consent Decree which shall continue some of the measures set forth in the Amended Consent Decree, reprioritize some specific remedial projects set forth in the 2021 IOAP Modification and add new measures to further the objectives of the Amended Consent Decree and the achievement of the levels of control for CSOs and SSOs as set forth in the approved IOAP Modification.

ES.1.3. ENVIRONMENTAL BENEFIT ANALYSIS

An environmental benefit analysis was prepared to confirm addressing the current infrastructure priorities would provide an equivalent or better environmental benefit than constructing the remaining SSDP projects by 2024.

MSD is required to construct SSDP projects to eliminate SSOs for the 2-year, 5-year, or 10-year storm event. The level of control (LOC) storm event was selected for each modeled SSO location. The LOC selection and modeling referenced in this analysis was performed in accordance with the approved IOAP, as required by the ACD. The 2012 IOAP requires MSD to achieve the following related to modeled SSOs by 2024:

- Construct 57 Final SSDP and 6 Interim SSDP projects of varying scopes to eliminate SSOs
- For 2-year storm, eliminate 100% modeled SSO volume and 100% modeled overflow locations
- For 5-year storm, eliminate 13% modeled SSO volume and 35% modeled overflow locations
- For 10-year storm, eliminate 10% modeled SSO volume and 18% modeled overflow locations

Through 2020 MSD has already over performed the expected environmental benefit for the bigger storms per the IOAP requirements by achieving the following:

- Constructed 41 of the Final SSDP and all six of the Interim SSDP projects (74% of the number of required projects).
- For 2-year storm, eliminated 82% modeled SSO volume and 67% modeled overflow locations.
- For 5-year storm, eliminated 72% modeled SSO volume and 45% modeled overflow locations.
- For 10-year storm, eliminated 54% modeled SSO volume and 37% modeled overflow locations.
- For the Ohio River, reduced median fecal coliform concentrations by 76% since 2007 based on data from ORSANCO collected 2001-2015.
- For Middle Fork and South Fork Beargrass Creek, reduced wet weather mean E-Coli concentrations an average of 70% since 2010 based on grab sample data collected in October 2010, September 2013, July 2014, and June 2017.

ES.1.3.1. ENVIRONMENTAL IMPACT OF 2-YEAR STORM

Table ES.1.3-1 summarizes the modeled performance for the 2-year storm events. As of August 2020, for the 2-year storm, MSD has reduced modeled SSO volumes from 20.8 MG in 2007 to 3.7 MG (82% reduction). Per the requested time extension, MSD will eliminate 98% of the modeled SSO volume by 2030 and achieve 100% SSO volume elimination for the 2-year storm event in 2035. The progressive performance for eliminating modeled SSO volume is shown in Figure ES.1.3-1.

Table ES.1.3-1 Two-Year Storm Event LOC and Modeled Performance

YEAR	MODELED VOLUME (MG)	% VOLUME ELIMINATED	MODELED SSO LOCATIONS	% LOCATIONS ELIMINATED
2007	20.8	0%	197	0%
2020	3.7	82%	65	67%
2030	0.4	98%	18	91%
2035	0,0	100%	0	100%
Required LOC	**0**	**100%**	**0**	**100%**

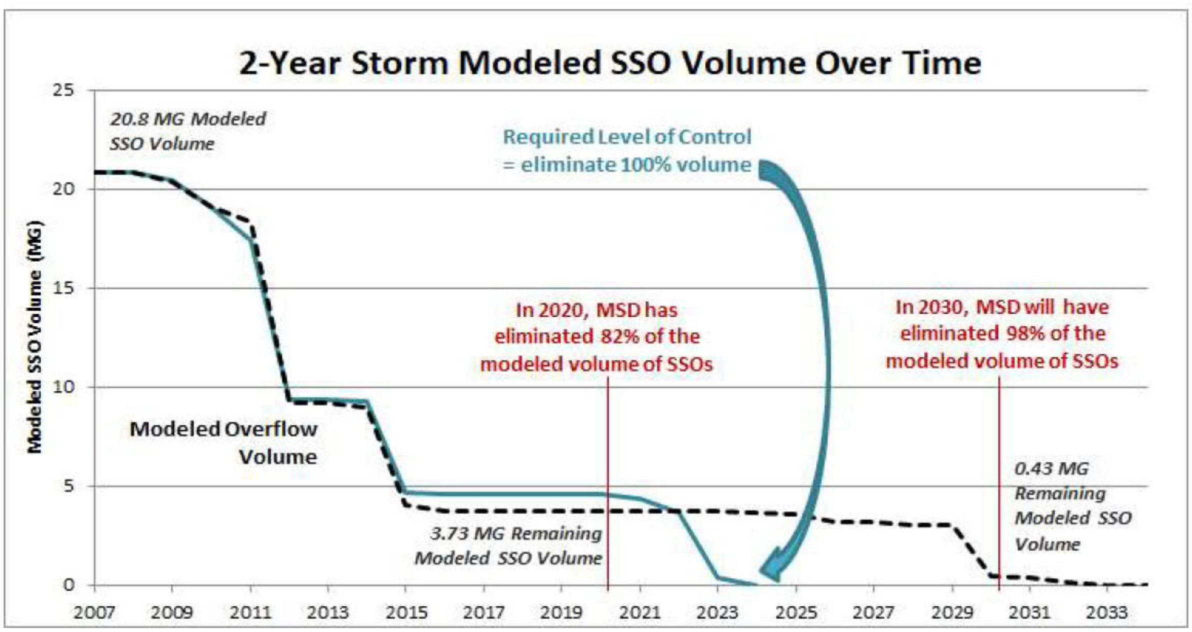

Figure ES.1.3-1 Two-Year Storm Event Modeled SSO Volumes

MSD is able to eliminate 98% of modeled SSO volume by 2030 by constructing the largest remaining SSDP project - the Upper Middle Fork (UMF) Phase 2 Project *(IOAP Project ID: IS_MISF_MF_NB01_M_01_C_A)*. This project involves replacing the existing 9 MGD UMF Pump Station with a 30 MGD Pump Station; constructing 10,200 feet of 30-inch force main and 14,000 feet of 24-inch to 36-inch relief interceptor parallel to the existing UMF Interceptor; and constructing a flow diversion structure on the existing UMF Interceptor and UMF Relief Interceptor with modulating control gates to integrate with MSD's real time control system. This project will eliminate 2.6 MG, 7.8 MG, and 13.6 MG of modeled SSO volume for the 2-year, 5-year and 10-year storm events, respectively.

With the time extension requested, the UMF Phase 2 Project will begin design in 2025 and be substantially complete in 2030. When the UMF Phase 2 Project is completed, modeled SSO volumes for the 2-year storm will be reduced by 98% and the number of modeled overflow locations by 91%. The progressive performance related to eliminating the number of SSO locations over time is shown graphically in Figure ES.1.3-2.

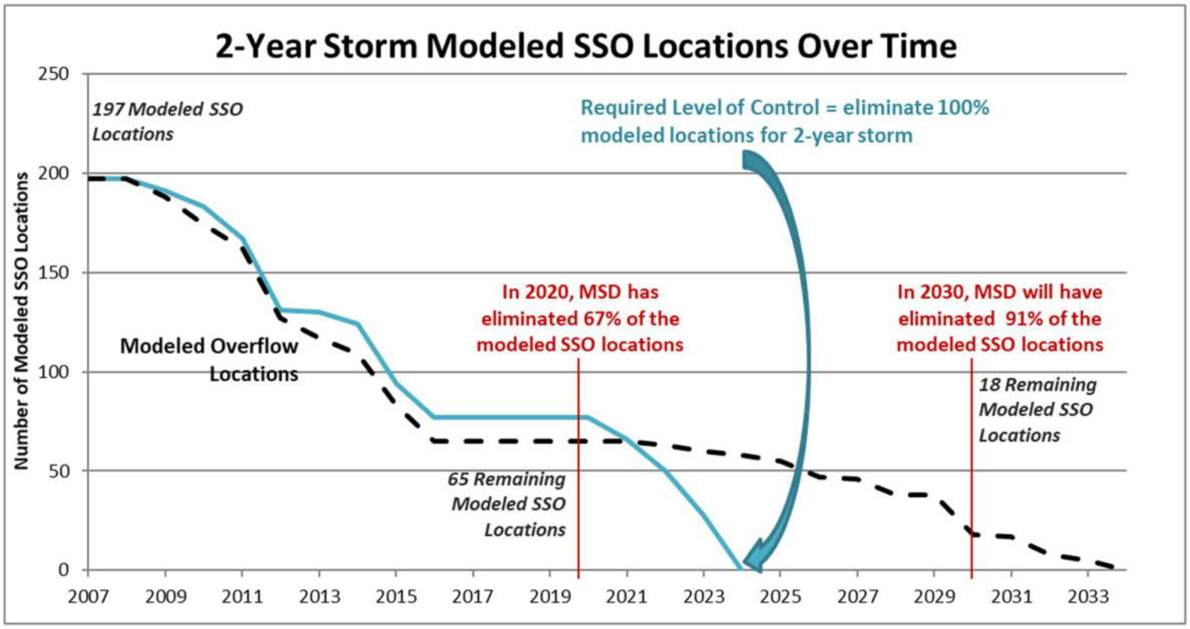

Figure ES.1.3-2 Two-Year Storm Modeled SSO Locations

The potential environmental impact of delaying completion of the UMF Phase 2 Project from 2024 to 2030, is an estimated 2.6 MG of SSO volume could occur during the 2-year storm, and approximately the same amount would overflow during the Typical Year. The Typical Year model simulation generally includes one storm event slightly larger than the 2-year storm. Therefore, for the time period of 2025 through 2030, an estimated SSO volume of 13 MG could theoretically occur assuming a 2-year storm event occurs every year.

ES.1.3.2. ENVIRONMENTAL IMPACT FOR 5-YEAR AND 10-YEAR STORMS

Many of the projects already constructed by MSD have achieved a higher level of control than required by the IOAP for the larger storm events. Through August 2020, MSD has eliminated 72% of the modeled SSO volume and 45% of the modeled SSO locations for the 5-year storm event as noted in Table ES.1.3-2. This exceeds the required minimum LOC for the 5-year storm event (14% of modeled SSO volume and 35% of modeled SSO locations). Similarly, through August 2020, MSD has eliminated 54% of the modeled SSO volume and 37% of the modeled SSO locations for the 10-year storm event; exceeding the minimum LOC of 10% of modeled SSO volume and 18% of modeled SSO locations (refer to Table ES.1.3-3).

Table ES.1.3-2 Five-Year Storm Event LOC and Modeled Performance

YEAR	MODELED VOLUME (MG)	% VOLUME ELIMINATED	MODELED SSO LOCATIONS	% LOCATIONS ELIMINATED
2007	47.7	0%	211	0%
2020	13.4	72%	117	45%
2030	6.1	87%	91	57%
2035	4.7	90%	75	64%
Required LOC	**41.5**	**14%**	**137**	**35%**

Table ES.1.3-3 Ten-Year Storm Event LOC and Modeled Performance

YEAR	MODELED VOLUME (MG)	% VOLUME ELIMINATED	MODELED SSO LOCATIONS	% LOCATIONS ELIMINATED
2007	75.4	0%	218	0%
2020	34.5	54%	137	37%
2030	23.5	69%	118	46%
2035	21.0	72%	108	50%
Required LOC	**68.2**	**10%**	**178**	**18%**

As MSD continues to construct the remaining SSDP projects, the LOC achieved during the larger storm events will continue to increase. Upon completion of Final SSDP projects, MSD will have eliminated approximately 90% of the modeled 5-year SSO volume and 72% of the modeled 10-Year SSO volume. MSD will achieve six times the required minimum IOAP LOC for the larger storm events. This is a drastically improved environmental benefit in that the projects are capturing more flow during large storms.

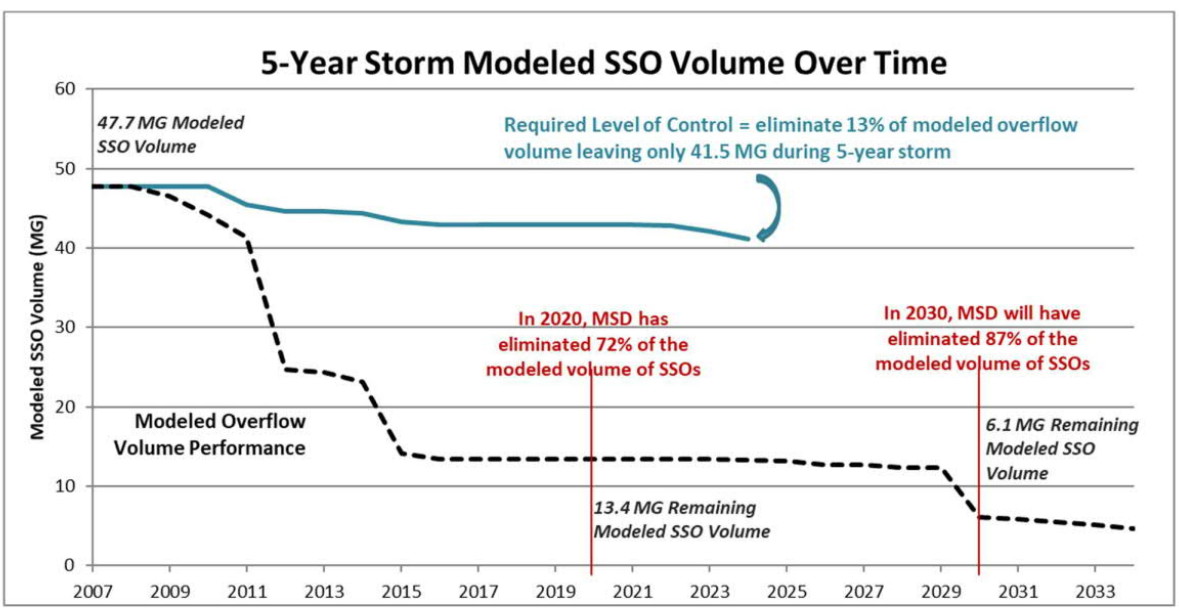

Figure ES.1.3-3 Five-Year Storm Event Modeled SSO Volumes

The progressive performance related to the 5-year storm modeled SSO volume reduction is presented in Figure ES.1.3-3. The similar figure for the 10-year storm event is provided in Figure ES.1.3-4.

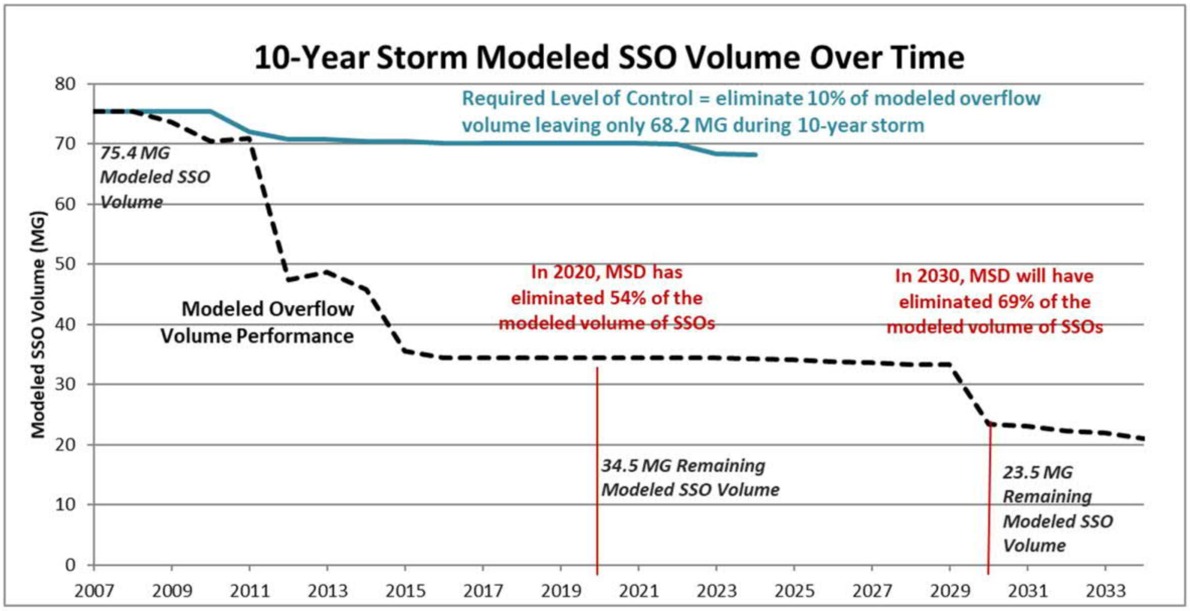

Figure ES.1.3-4 Ten-Year Storm Event Modeled SSO Volumes

Graphs showing the progressive elimination of modeled SSO locations over time for the 5-year, and 10-year storm events are provided in Figure ES.1.3-5 and Figure ES.1.3-6, respectively.

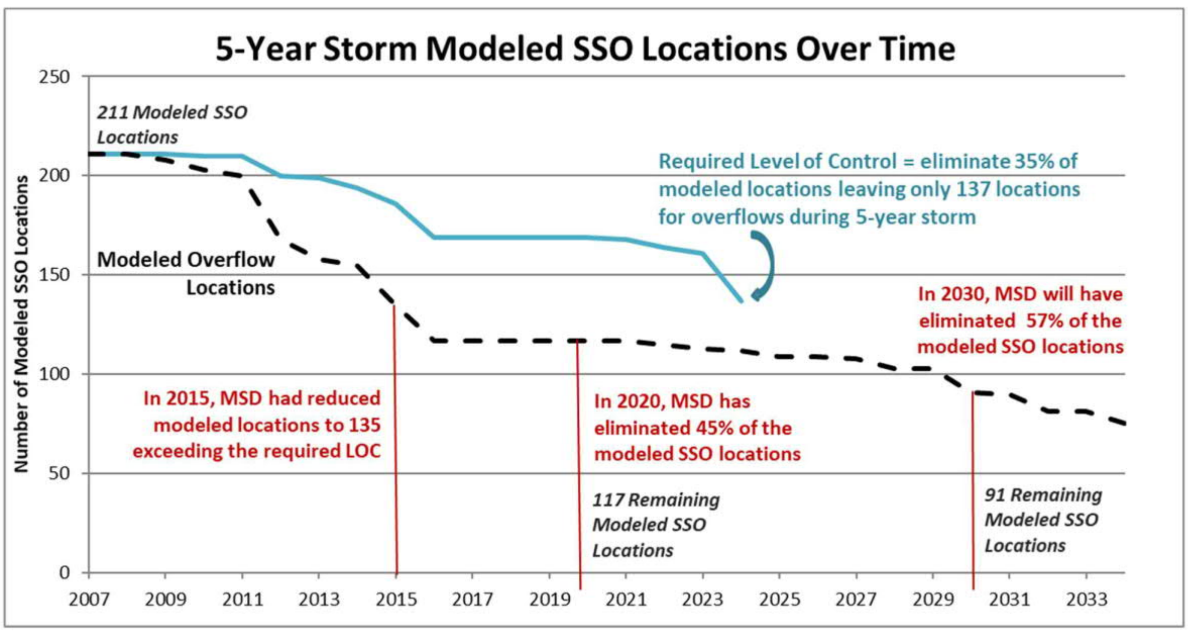

Figure ES.1.3-5 Five-Year Storm Modeled SSO Locations

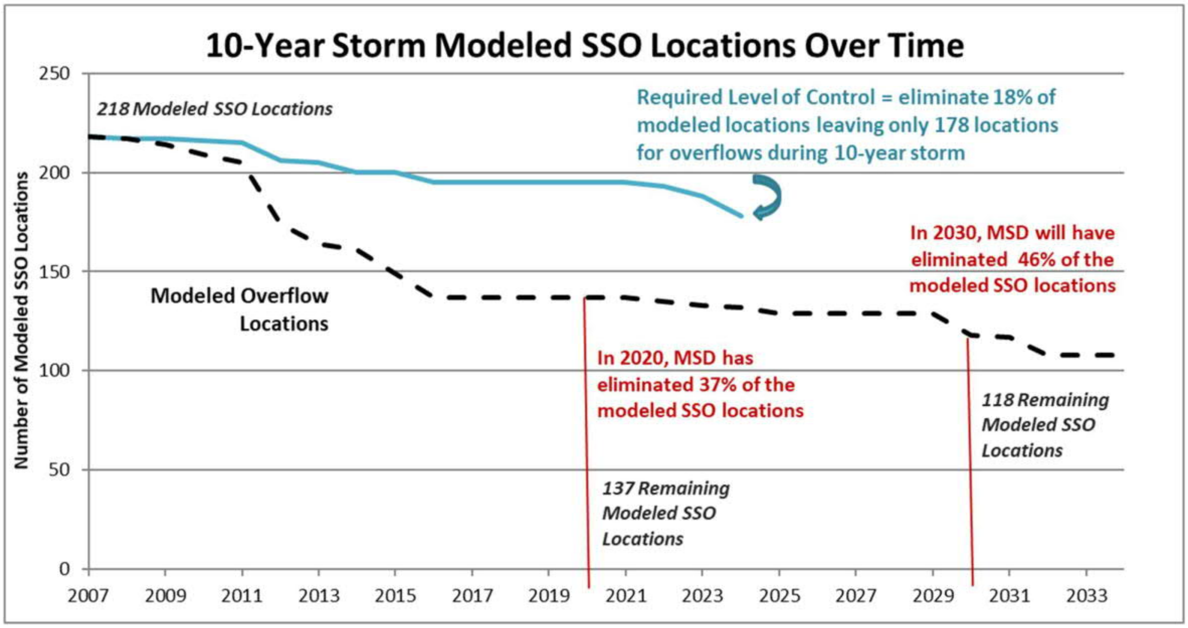

Figure ES.1.3-6 Ten-Year Storm Modeled SSO Locations

ES.1.3.3. ENVIRONMENTAL IMPACT OF MORRIS FORMAN WQTC

The Morris Forman WQTC is the largest wastewater treatment plant in the State and discharges an average of 100 MG per day of effluent. The plant treats combined sewage and discharges approximately 37 billion gallons of treated effluent annually. The wet weather capacity of the Morris Forman WQTC is 330 MGD when all treatment units are fully operational. The current condition and treatment capacity of the four Sedimentation Basins limits peak wet weather flow capacity to 240 MGD. MSD is currently designing improvements to the Sedimentation Basins that should restore peak treatment capacity to 330 MGD in 2026. Flows in excess of 240 MGD are discharged through CSOs. MSD completed model runs to assess the potential environmental impact of Morris Forman's reduced wet weather capacity.

MSD evaluated the modeled result for AAOV (annual average overflow volume) impacts to compare the environmental benefit of the UMF Phase 2 Project with the Morris Forman WQTC Sedimentation Basin Project.

- According to the model, the Upper Middle Fork Phase 2 Project mitigates approximately 45 MG of modeled CSO volume, in addition to the 2.6 MG of modeled SSO volume for the 2-year storm event.
- Having the capacity of the Morris Forman WQTC limited to 240 MGD, results in an increase of approximately 275 MG of additional AAOV.
- The additional 275 MG is primarily discharged through CSO015, CSO016, CSO191, CSO210, and CSO211.
- Therefore, the environmental impact with respect to total overflow volume of Morris Forman operating at capacity is approximately 6 times that of the UMF Phase 2 Project.

The Morris Forman WQTC Sedimentation Basin Rehabilitation Project is proposed to be added to the IOAP. Larger storm events require more capacity to treat greater flow volumes. Therefore, the environmental benefit of improving the Morris Forman WQTC outweighs the collection system benefit achieved by the UMF Phase 2 Project.

ES.1.3.4. ENVIRONMENTAL IMPACT OF PADDY'S RUN PUMP STATION

The environmental impact associated with reliable operation of the Paddy's Run Pump Station relates to 1) CSO mitigation and 2) community flood protection. The Bells Lane Wet Weather Treatment Facility has a capacity of 50 MGD. Without Bells Lane operating, CSO015 would discharge an additional 50 MGD every event for the duration of the event. However, when the Ohio River elevation is high, the Bells Lane Facility cannot operate unless the Paddy's Run Pump Station is operating. Failure of the Paddy's Run Pump Station would not allow CSOs to occur for events larger than the LOC event, resulting in combined sewage ponding in upstream residential areas, including streets, basements, and first floors.

In addition to CSO mitigation, there would be huge environmental implications if the Paddy's Run Pump Station were not fully operational during a high river or flood event. The 925 MGD Pump Station protects 214,500 people, 70,000 homes, 6,000 businesses, and 40 neighborhoods. The extent of land that would be impacted by the Paddy's' Run Station not operating as intended is shown in the inundation map provided in Figure ES.1.3-7. The map shows the results of modeling a breach in the system just north of Paddy's Run in 1937 flood conditions as determined by the USACE[1]

According to the US Department of Homeland Security[2], flooding in this area would impact the environment due to the industrial activity and the major petro-chemical industries within the Rubbertown area of Louisville. Critical chemical products such as calcium carbide (source of acetylene gas – Carbide Industries is the only manufacturer of carbide in North America), the sole source in the United States for binding materials used in solid rocket fuels (American Synthetic Rubber Company) and chlorinated polyvinyl chloride (CPVC) critical for manufacturing and construction industries in the United States. The facility managers noted a 1937-like flood at Rubbertown would result in significant loss of packaged inventory, catastrophic equipment loss, and unrecovered fixed costs for companies such as Dow Chemical, Hexion, American Synthetic Rubber Company, Arkema, Chemours, DuPont, Eckart, Carbide Industries, Zeon, Lubrizol and PolyOne.

The list of chemicals used by various industries within Rubbertown includes: Butadiene, Anhydrous Ammonia, Nitrogen, Calcium Carbide, Vinyl Fluoride, Anhydrous Hydrogen Fluoride, Difluoroethane, Hydrogen Fluoride, Hydrofluoric Acid, Chlorine, Chloroform, Aluminum Powder and Paste, Zinc Paste, Vinyl Acetate Monomer, Vinylidene Chloride, Vinyl Chloride, Phenol, Formaldehyde. If flood waters were to come in contact with these chemicals, the health and safety of the public would be affected in addition to the environment and quality of local waterways.

"[1]Preliminary Risk Characterization at Paddy's Run and Western Parkway Flood Pump Stations". TetraTech, June 30, 2017.
[2] "Resiliency Assessment, Louisville Metro Catastrophic Urban Flood Planning". The Regional Resiliency Assessment Program (RRAP). Department of Homeland Security, US Army Corps of Engineers (Louisville Metro Silver Jackets). 2019.

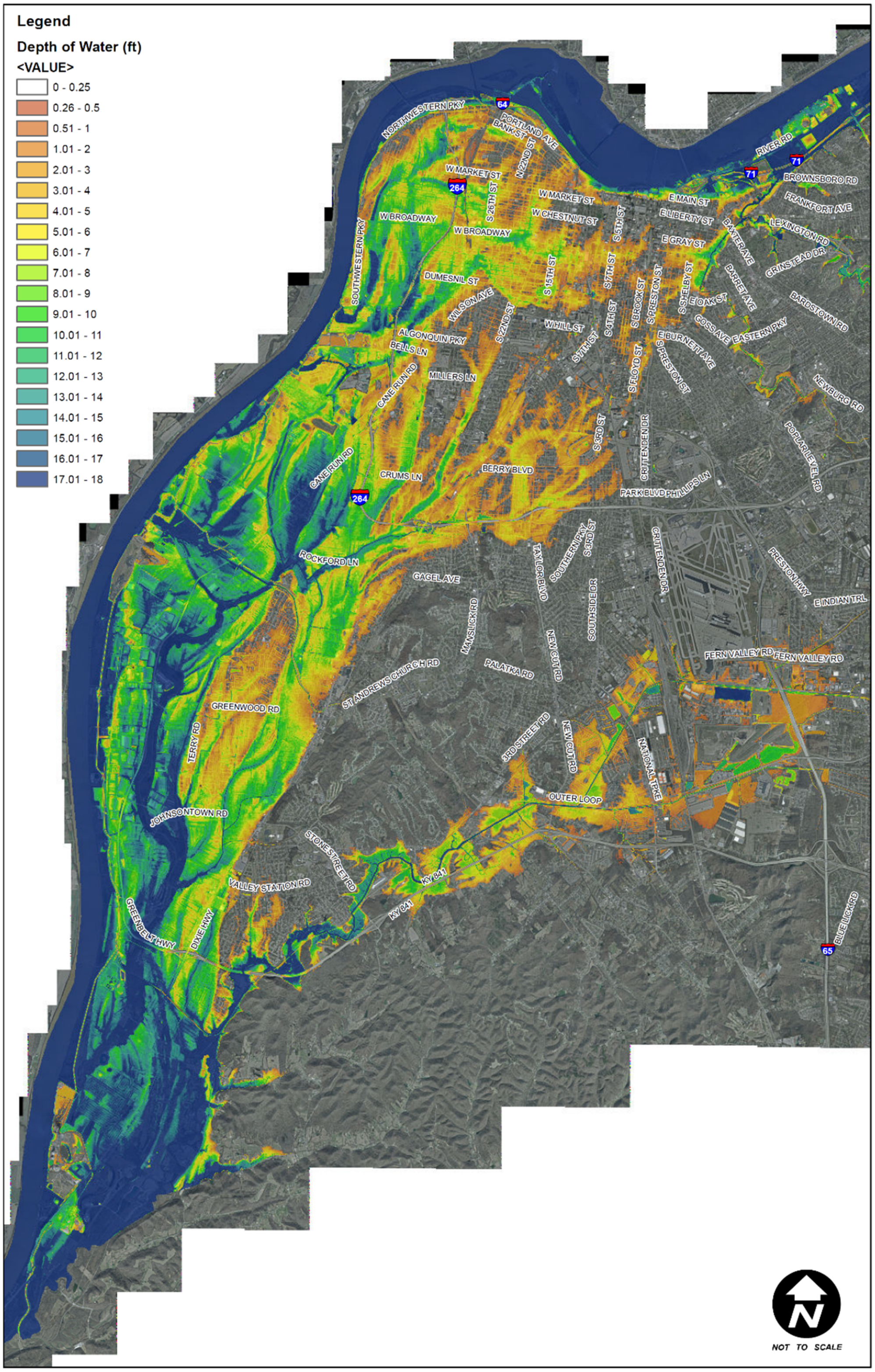

Figure ES.1.3-7 Inundation Map for 1937-Like Flood Condition Without Paddy's Run Pump Station

ES.1.3.5. ENVIRONMENTAL ANALYSIS CONCLUSION

Comparing the potential modeled volumes, suggests a greater environmental benefit is associated with the Morris Forman WQTC and Paddy's Run Pump Station projects as compared to the UMF Phase 2 Project for the following reasons:

Modeled Conditions:

- As of August 2020, MSD has eliminated 82% modeled SSO volume with only 3.73 MG remaining during the 2-year storm event.
- The SSOs are not continuous and their occurrence is solely driven by weather.
- The larger CSO modeled volume (275 MG) poses significantly more environmental impact than the smaller SSO modeled volume associated with the remaining SSDP projects (3.73 MG)

SSDP – UMF Phase 2 Project:

- The project will eliminate approximately 45 MG of modeled CSO volume (Typical Year) and 2.6 MG of modeled SSO volume (2-year storm) by 2030, just six years into the requested 10-year SSDP extension.
- Any SSOs associated with the UMF Phase 2 Project would be directed to Beargrass Creek (which discharges to the Ohio River upstream of the Morris Forman WQTC), which already has demonstrated an improved water quality compared to pre-IOAP conditions.

Morris Forman WQTC Project:

- The Morris Forman WQTC discharges approximately 100 MGD of effluent, equivalent to nearly 37 BG per year.
- The Morris Forman WQTC effluent will not comply with permit conditions for TSS and BOD until the new Biosolids Facility is constructed and on-line.
- The WQTC's limited capacity (240 MGD vs. 330 MGD) results in an additional 275 MG of modeled CSO volume during the Typical Year.

Paddy's Run Pump Station Project:

- The Bells Lane Wet Weather Treatment Facility cannot operate if the Ohio River it at high elevation and the Paddy's Run Pump Station is not operating as intended. This situation will result in an additional 50 MGD of overflow ultimately discharged to CSO015. Furthermore, the CSO discharge would be temporarily stored in streets, basements and potentially houses upstream until river floodwaters recede.
- The Pump Station protects 214,500 people, 70,000 homes, 6,000 businesses, and 40 neighborhoods from potential exposure to floodwaters containing industrial chemicals and combined sewage.

ES.1.4. INTEGRATED OVERFLOW ABATEMENT PLAN REPORT ORGANIZATION

As described previously, the IOAP is a three-volume document. Each volume details distinct aspects of the comprehensive program.

ES.1.4.1. VOLUME 1 – INTEGRATED OVERFLOW ABATEMENT PLAN

The first volume describes overarching, programmatic aspects that are common to all parts of the IOAP as well as the requirements, processes, and factors influencing the development of the Final LTCP (Volume 2) and Final SSDP (Volume 3).

- **Chapter 1 – Introduction**: The Introduction provides a general description of wet weather overflows; the history of the Consent Decree Amendments and IOAP Modifications; and the requirements of the Consent Decree. MSD's use of the Presumption Approach is highlighted in this Chapter.
- **Chapter 2 - IOAP Approach**: This chapter describes MSD's organizational vision and the watershed approach as it relates to the IOAP. Chapter 2 also describes the Waterway Improvements Now (Project WIN) program and elaborates on its strategic character. The IOAP's supporting methods, programs, and initiatives, including the role of community values in the values-based risk management process are detailed. This process provides input to the benefit/cost analysis that is the basis for the structured decision-making process used to evaluate and select which projects are priorities and will be implemented to achieve the IOAP goals.
- **Chapter 3 - Public Participation and Agency Interaction**: The Consent Decree requires that MSD assemble a Wet Weather Team (WWT) to, among other things, "develop a program for public information, education, and involvement." These three components are collectively referred to as public participation. Chapter 3 describes the role of the public participation program with engaging Louisville Metro's citizens to assist in developing, evaluating, and selecting the projects that comprise the IOAP. Chapter 3 also describes the ongoing public notification, education, and outreach program enhancements to maximize customer reach.
- **Chapter 4 - Integrated Overflow Abatement Program**: This chapter describes the overall action plan for addressing all the Consent Decree requirements. Included in these requirements is the Early Action Plan (EAP) implementation. The EAP includes an update of the compliance report for the Nine Minimum Controls (NMC) program, Sewer Overflow Response Protocol (SORP) revisions and implementation, completion of specified capital projects, and development and implementation of a CMOM program. In addition, the chapter includes an overview discussion of the development and implementation of the Interim LTCP, the Updated Sanitary Sewer Overflow Plan (SSOP), and the Interim SSDP. Many of these activities occurred in parallel to preparation of the IOAP, and in many cases, the implementation precedes completion of the IOAP; however, these activities are considered an integral part of the overall plan to achieve the required control of overflow and unauthorized discharges from the combined and sanitary sewer systems. Finally, Chapter 4 provides details related to the specific remedial projects and asset management program added to the IOAP via the Second ACD.
- **Chapter 5 - Regulatory Compliance**: This chapter describes the framework of regulatory requirements that the IOAP must satisfy in accordance with the Presumption Approach. This chapter also draws a roadmap showing how the IOAP achieves compliance with these regulations and creates an approvable LTCP and SSDP.

- **Chapter 6 - IOAP Implementation**: This chapter was replaced for the 2021 IOAP Modification. This chapter presents an implementation plan that outlines operational, financial, and post-construction compliance methodologies necessary to advance and sustain the recommendations of the IOAP. This chapter also addresses the impact of the IOAP capital and operating costs on MSD's rates.

ES.1.4.2. VOLUME 2 FINAL LTCP

The second volume of the IOAP focuses on the control and mitigation of the CSOs.

- **Chapter 1 – Introduction**: This chapter includes a history of EPA's Control Policy for CSOs and a summary of the policy's key elements. This chapter also provides general descriptions of the current CSO control efforts, control processes, and criteria for success.
- **Chapter 2 - System Characterization**: This chapter provides extensive analysis of CSO areas. Analysis includes existing baseline conditions of the CSO area, monitoring of CSO flows, CSO quality sampling, and combined modeling of the sewer system and receiving waters.
- **Chapter 3 - Development and Evaluation of Alternatives for CSO Control**: This chapter discusses the approach and factors used to identify, develop, evaluate, and select projects that make up the recommended projects and programs in the Final LTCP.
- **Chapter 4 - Selection of the Final CSO Long-Term Control Plan**: This chapter generally describes the procedures used to select the level of control, prioritize projects, and develop the Final LTCP. An overview describing LTCP progress to-date and modifications made is provided at the beginning of this chapter.
- **Note: In the 2012 IOAP, a Chapter 5** was included that provided a summary of project modifications to the IOAP between 2009 and 2012. The 2012 project modifications, in addition to schedule modifications as part of this submittal, have been incorporated into Chapters 3 and 4 of the 2021 Final LTCP. Therefore, Chapter 5 has been removed from the 2021 Final LTCP.

ES.1.4.3. VOLUME 3 FINAL SSDP

The third volume of the IOAP focuses upon control and mitigation of SSOs.

- **Chapter 1 – Introduction**: This chapter presents summaries of previous projects and programs and describes their relationship to the IOAP planning process. Previous projects and programs include the Updated SSOP, the CMOM program, the SORP, and the Interim SSDP. The final section of this chapter describes in general terms the approach used to evaluate the projects and programs of the 2021 Final SSDP.
- **Chapter 2 – System Characterization**: This chapter defines the goals of the system characterization program and provides an extensive compilation and analysis of unauthorized discharges in the SSS. This chapter includes service area maps of the unauthorized discharge areas, associated WQTCs, collection system modeling, and system monitoring. This chapter also includes a description of the computer models used to simulate the SSS areas.
- **Chapter 3 – Development and Evaluation of Alternatives for SSO Elimination**: This chapter presents the methodologies used to evaluate the various discharge elimination

solutions. It also defines and discusses strategies and technologies available to control and eliminate unauthorized discharges in the SSS. Based on these strategies and technologies, alternatives were developed for elimination of the unauthorized discharge. Finally, this chapter provides a summary of each discharge abatement alternative and the general basis for changes made to the initially selected measure(s) for projects through 2020. The evaluation criterion included feasibility screening, computer modeling, quality control, level of protection, cost estimates, and a benefit/cost analysis.

- **Chapter 4 – Selection of the Final Sanitary Sewer Discharge Plan**: This chapter includes an explanation of the values-based risk management process used to select and prioritize the Final SSDP alternatives. The final section examines the various issues associated with implementation of the alternative(s) selected as integral to the Final SSDP. Issues discussed include community values, benefit/cost analysis, environmental impact, technical concerns, prioritization of projects, and implementation schedules compatible with the Consent Decree requirements. This chapter presents a summary of the Final SSDP projects including changes made since 2009, project completion dates, technologies, and the level of protection.
- **Note: In the 2012 IOAP, a Chapter 5** was included that provided a summary of project modifications to the IOAP. The 2012 project modifications, in addition to schedule modifications as part of this submittal, have been incorporated into Chapters 3 and 4 of Volume 3. Therefore, Chapter 5 has been removed from the Final SSDP.

ES.1.5. 2021 IOAP MODIFICATIONS

A crosswalk summarizing the changes to all three IOAP volumes is provided Table ES.1.5-1.

- **Projects:** The status of the names LTCP and SSDP projects was updated including minor modification approval dates, project certification dates, and new requirements under the Second ACD.
- **New Information:** Information regarding the status of MSD's wastewater system has been updated throughout all the volumes to reflect current conditions as of December 31, 2020, where appropriate. Some information from the 2009 and 2012 documents remains to provide historical context related to the overall IOAP.
- **Presumption Approach:** Information was revised to clarify MSD is using the Presumption Approach for determining Consent Decree compliance.
- **Consolidated Information:** Information related to the Consent Decree history, public outreach/participation programs, and the Plumbing Modification Program was deleted from Volumes 2 and 3 and consolidated into Volume 1.

Table ES.1.5-1 2021 IOAP Modification Crosswalk

CRITERIA	DESCRIPTION	VOLUME 1 CHAPTERS OR SECTIONS	VOLUME 2 CHAPTERS OR SECTIONS	VOLUME 3 CHAPTERS OR SECTIONS	2012 IOAP SUBMITTAL	2021 IOAP MODIFICATION
Projects	Work Progress	Table 1.1-1 modifications	1.3.1.4 LTCP activities 4.1, LTCP revised dates Table 4.1-6 storage	1.1.1SSOP, ISSDP 2.2.1 WQTC Elims Table 4.0-1 projects	Work through 2012 was noted	Added summary of work performed 2009 - present
	Minor Project Modifications	Table ES1.1-3 Final LTCP Table ES1.1-6 Final SSDP 6.1 IOAP Schedule	Table 4.0-1 Appendix 4.0-1 Appendix 4.0-2	Table 4.0-1 Appendix 4.0-1 Appendix 4.0-2	Information was accurate through 2012.	Revised LTCP and SSDP tables to include all project modifications and provide copies of letter modifications and certifications.
	New Requirements	4.7 Second ACD requirements	Table ES1.1-3	Table ES1.1-6	N/A	New early action projects for Morris Forman WQTC and Paddy's Run Pump Station, Critical Interceptors, and Asset Management Program. LTCP & SSDP time extensions.
New Information Since 2012 IOAP Submittal	Clarified which information is from 2009, 2012, 2021	Multiple places throughout Chapters 1, 2, 3, 4, 5 and 6	Multiple places throughout Chapters 1, 2, 3, and 4. Information from the 2012 Chapter 5 was incorporated into Chapters 3 and 4.	Multiple places throughout Chapters 1, 2, 3, and 4. Information from the 2012 Chapter 5 was incorporated into Chapters 3 and 4.	Process and data remain valid and accurate. Chapter 5 was added for Volumes 2 and 3 in 2012.	New note added at the front of each chapter. Chapter 5 from Volumes 2 and 3 was deleted in 2021.
	Document Naming Nomenclature	1.1.6 Second ACD 1.4 CD requirements	1.1.2 Final LTCP	1.1.1 Final SSDP	N/A	The terms IOAP, Final LTCP, and Final SSDP refer to the 2021 versions. The amendments are referred to as the First ACD and Second ACD.

Table ES.1.5-1 2021 IOAP Modification Crosswalk

CRITERIA	DESCRIPTION	VOLUME 1 CHAPTERS OR SECTIONS	VOLUME 2 CHAPTERS OR SECTIONS	VOLUME 3 CHAPTERS OR SECTIONS	2012 IOAP SUBMITTAL	2021 IOAP MODIFICATION
	Progress since the 2012 IOAP Submittal	1.2 system information 1.1.5 minor modifications 2.2 water quality 3.5 current/future program 3.6.1 ACD reporting 3.6.2 regulatory meetings 4.1.4.2 fixed generators 4.1.4.3 revised SCAP 4.1.4.4 revised SORP 4.4. WQTC eliminations 4.5.1 source control 5.4 approvable Final LTCP 5.5 approvable Final SSDP 6.2 financial plan 6.3.1.1 rain gauge map	1.3.1.4 LTCP activities 1.3.4.2 ORSANCO 2.4.3.1 rain gauges 2.4.4 model 2.4.4.4 flow monitors 2.4.4.5 water quality 2.4.6.4 model 2.4.6.5 model 2.9.1 water quality 3.2.3.1 RTC Phase 1 3.2.5.9 dry well projects 3.2.5.10 green projects 4.1.2.1 green projects	1.3.2 CMOM Report 1.3.3 Hansen system 1.3.3 SORP 1.3.4 ISSDP 2.1.8 small WQTCs 2.2.3.1 flow monitoring 2.2.3.2. rain gauges 2.3.1. modeling 2.3.5.11 model 2.4.3 model regions 3.3 all tables 3.3.1.1 screening 3.3 benefit-cost analyses	Relevant information in 2012 Tables were labeled as outdated and referred to Volume 2, Chapter 5. In Volume 3, the tables in section 3.3 were updated or removed and the red screening box was removed that stated "SSDP information outdated refer to Chapter 5".	New information added to reflect work or pertinent information since the 2012 IOAP submittal
	Verb Tense	Multiple places throughout Chapters 1, 2, 3, 4, 5 and 6	Multiple places throughout Chapters 1, 2, 3, and 4	Multiple places throughout Chapters 1, 2, 3, and 4	No change to content	Verb changed to past tense for work that been performed
Presumption Approach	Clarification	3.7 effectiveness 5.1.1 key findings 5.2.1approaches 5.2.2, 5.2.3 water quality 6.3 compliance monitoring	2.9 receiving waters Chapter 3 Introduction 3.1.1 approach 4.4 measures of success	N/A	Both Presumption and Demonstration Approaches discussed	Added language clarifying the 2021 Final LTCP exceeds the requirements of the Presumption Approach. Deleted language not Presumption Approach.
Consolidated Information	Consent Decree Background	1.1 background	1.1 background	1.1.1 background	Background information was dispersed among three IOAP Volumes	Consolidated information from all volumes into Volume 1, Chapter 1
	Plumbing Modification Program	4.5.1 basement backups 4.5.2 private sources	1.3.1.2 LTCP Activities	1.3.1.4 PMP Program	Reduced text added reference to Volume 1	Consolidated information from all volumes into Volume 1, Chapter 4, section 4.5.1

Table ES.1.5-1 2021 IOAP Modification Crosswalk

CRITERIA	DESCRIPTION	VOLUME 1 CHAPTERS OR SECTIONS	VOLUME 2 CHAPTERS OR SECTIONS	VOLUME 3 CHAPTERS OR SECTIONS	2012 IOAP SUBMITTAL	2021 IOAP MODIFICATION
	Public Information	3.5 public program 3.7 customer survey 5.6 regulatory meetings	1.3.2 public participation 1.3.4 NMC-8 3.1.1.3 public participation 4.2 public participation	1.3.3.3 public notification, 4.3 public participation	Reduced text added reference to Volume 1	Consolidated information from volumes into Volume 1, Chapter 3, and expanded text for program through 2035.

A summary of the new projects incorporated into the Second ACD not part of the Final LTCP or Final SSDP are listed in Table ES.1.5-2.

Table ES.1.5-2 Summary of New Work Added to the Second ACD

PROJECT NAME AND IOAP ID	PROJECT DESCRIPTION	2021 TECHNOLOGY	2021 ESTIMATED COST	2021 SCHEDULE COMPLETION DATE
Morris Forman WQTC New Biosolids Facility *L_OR_MF_A*	Construct new thermal hydrolysis treatment process to be used in tandem with a combination of repurposed and new systems components.	Thermal Hydrolysis Process (THP)	$197,800,000	12/31/2030
Paddy's Run Pump Station Capacity Improvements *L_OR_MF_B*	Construction of a new 5,250, sq foot Pump Station rated at 1,900 MGD to replace the existing outdated facility.	New Pump Station	$115,000,000	12/31/2026
Buechel Trunk Sewer Rehabilitation *C_SF_MF_B*	Rehabilitation of approximately 20,500 feet of 12-inch to 30-inch sewers.	Sewer Lining & Point Repair	$3,000,000	12/31/2026
Harrods Creek Force Main Repair *C_HC_HC_A*	Repair of 3,200 feet of 18-inch to 30-inch force main.	Sewer Lining & Point Repair	$8,400,000	12/31/2026
Prospect Phase II Area Sewers Rehabilitation *C_HC_HC_B*	Rehabilitation of approximately 2,000 feet of 6-inch to 15-inch sewers.	Sewer Lining & Point Repair	$3,000,000	12/31/2026
Broadway Interceptor Infrastructure Rehabilitation *C_OR_MF_A*	Rehabilitation of approximately 5,4000 feet of 84-inch to 96-inch sewers.	Sewer Lining & Point Repair	$10,000,000	12/31/2026
I-64 and Grinstead Infrastructure Rehabilitation C_MI_MF_A	Rehabilitation of approximately 13,700 feet of 8-inch to 123-inch sewers.	Sewer Lining & Point Repair	$16,000,000	12/31/2026
Large Diameter Sewer Rehabilitation *C_OR_MF_B*	Program including the inspection, pre-design services, design work to the 60% design level and construction phase professional services.	Sewer Lining & Point Repair	$8,300,000	12/31/2026
Rudd Ave Sewer Infrastructure Rehabilitation *C_OR_MF_C*	Rehabilitation of approximately 4,020 feet of 120-inch to 138-inch sewers,	Sewer Lining & Point Repair	$2,300,000	12/31/2026
Western Outfall Infrastructure Rehabilitation *C_OR_MF_D*	Rehabilitation of approximately 18,350 feet of 108-inch to 141-inch sewers.	Sewer Lining & Point Repair	$16,000,000	12/31/2026
Nightingale Sewer Rehabilitation *C_SF_MF_A*	Rehabilitation of approximately 49,500 feet of 6-inch to 18-inch sewers.	Sewer Lining & Point Repair	$3,000,000	12/31/2026
Strategic Asset Management Plan (SAMP) *C_DW_DW_A*	Submittal of a draft plan outlining how MSD will prioritize and perform asset management.	Report	N/A	06/30/2021
Asset Management Program FY21 – FY25 *C_DW_DW_B*		Various	$125,000,000	12/31/2025

PROJECT NAME AND IOAP ID	PROJECT DESCRIPTION	2021 TECHNOLOGY	2021 ESTIMATED COST	2021 SCHEDULE COMPLETION DATE
Asset Management Program FY26 – FY30 *C_DW_DW_C*	Improvements to existing WQTC, Pump Station, Flood Pump Station, sewers, and related assets serving the wastewater system.	Various	$125,000,000	12/31/2030
Asset Management Program FY31 – FY35 *C_DW_DW_D*		Various	$125,000,000	12/31/2035

Notes regarding IOAP Naming Nomenclature *First Letter_Second Grouping_Third Grouping_ Fourth Grouping*

- First letter represents the Program: L = LTCP; S = SSDP; C = combined LTCP & SSDP
- Second grouping of letters represents the major basin the project is located in: CC = Cedar Creek; DW = District-Wide; FF = Floyds Fork; GC = Goose Creek; HC = Harrods Creek; MC = Mill Creek; MI = Middle Fork Beargrass Creek; MU = Muddy Fork Beargrass Creek; OR = Ohio River; PE = Pennsylvania Run; PO = Pond Creek; SF = South Fork Beargrass Creek
- Third grouping of letters represents the wastewater treatment plant that receives the flow from the project sewers: CC = Cedar Creek WQTC; DW = District-Wide; FF = Floyds Fork WQTC; HC = Hite Creek WQTC; MF = Morris Forman WQTC; WC = West County (DRG) WQTC
- Fourth grouping of letters represents a unique identifier to differentiate between projects of the same project that are located in the same basin and WQTC. These letters begin with “A” and continue as needed.

ES.1.5.1. IOAP 2021 MODIFICATION TO VOLUME 1

The revisions incorporated into Volume 1 of the IOAP provide context for the Second ACD finalized in 2021. In some places, the order which background information was presented was revised to be chronological. The 2021 updates and programmatic compliance status related to the Final LTCP are summarized herein.

- **Current System Information**: Information regarding the status of MSD's wastewater system has been updated to reflect current conditions as of December 31, 2020 where appropriate throughout all chapters.
- **Historical Context**: Some information from the 2009 and 2012 documents remains to provide historical context related to the overall IOAP. A crosswalk summarizing the Volume 1 changes between the 2012 and 2021 IOAP documents was provided in Table 1.0-1.
- **Water Quality**: As acknowledged in the ACD, bacteria levels have decreased in the Ohio River and Beargrass Creek since the IOAP was started according to ORSANCO and MSD wet weather sampling data.
- **Public Participation & Agency Interaction**: Since 2015, MSD's Community Engagement Strategy has been expanded for significant capital projects, enhancing advertising and marketing strategies, developing social media platform messaging, ramping up earned media opportunities, pursuing additional education programs and partnerships, and overall re-branding to promote safe, clean waterways. A foundational component of the future program will be one of continuous improvement, striving to ultimately advance customer behavior objectives of the IOAP.
- **Regulatory Reporting**: MSD shall submit to the Cabinet and EPA a Mid-Year Status Report summarizing the first 6 months of its fiscal year, July 1st through December 31st. The Mid-Year Status Report summarizing the final 6 months of the fiscal year will be captured as a component of the Annual Report as set forth below. The first Mid-Year Status Report shall be submitted by February 28, 2022 and will reoccur annually by February 28th of each year. MSD shall submit an Annual Report for the preceding fiscal year period of July 1st through June 30th by September 30th of each year.
- **Comprehensive Performance Evaluation**: Each of the small WQTCs that had SSOs in their watersheds were eliminated as part of MSD's long-term strategic plan to eliminate small WQTCs in its service area. Expansion of the Derek R. Guthrie WQTC to 60 MGD average day and 300 MGD peak day (for short durations) was completed in 2018 and the State approved is rerating in 2020. Similarly, expansion of the Floyd's Fork WQTC to 6.5 MGD was completed in 2012. The Hite Creek WQTC is under construction to expand its capacity to 9 MGD ADF and 24 MGD peak flow. Construction is scheduled for completion in FY22.
- **Plumbing Modification Program**: Since the program's inception, MSD has completed over 17,992 projects totaling approximately $21.7 million dollars. The countywide program is now available to all MSD customers experiencing basement backups. MSD will pay up to $4,000 per residence for plumbing modifications. Generally, installations average about $2,500.
- **Specific Remedial Projects and Programs**: A new Section 4.7 was added to Chapter 4 to document the work MSD agreed to incorporate into the Second ACD related to the Morris

Forman WQTC New Biosolids Facility, Paddy's Run Pump Station Capacity Upgrade, Critical Interceptors Projects, and the Asset Management Program.

- **Morris Forman WQTC New Biosolids Facility**: MSD will construct a modern biosolids processing facility at the Morris Forman WQTC that utilizes a thermal hydrolysis pretreatment process (THP) to create a useable biogas. Benefits of the new facility include improved effluent quality; production of 4 MW of power; decreased consumption of natural gas; and reduced landfill utilization capacity. This project will be substantially complete no later than December 31, 2030.
- **Paddy's Run Pump Station Capacity Upgrade**: MSD will construct a new 5,250 sq foot pump station rated at 1,900 MGD, install the associated discharge piping system over the existing levee to a new outfall structure on the Ohio River, and demolish the existing pump station. This project will be substantially complete no later than December 31, 2026.
- **Morris Forman WQTC Sedimentation Basins Rehabilitation**: The Morris Forman WQTC is limited to a max wet weather flow of 240 MGD due to capacity constraints with the sedimentation basins. When the four sedimentation basins have been fully rehabilitated, they will enable the WQTC to process up to 330 MGD. This will reduce the level of pollutants discharged into the Ohio River. This project will be substantially complete no later than December 31, 2026 as required in the Agreed Order with the State. This project is not part of the Second ACD but is referenced given its relevance to restoring wet weather treatment capacity to the Morris Forman WQTC.
- **Critical Interceptors Projects**: MSD has agreed to complete nine critical sewer rehabilitation projects totalling an estimated $70 during FY21 through FY25 (by December 31, 2026).
- **Asset Management (AM) Program**: MSD agreed to invest an average of $25M per fiscal year on wastewater AM improvements totaling no less than $125M in five-year increments through 2035. As such, MSD will invest $125M from FY21 to FY25 for existing wastewater collection system and WQTC assets; $125M from FY26 to FY30; and $125M from FY31 to FY35. This time frame coincides with the time extension granted for the remaining SSDP projects. MSD will document annual and 5-year progress in its Consent Decree Annual Report. MSD will submit its Strategic Asset Management Plan to the Regulators no later than June 30, 2021.
- **Presumption Approach**: The Presumption Approach requires a program to meet any of the following three criteria: elimination or capture for treatment of 85 percent of the combined sewer flow generated during a wet weather event; allow no more than an average of four overflows per year; or a reduction of not less than the mass of pollutants that were identified as causing water quality impairments. The 2021 IOAP will be compliant with the Presumption Approach.
- **Financial Plan**: MSD updated the information in Volume 1, Chapter 6, Section 6.2 to reflect current financial criteria as of December 31, 2020 including the 5-year CIP forecast for FY21 through FY25.

ES.1.5.2. LTCP 2021 MODIFICATION TO VOLUME 2

The second volume describes MSD's planning approach and implementation of the 25 LTCP projects. The revisions incorporated into Volume 2 of the IOAP provide context for Second ACD. In some places, the order which background information was presented was revised to be chronological. The 2021 updates and programmatic compliance status related to the Final LTCP are summarized herein.

- **Second ACD**: The initial Final LTCP initially included 28 gray projects and 19 green demonstration projects. Through the adaptive management process 27 of the 28 gray projects were modified. Some projects were consolidated, and others were split into multiple projects. The result was 25 Final LTCP projects, of which MSD has certified completion for 24. The Waterway Protection Tunnel remains under construction and will be completed by December 31, 2022. All green demonstration projects were constructed by MSD.
- **Current System Information**: Information regarding the status of MSD's wastewater system has been updated to reflect current conditions as of December 31, 2020 where appropriate throughout all chapters.
- **Historical Context**: Some information from the 2009 and 2012 documents remains to provide historical context related to the overall IOAP. A crosswalk summarizing the Volume 2 changes between the 2012 and 2021 IOAP documents was provided in Table 1.0-1.
- **Public Participation**: Information regarding MSD's public outreach and participation programs was deleted from Volume 2, Chapters 3 and 4, and updated and consolidated into Volume 1, Chapter 3.
- **Ohio River Water Quality Monitoring**: MSD continues to receive Ohio River water quality data from ORSANCO. During the contact recreation season, ORSANCO regularly samples for E-coli and fecal coliforms. On a weekly basis ORSANCO samples for river conditions and E-coli. On a bimonthly basis, ORSANCO samples for various water quality parameters to evaluate attainment of established water quality criteria. Every two years, ORSANCO completes the Ohio River Water quality Conditions 305(b) Report to confirm the river is of sufficient quality for its intended uses. Every ten years, ORSANCO evaluates water quality trends including ecological conditions. Information and result of ORSANCO's water quality programs is found at www.ORSANCO.org.
- **Beargrass Creek Water Quality Monitoring**: MSD continues to collect water quality samples from 16 sites along Beargrass Creek. MSD staff compiled bacteria and flow data collected near the Big 4 sites used to compute Event Mean Concentrations (EMCs) for 4 wet weather sample events: October 2010; September 2013; July 2014; and June 2017. It was determined that the June 2017 event too much antecedent rain to be considered a qualifying event.
- **Flow Monitoring:** MSD has greatly expanded its long-term flow monitoring network, including monitors on the combined sewer outfalls. MSD has been utilizing data from this network to recalibrate the hydrologic and hydraulic models used to size overflow abatement projects and refine individual project approaches and sizes based on an improved understanding of the sewer system operation and the relationship of certain overflows to one another.
- **In-Stream Monitoring**: MSD's program has an extensive in-stream monitoring effort for tributary streams and emergency spill responses, including ambient monitoring at 28 Long Term Monitoring Network (LTMN) locations across Jefferson County to monitor multiple physical and biological parameters in accordance with the MS4 permit. Recreational contact monitoring is conducted seasonally from May through October at 27 of the 28 ambient monitoring sites for E. coli.

- **Green Infrastructure**: Through December 2020, MSD has completed all green infrastructure demonstration projects as well the other green infrastructure program elements, totaling nearly $42 million for an incremental system benefit. MSD's commitment to capture and treat or remove 95 percent of the systemwide CSO volume exceeds the requirements of the CSO Policy Presumption Approach. Additional or future green infrastructure projects are not necessary to achieve the required LOC. The approach presented throughout Chapter 3 to develop and implement the program remains accurate.
- **System Storage**: Through December 2020, MSD had constructed or developed 126 MG of system storage. The Phase 1 Real Time Control Program provided a total of 41 MG of this storage. The remainder of the storage volume was attributed to the basins listed in Table 4.1-6, or additional RTC/ILS projects. By December 2022, the Waterway Protection Tunnel will provide an additional 52 MG of system storage. Upon completion of the LTCP, MSD will have 178 MG of total storage available to help manage wet weather.

ES.1.5.3. SSDP 2021 MODIFICATION TO VOLUME 3

The third volume describes MSD's planning approach and implementation of the 60 Sanitary Sewer Discharge Plan (SSDP) projects. The revisions incorporated into Volume 3 of the IOAP provide context for Second Amended Consent Decree (ACD) negotiated in 2021. In some places, the order which background information was presented was revised to be chronological. The 2021 updates and programmatic compliance status related to the Final SSDP are summarized herein.

- **Second ACD**: The Final SSDP initially included 60 projects. Through the adaptive management process, three projects have bene deleted. Of the 57 Final SSDP projects, 41 have been completed and 16 projects remain (refer to Table ES.1.1-6 respectively). The dates for completing the remaining SSDP projects were extended to 2025, 2030, or 2035. and Table ES.1.1-7
- **Current System Information**: Project modifications due to improved system characterization data, hydraulic model recalibration and other changed conditions are described in Chapters 3 and 4 to reflect current 2021 conditions.
- **Historical Context**: Some information from the 2009 and 2012 documents remain to provide historical context related to the overall IOAP. A crosswalk summarizing the Volume 3 changes between the 2012 and 2021 IOAP documents was provided in Table 1.0-1 of Volume 3.
- **Public Participation**: Information regarding MSD's public outreach and participation programs was deleted from Volume 3, Chapters 1 and 4, and updated and consolidated into Volume 1, Chapter 3.
- **Sanitary Sewer Overflow Plan (SSOP)**: MSD prepared and submitted the Updated Sanitary Sewer Overflow Plan (SSOP) on February 10, 2006. Activities required under the Updated SSOP have been completed.
- **Plumbing Modification Program (PMP):** Information regarding the PMP was deleted from Volume 3, Chapter 1 and updated and consolidated into Volume 1, Chapter 4, Section 4.5.1.
- **Capacity, Management, Operations, and Maintenance (CMOM) Program**: The CMOM Self-Assessment Report was submitted to EPA and KDEP on February 10, 2006. MSD

received a letter of approval on August 22, 2006. Although the program implementation deadlines from the CMOM Self-Assessment Report were previously met, MSD continues to enhance the activities. Highlights of the CMOM program implementation are provide annually in the Consent Decree Annual Report.

- **Sewer Overflow Response Protocol (SORP):** MSD initially submitted the Sewer Overflow Response Protocol (SORP) to EPA and KDEP on February 10, 2006, received comments on March 13, 2006, resubmitted on May 12, 2006 and received an approval letter for the SORP on August 22, 2006. MSD completely revised the SORP in 2011. Final approval of the updated SORP document was received February 21, 2012. Modifications were made to the document in 2016 to reflect the elimination of the Jeffersontown WQTC and were approved on July 21, 2017.
- **Interim Sanitary Sewer Discharge Plan (ISSDP)**: MSD submitted an Interim Sanitary Sewer Discharge Plan (ISSDP) for approval on September 30, 2007. Comments were received on January 8, 2008. MSD resubmitted the revised ISSDP on March 7, 2008 and received an approval letter for the ISSDP on July 24, 2008. All projects required by the ISSDP have been completed and certified.
- **Elimination of Small WQTCs**: During the development of the 2009 IOAP, MSD operated fifteen small WQTCs in addition to six regional plants. All fifteen of the small WQTCs, and one regional WQTC, have been eliminated and the flow has been rerouted to MSD's regional WQTCs.
- **Flow Monitoring**: As of December 2020, MSD has approximately 35 meters installed in long-term locations and 60 temporary meters that can be moved to validate/calibrate targeted areas of specific models. These values will continue to fluctuate as new meters are purchased and older meters are retired, but MSD is committed to maintaining a sufficient quantity of meters to monitor large system changes and reviewing targeted areas in detail.
- **Rain Gauge Network**: MSD has since expanded its rain gauge network, and rainfall data is gathered at 46 rain gauge sites. Some of the sites are outside of MSD's service area to better predict incoming rain events and to analyze rainfall patterns.
- **Rainfall Derived Infiltration/Inflow**: Since the 2009 IOAP, RDI/I have been evaluated in areas where rehabilitation was targeted. In some cases, rehab successfully reduced the RDI/I substantial amounts, and in other cases reductions were less successful. Prior to final design of an SSDP project, models are calibrated to their current condition, and future RDI/I reduction is removed from the model for final project sizing.
- **Hydraulic Models**: In 2010, each model was updated, and calibration was verified, and the results were used in the 2012 SSDP. Since the 2012 SSDP, each modeled area is generally reviewed every two years to determine if an update to the model is necessary. Models in rapidly growing areas are sometimes updated more frequently.

Table ES.1.1-3 Final LTCP Projects Including Project Modifications

	FINAL LTCP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 CSO(S) CONTROLLED & LEVEL OF CONTROL	2009 TECHNOLOGY AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 CSO(S) CONTROLLED & LEVEL OF CONTROL	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 CSO(S) CONTROLLED & APPROVED LEVEL OF CONTROL	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
1	CSO108 Dam Modification, *L_SO_MF_108_S_09A_B_A_4*	Beargrass Creek South Fork	4 overflows per TY for CSO 108	CSO Structure Improvements	$150,000	2010	4 overflows per TY for CSO 108	CSO Structure Improvements	No Change	No Change	2018. Project remains the same, based on additional calibration of the hydraulic model, the level of control was changed from 4 to 8 overflows per Typical Year.	8 overflows per TY for CSO 108	CSO Structure Improvements	$107,600	2010
2	Adams Street Sewer Separation (*formerly Storage Basin*), *L_OR_MF_172_S_09B_B_A_0*	Ohio River	0 overflows per TY for CSO 172	0.12 MG Storage Basin	$983,000	2012	0 overflows per TY for CSO 172	Sewer Separation	$20,000	2012	2012. Sewer separation replaced 0.12 MG storage basin. Upon inspection of the sewer system, all but two catch basins were separated already during recent redevelopment. MSD completed remaining separations.	0 overflows per TY for CSO 172	Sewer Separation	$92,300	2012
3	CSO 123 Downspout Disconnection, *L_MI_MF_123_S_08*	Beargrass Creek Middle Fork	CSO 123	Downspout Disconnection	$315,000	2012	No Change	Downspout Disconnection	No Change	No Change	No Change	CSO 123	Downspout Disconnection	Costs included under Green Program	2012
4	34th Street Flood Pump Station DWO Elimination, *L_OR_MF_019_S_03_A_B*	Ohio River	CSO019	Flow Control	$541,000	2012	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$646,000	2012
5	4th Street Flood Pump Station DWO Elimination, *L_OR_MF_022_M_03_A_A*	Ohio River	CSOs 022, 023	Flow Control	$944,000	2012	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$986,400	2012
6	27th Street Flood Pump Station DWO Elimination, *L_OR_MF_019_S_03_A_A*	Ohio River	CSO019	Flow Control	$476,000	2013	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$726,700	2013
7	Shawnee Flood Pump Station DWO Elimination, *L_OR_MF_189_M_03_A_A*	Ohio River	CSOs 104, 105, 189	Flow Control	$411,000	2013	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$1,065,100	2013
8	CSO 206 Sewer Separation, *L_MI_MF_206_S_08_A_A_0*	Beargrass Creek Middle Fork	CSO 206	Sewer Separation	$3,842,000	2013	No Change	Sewer Separation	No Change	No Change	No Change	0 overflows per TY for CSO 206	Sewer Separation	$577,300	2013
9	CSO058 In-Line Storage & Green Infrastructure, *L_OR_MF_058_S_08_A_A_0*	Ohio River	0 overflows per TY for CSO 058	Sewer Separation	$1,361,000	2014	8 overflows per TY for CSO 058	Sewer Separation	No Change	No Change	2014, 2020. In 2014 project changed to weir modifications to address surcharging in lieu of ineffectual sewer separation. In 2020 project incorporated into 13th & Rowan remedy.	8 overflows per TY for CSO 058	Sewer Separation	Costs included in Waterway Protection Tunnel LTCP Project #25	2014
10	17th Street Flood Pump Station DWO Elimination, *L_OR_MF_190_S_03_A_A*	Ohio River	CSO 190	Flow Control	$625,000	2014	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$756,500	2014
11	CSO140 In-Line Storage & Green Infrastructure Controls, *L_MI_MF_140_S_08_A_A_0*	Beargrass Creek Middle Fork	0 overflows per TY for CSO 140	Sewer Separation	$3,150,000	2015	0 overflows per TY for CSO 140	CSO Structure Improvements	$574,000	2015	2012. Reconstructed the CSO structure to increase the low flow line to a 42-inch diameter opening which increased the conveyance capacity in lieu of sewer separation.	0 overflows per TY for CSO 140	CSO Structure Improvements	$54,700	2015

Table ES.1.1-3 Final LTCP Projects Including Project Modifications

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12	CSO160 In-Line Storage & Green Infrastructure, *L_OR_MF_160_S_08_A_A_0*	Ohio River	0 overflows per TY for CSO 160	Sewer Separation	$237,000	2015	0 overflows per TY for CSO 160	In-Line Storage and Sewer Separation	$231,000	2015	2012. In-line storage provided by a combination of raising the existing overflow weir and installing 88 feet of 72-inch diameter pipe.	0 overflows per TY for CSO 160	In-Line Storage and Sewer Separation	$248,200	2015
13	CSO093 Structural Modifications & Green Infrastructure, *L_SO_MF_093_S_08_A_A_0*	Beargrass Creek South Fork	0 overflows per TY for CSO 093	Sewer Separation	$952,000	2015	0 overflows per TY for CSO 093	CSO Structure Improvements	$488,000	2015	2012. Reconstruction of the CSO structure replaced the existing leaping weir with a more conventional overflow weir in lieu of sewer separation.	0 overflows per TY for CSO 093	CSO Structure Improvements	$1,693,200	2015
14	Story Avenue & Spring Street Green Infrastructure (*formerly Storage Basin*), *L_SO_MF_130_S_09B_B_A_8*	Beargrass Creek South Fork	8 overflows per TY for CSO 130	0.01 MG Storage Basin	$1,077,000	2016	8 overflows per TY for CSO 130	Green Projects	$896,000	2016	2012. Construction of a suite of green infrastructure projects in lieu of the storage basin.	8 overflows per TY for CSO 130	Green Projects	$1,070,000	2016
15	CSO190 Green Infrastructure Solution (*formerly 18th & Northwestern Pkwy Storage Basin*), *L_SO_MF_190_S_09B_B_A_8*	Ohio River	8 overflows per TY for CSO 190	1.31 MG Storage Basin	$4,514,000	2017	8 overflows per TY for CSO 190	1.24 MG Storage Basin	$5,039,000	2017	2015. Green infrastructure solutions for CSO 190 replaced the storage basin at 18th and Northwestern Parkway.	8 overflows per TY for CSO 190	Green Infrastructure	$6,418,200	2017
16	Bells Lane Wet Weather Treatment Facility *(formerly Paddy's Run)*, *L_OR_MF_015_M_13_B_B_8*	Ohio River	8 overflows per TY for CSO 015, 191	50 MGD Treatment Facility	$24,940,000	2014	8 overflows per TY for CSO 015, 191	50 MGD Treatment Facility, 25 MG Storage via Real Time Control Optimization of Main Diversion Structure	$68,472,000	2016	2012, 2016. Optimization of flow through Morris Forman's Main Diversion Structure and MSD's Real Time Control strategy added storage volume. Additional time for construction was requested due to size increase, moving the site, offline storage, and integration of Southwestern Pump Station. Changed completion deadline from December 31, 2016 to September 30, 2017.	8 overflows per TY for CSOs 015 and 191	50 MGD Treatment Facility, 25 MG Storage via Real Time Control Optimization of Main Diversion Structure	$51,761,000	2017
17	Nightingale Pump Station Replacement & Storage, *L_SO_MF_018_S_03_A_A*	Beargrass Creek South Fork	0 overflows per TY for CSO 018	60 MGD Pump Station, 0 MG Storage	$15,710,000	2016	0 overflows per TY for CSO 0180 overflows per TY for CSO 018	33 MGD Pump Station with 7.7 MG Storage	$22,123,000	2016	2012, 2016. In 2012 reduced pumping capacity from 60 MGD to 33 MGD and added a 7.7 MG Storage Basin. In 2016, changed completion deadline from December 31, 2016 to June 30, 2017.	0 overflows per TY for CSO 018	33 MGD Pump Station with 7.7 MG Storage	$38,032,000	2017
18	Logan & Breckenridge Street Storage Basin, *L_SO_MF_092_M_09B_B_D_8* *(includes former Beargrass Creek Parallel Interceptor Project)* *(includes former Calvary - Creekside Storage Basin Project)*	Beargrass Creek South Fork	8 overflows per TY for CSOs 091, 113, 117, 146, 149, 152	Logan 11.83 MG Basin Calvary 3.46 MG Basin Combined 15.29 MG	Logan $30,320,000 Calvary $13,720,000 Combined $44,040,000	2017	8 overflows per TY for CSOs 091, 097, 106, 110, 111, 113, 117, 137, 146, 148, 149, 151, 152	Calvary Creekside Basin & Beargrass Parallel Interceptor eliminated and consolidated with 16.6 MG storage at the Logan Street Basin	$48,243,000	2018	2016. Technical functionality of project remained the same. Modified project to bury the basin and allow community-accessible open space above it.	8 overflows per TY for CSOs 091, 097, 106, 110, 111, 113, 117, 137, 146, 148, 149, 151, 152	16.6 MG Storage Basin	$92,821,600	2017

Table ES.1.1-3 Final LTCP Projects Including Project Modifications

	FINAL LTCP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 CSO(S) CONTROLLED & LEVEL OF CONTROL	2009 TECHNOLOGY AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 CSO(S) CONTROLLED & LEVEL OF CONTROL	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 CSO(S) CONTROLLED & APPROVED LEVEL OF CONTROL	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
19	Southern Outfall In-Line Storage at 43rd Street (SOR1) (*formerly Algonquin Parkway Storage Basin*), *L_OR_MF_211_M_13_B_A_8*	Ohio River	*former project subsequently eliminated and replaced in 2012: 8 overflows per TY for CSO 016, 210, 211*	*former project subsequently eliminated and replaced in 2012: 4.84 MG Storage Basin*	*former project subsequently eliminated and replaced in 2012: $17,300,000*	*former project subsequently eliminated and replaced in 2012: 2018*	8 overflows per TY for CSO 016, 210, 211	11.4 MG In-Line Storage	$3,544,000	2018	2012. Optimized operating rules between the Bells Lane Wet Weather Treatment Facility and the Morris Forman WQTC's Main Diversion Structure demonstrated that only inline storage was needed at SOR1 and SOR2. Eliminated the Algonquin storage basin portion of the project.	8 overflows per TY for CSOs 016, 210. 211	11.4 MG In-Line Storage	$2,999,500	2018
20	Central Relief Drain CSO In-Line Storage, Green Infrastructure & Distributed Storage, *LOR_MF_155_M_09B_B_B_4-1*	Ohio River	N/A	N/A	N/A	N/A	8 overflows per TY for CSOs 028, 029, 034, 036, 178, 181, 193, 195, 196, 197, 199, 200X, 202	Diversion, Weir Modifications, Green Infrastructure	$2,184,000	2020	2012. Project was added to the IOAP in order to split the Central Relief Drain work from the 13th Street & Rowan Project.	8 overflows per TY for CSOs 028, 029, 034, 036, 178, 181, 193, 195, 196, 197, 199, 200X, 202	Diversion, Weir Modification, Green Infrastructure	$569,572	2018
21	Morris Forman WQTC Headworks Improvements *(formerly Algonquin Parkway Storage Basin and formerly SOR2), L_OR_MF_160_S_08_A_A_0*	Ohio River	*former project subsequently eliminated and replaced in 2012: 8 overflows per TY for CSO 016, 210, 211*	*former project subsequently eliminated and replaced in 2012: 4.84 MG Storage Basin*	*former project subsequently eliminated and replaced in 2012: $17,300,000*	*former project subsequently eliminated and replaced in 2012: 2018*	8 overflows per TY for CSOs 016, 210, 211	In-Line Storage at two locations SOR1, SOR2	$3,544,000	2018	2012. In 2012, eliminated SOR2 project and replaced with flow control improvements at the Main Diversion Structure and rehabilitation of Morris Forman WQTC Headworks in order to increase maximum sustainable treatment capacity to 330 MGD.	8 overflows per TY for CSOs 016, 210, 211	Flow Control, Treatment Improvement	$13,175,805	2018
22	Clifton Heights Storage Basin, *L_MU_MF_154_M_09B_B_A_8*	Beargrass Creek Muddy Fork	8 overflows per TY for CSOs 132, 154, 167	6.55 MG Storage Basin	$13,870,000	2018	4 overflows per TY for CSOs 132, 154, 167	4.28 MG Storage Basin	$14,166,000	2018	2012, 2014. In 2012 revised basin from 6.55 MG to 4.28 MG and level of control from 8 overflows per Typical Year to 4. In 2014, revised basin size to 7.0 MG.	4 overflows per TY for CSOs 088, 131, 132, 154, 167	7.0 MG Storage Basin	$33,390,500	2018
23	Portland CSO Basin, *L_OR_MF_019_S_13_B_A_8*	Ohio River	8 overflows per TY for CSO 019	6.37 MG Storage Basin	$20,000,000	2019	No Change	6.37 MG Storage Basin	No Change	No Change	2015. Increased basin size from 6.37 MG to 6.7 MG. The larger size does not reduce CSO occurrences significantly but does provide a reduced residual AAOV.	8 overflows per TY for CSO 019	6.7 MG Storage Basin	$37,894,500	2019

Table ES.1.1-3 Final LTCP Projects Including Project Modifications

<table>
<tr><th colspan="3">FINAL LTCP PROJECT NAME AND IOAP ID</th><th>RECEIVING STREAM</th><th>2009 CSO(S) CONTROLLED & LEVEL OF CONTROL</th><th>2009 TECHNOLOGY AND SIZE</th><th>2009 COST ESTIMATE</th><th>2009 FINISH DATE</th><th>2012 CSO(S) CONTROLLED & LEVEL OF CONTROL</th><th>2012 TECH AND SIZE</th><th>2012 COST ESTIMATE</th><th>2012 FINISH DATE</th><th>MODIFICATION APPROVAL YEAR AND DESCRIPTION</th><th>2021 CSO(S) CONTROLLED & APPROVED LEVEL OF CONTROL</th><th>2021 TECH AND SIZE</th><th>2021 COST ESTIMATE</th><th>2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR</th></tr>
<tr><td>24</td><td colspan="2">Southwestern Parkway Storage Basin, L_OR_MF_105_M_13_B_A_0</td><td>Ohio River</td><td>0 overflows per TY for CSOs 104, 105, 189</td><td>5.08 MG Storage Basin</td><td>$17,620,000</td><td>2018</td><td>0 overflows per TY for CSOs 104, 105, 189</td><td>11.07 MG Storage Basin</td><td>$30,937,000</td><td>2018</td><td>2012, 2015, 2018. In 2012, increased basin size form 5.08 MG to 11.07 MG. In 2015, increased basin size from 11.07 MG to 20 MG, with a level of control of 8 overflows per Typical Year and no net system-wide increase in AAOV. In 2018, Revised project deadline to June 30, 2019 and corrected inline storage volume submitted with 2015 minor modification fact sheet to 6.3 MG.</td><td>8 overflows per TY for CSOs 104, 105, 189</td><td>20 MG Storage basin, 6.3 MG In-Line Storage</td><td>$80,623,100</td><td>2019</td></tr>
<tr><td rowspan="4">25</td><td rowspan="4">Waterway Protection Tunnel</td><td>(formerly I-64 & Grinstead CSO Basin), L_MI_MF_127_M_09B_B_A_8)</td><td>Beargrass Creek Middle Fork</td><td>8 overflows per TY for CSOs 125, 126, 127, 166</td><td>2.74 MG Storage Basin</td><td>$12,950,000</td><td>2014</td><td>4 overflows per TY for CSOs 125, 126, 127, 166</td><td>8.5 MG Storage Basin + Storm water Diversions</td><td>$48,591,000</td><td>2020</td><td rowspan="4">2012, 2015, 2016, 2018.In 2012, basins sizes were adjusted based on re-calibration. In 2015, basin sizes were adjusted as part of Basin Balancing Modification. In 2016, revised design to a 31.8 MG tunnel solution that consolidates CSO controls for 13th Street and Rowan Street, Story Avenue and Main Street, and Lexington and Payne Street Storage Basins.
In 2018, changed project name to “Waterway Protection Tunnel” and revised design to a 52.2 MG tunnel solution that consolidates CSO controls for Ohio River Tunnel and I-64 & Grinstead Drive Storage Basin.</td><td rowspan="4">8 overflows per TY for CSOs 020, 022, 023, 050, 051, 052, 053 ,054, 055, 056, 058, 062, 150, 155
4 overflows per TY for CSOs 125, 126, 127, 166
0 overflows per TY for CSOs 082, 083, 084, 118, 119, 120, 121, 141, 153</td><td rowspan="4">52.2 MG CSO Storage Tunnel</td><td rowspan="4">$253,401,700</td><td rowspan="4">2022</td></tr>
<tr><td>(formerly 13th Street & Rowan Street Storage Basin), L_OR_MF_155_M_09B_B_B_4)</td><td>Ohio River</td><td>4 overflows per TY for CSOs 022, 023, 050, 051, 052, 053 ,054, 055, 056, CRD, 150, 155</td><td>14.44 MG Storage Basin</td><td>$49,680,000</td><td>2020</td><td>8 overflows per TY for CSOs 022, 023, 050, 051, 052, 053 ,054, 055, 056, 058, 150, 155</td><td>4.36 MG Storage Basin</td><td>$27,863,200</td><td>2020</td></tr>
<tr><td>(formerly Story Avenue & Main Street Storage Basin), L_OR_MF_020_S_09B_B_A_8)</td><td>Ohio River</td><td>8 overflows per TY for CSO 020</td><td>0.13 MG Storage Basin</td><td>$1,580,000</td><td>2013</td><td>8 overflows per TY for CSO 020</td><td>5.42 MG Storage Basin</td><td>$12,576,000</td><td>2020</td></tr>
<tr><td>(formerly Lexington Road & Payne Street Storage Basin), L_SO_MF_083_M_09B_B_A_8)</td><td>Beargrass Creek South Fork</td><td>8 overflows per TY for CSOs 082, 084, 118, 119, 120, 121,141, 153</td><td>7.31 MG Storage Basin</td><td>$25,200,000</td><td>2020</td><td>0 overflows per TY for CSOs 082, 084, 118, 119, 120, 121,141, 153</td><td>8.18 MG Storage Basin</td><td>$25,904,000</td><td>2020</td></tr>
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Table ES.1.1-6 Final SSDP Projects Including Project Modifications

	FINAL SSDP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2009 TECH AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 SSO(S) ELIMINATED & APPROVED LEVEL OF PROTECTION	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
CEDAR CREEK AREA															
1	Running Fox PS Elimination *S_CC_CC_MSD1080_S_01-C*	Little Cedar Creek	2-yr, 3-hr storm for MSD1080-LS	Flow Diversion	$99,000	2023	No change	Flow Diversion	$59,700	2023	No change	2-yr, 3-hr storm for MSD1080-LS	Flow Diversion	$59,700	2010
2	Fairmount Rd PS Off-line Storage *S_FF_CC_81316_M_03_C_A*	Big Run	N/A	N/A	N/A	N/A	2-yr, 3-hr storm for 81316, 97362	Off-Line Storage	$13,439,000	2015	2012. Project added to send the flows from eliminated Jeffersontown WQTC to the Cedar Creek WQTC.	2-yr, 3-hr storm for 81316, 97362	Off-Line Storage	$14,753,500	2015
3	Idlewood Inline Storage *S_CC_CC_70158_M_09A_C*	Cedar Creek	2-yr, 3-hr storm for 28998, 28984, 63094, 63095, 70158	Inline Storage	$2,921,000	2023	No change	Inline Storage	$2,317,000	2023	2021.Revised completion date to December 31, 2025.	2-yr, 3-hr storm for 28998, 28984, 63094, 63095, 70158	Inline Storage	$4,087,400	2025
4	Bardstown Rd PS Improvements *S_CC_CC_MSD1025_S_03_B*	Big Run	5-yr, 3-hr storm for 88545	PS Upgrade	$401,000	2021	No change	PS Upgrade	$401,000	2021	2021.Revised completion date to December 31, 2030.	5-yr, 3-hr storm for 88545	PS Upgrade	$3,400,000	2030
5	Little Cedar Creek Interceptor Improvements *S_CC_CC_67997_M_01_C*	Little Cedar Creek	2-yr, 3-hr storm for 67997, 67999, 86423, 86424, 89195, 89196, 89197	Pipe Upgrades	$2,921,000	2024	No Change	Pipe Upgrades	$2,921,000	2024	2021.Revised completion date to December 31, 2025. Future. Modeling on-going, project may be eliminated.	2-yr, 3-hr storm for 67997, 67999, 86423, 86424, 89195, 89196, 89197	Pipe Upgrades	$2,400,000	2025
HITE CREEK AREA															
6	Floydsburg Rd SSES, Rehabilitation and PS Upgrade *S_HC_HC_MSD1086_M_07_C_A*	Floyds Fork, South Fork Harrods Creek	2-yr, 3-hr for MSD1086-PS, 90776, 108956, 108957, 108958	I/I Reduction	$59,000	2016	No change	I/I Reduction	$59,000	2010	No change	2-yr, 3-hr for MSD1086-PS, 90776, 108956, 108957, 108958	I/I Reduction	$50,200	2010
7	Meadow Stream PS & Force Main Upgrade *S_HC_HC_MSD1082_S_09A_C*	Floyds Fork	2-yr, 3-hr storm for 91087, MSD1082-PS	0.5 MG Storage Basin	$1,198,000	2010	10-yr, 3-hr storm for 91087, MSD1082-PS	3.89 MGD PS, new 18-inch FM	$1,011,900	2012	2012. Project changed from small storage basin to PS upgrade and new FM due to capacity needs of Crestwood. Changed LOC from 1.82 inch to 2.6 inch.	10-yr, 3-hr storm for 91087, MSD1082-PS	3.89 MGD PS, new 18-inch FM	$1,011,900	2012
8	Kavanaugh Rd PS Improvements *S_HC_HC_MSD1085_S_03_A*	Hite Creek	10-yr, 3-hr storm for MSD1085-PS	PS & FM Upgrades	$1,729,000	2024	No change	PS & FM Upgrades	$1,729,000	2024	2021.Revised completion date to December 31, 2025.	10-yr, 3-hr storm for MSD1085-PS	PS & FM Upgrades	$4,300,000	2025
FLOYDS FORK AREA															
9	Woodland Hills PS Diversion *S_FF_FF_NB01_S_01_C_A*	Pope Lick	2-yr, 3-hr storm for 33003, 65531	Flow Diversion	$21,000	2011	No change	Flow Diversion	$19,400	2011	No change	2-yr, 3-hr storm for 33003, 65531	Flow Diversion	$19,400	2010
10	Eden Care PS SSO Investigation *S_FF_FF_NB02_S_13_C*	Floyds Fork	N/A storm for Eden Care PS (MSD1105-PS)	Monitoring	N/A	2012	N/A	Monitor	N/A	2012	2012. One overflow documented at this location. MSD cleaned sewers in the vicinity and had no documented overflows for more than 3 years.	N/A	Monitoring Complete	N/A	2012

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11	Ashburton PS Improvements and Diversion *S_FF_FF_NB03_M_01_C_A*	Floyds Fork	2-yr, 3-hr storm for Olde Copper Court PS (MSD0165-PS), Ashburton PS (MSD0166-PS)	FM & Pipes Upgrade	$168,000	2021	No change	FM & Pipes Upgrade	$30,300	2009	No change	2-yr, 3-hr storm for Olde Copper Court PS (MSD0165-PS), Ashburton PS (MSD0166-PS)	FM & Pipes Upgrade	$30,300	2009
JEFFERSONTOWN AREA															
12	Jeffersontown WQTC Elimination *S_JT_NB01_M_01_C_A*	Chenoweth Run	2-yr, 3-hr storm for 28390, 28391, 28392, 28395, 28551, 31733, Jeffersontown WQTC (28173, 64505, MSD0255, ISO28-SI)	Offline Storage, Pipe Upgrades, WQTC Eliminations	$28,386,000	2015	No change	Offline Storage, Pipe Upgrades, WQTC Eliminations	$38,773,700	2015	2010. Modified elimination plan to move new PS to Municipal Yard and divert portion of service area to Cedar Creek WQTC.	2-yr, 3-hr storm for 28390, 28391, 28392, 28395, 28551, 31733, Jeffersontown WQTC (28173, 64505, MSD0255, ISO28-SI)	Offline Storage, Pipe Upgrades, WQTC Eliminations	$38,773,700	2015
13	Chenoweth Hills WQTC Elimination and PS Improvements *S_JT_JT_NB01A_M_03_C*	Chenoweth Run	2-yr, 3-hr storm for Chenoweth Run PS (MSD0196-PS, 86052, 64096), Chenoweth WQTC PS (MSD0263A-PS), Chenoweth Hills WQTC (MSD0263)	Flow Diversion, WQTC Eliminations	$3,749,000	2015	No change	Flow Diversion, WQTC Eliminations	$3,749,000	2015	2015. Eliminated Pump Stations and WQTC via gravity to Cedar Creek.	2-yr, 3-hr storm for Chenoweth Run PS (MSD0196-PS, 86052, 64096), Chenoweth WQTC PS (MSD0263A-PS), Chenoweth Hills WQTC (MSD0263)	Flow Diversion, WQTC Eliminations	$3,011,700	2015
14	Dell Rd & Charlane Parkway Interceptor *S_JT_JT_NB02_M_01_C*	Beatty Brook	2-yr, 3-hr storm Charlane Pkwy (28250, 28249, 28340, 28336, 104289,) Dell Rd (28413, 28414, 28415, 28416, 28417)	Pipe Upgrades	$1,347,000	2022	No Change	Pipe Upgrades	$1,347,000	2022	2021.Revised completion date to December 31, 2030.	2-yr, 3-hr storm Charlane Pkwy (28250, 28249, 28340, 28336, 104289,) Dell Rd (28413, 28414, 28415, 28416, 28417)	Pipe Upgrades	$8,800,000	2030
15	Raintree and Marian Court PS Eliminations Phase 1 *S_JT_JT_NB03_M_01_C*	Beatty Brook	2-yr, 3-hr storm for Marian Ct PS (28729), Raintree PS (MSD0149-PS)	Flow Diversion	$371,000	2021	2-yr, 3-hr storm for Marian Ct PS (28729), Raintree PS (MSD0149-PS)	Flow Diversion	$371,000	2021	2021.Revised completion date to December 31, 2025.	2-yr, 3-hr storm for Marian Ct PS (28729), Raintree PS (MSD0149-PS)	Flow Diversion	$165,700	2025
16	Raintree and Marian Court PS Eliminations Phase 2 *S_JT_JT_NB03_M_01_C*		2-yr, 3-hr storm for 28719, 28711	Pipe Upgrades	$1,062,000	2021	2-yr, 3-hr storm for 28719, 28711	Pipe Upgrades	Cost combined with Phase 1	2021	2021.Revised completion date to December 31, 2030. Future: Lag in schedule allows flow monitoring for Phase 1 PS eliminations.	2-yr, 3-hr storm for 28719, 28711	Pipe Upgrades	$1,800,000	2030
17	Monticello PS Elimination *S_JT_JT_NB04_M_01_A*	Fern Creek	10-yr, 3-hr storm for Monticello Place PS (MSD0151-PS, 27969)	Flow Diversion	$304,000	2022	10-yr, 3-hr storm for Monticello Place PS (MSD0151-PS, 27969)	Flow Diversion	$207,000	2022	2021.Revised completion date to December 31, 2025. Future: Flow monitoring and calibration underway – project may not be necessary.	10-yr, 3-hr storm for Monticello Place PS (MSD0151-PS, 27969)	Flow Diversion	$464,000	2025

Table ES.1.1-6 Final SSDP Projects Including Project Modifications

	FINAL SSDP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2009 TECH AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 SSO(S) ELIMINATED & APPROVED LEVEL OF PROTECTION	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
MIDDLE FORK AREA															
18	Middle Fork Relief Interceptor, Wet Weather Storage, Upper Middle Fork LS Diversion Phase 1: Buechel Basin *S_MISF_MF_NB01_M_01_C_A1*	Middle Fork Beargrass Creek	2-yr, 3-hr storm for 02932, 02932, 02933, 02935, 08537, 23211, 23212, 27005, 51221, 51160, 51161, 45835, 47583, 47593, 47596, 47603, 47604, 90700, IS021A-SI, 08935-SM	Storage Basin	$15,170,000	2023	No Change	Storage Basin	$33,684,200	2013	No Change	2-yr, 3-hr storm for 02932, 02932, 02933, 02935, 08537, 23211, 23212, 27005, 51221, 51160, 51161, 45835, 47583, 47593, 47596, 47603, 47604, 90700, IS021A-SI, 08935-SM	Storage Basin	$33,684,200	2013
19	Middle Fork Relief Interceptor, Wet Weather Storage, Upper Middle Fork LS Diversion Phase 2: UMFLS & Relief Interceptor *S_MISF_MF_NB01_M_01_C_A1*			1.6 MG Offline Storage, PS & FM Upgrades	$19,889,000	2023	No Change	1.6 MG Offline Storage at UMFLS, PS & FM Upgrades	$19,889,000	2023	2018. Replaced offline storage at UMFLS with new 30 MGD PS at UMF Site. 2021.Revised completion date to December 31, 2030.		New 30 MGD PS, Pipe & FM Upgrades	$86,408,000	2030
20	Goose Creek PS Improvements and Wet Weather Storage Phase 1: Devondale PS *S_MI_MF_NB04_M_03_B*	Goose Creek	5-yr, 3-hr storm 46891, 62418, 91629, 91630, 10593, 43472, 21628-W	Offline Storage, PS & FM Upgrades	$2,775,000	2023	No Change	Offline Storage, PS & FM Upgrades	$2,775,000	2016	2015. Combined project with Bancroft WQTC elimination. Moved storage and PS to Bancroft site instead of Devondale PS.	5-yr, 3-hr storm 46891, 62418, 91629, 91630, 10593, 43472, 21628-W	Offline Storage, PS & FM Upgrades	$5,242,800	2016
21	Goose Creek PS Improvements and Wet Weather Storage Phase 2: Goose Creek PS Improvement *S_MI_MF_NB04_M_03_B*			PS & FM Upgrades	$1,676,000	2023	No Change	PS & FM Upgrades	$1,676,000	2023	2021.Revised completion date to December 31, 2035.		PS & FM Upgrades	$6,978,600	2035
22	Anchor Estates PS Elimination Phase 1: Anchor PS Elimination *S_MI_MF_NB06_M_01_A_A_1*	Middle Fork Beargrass Creek	10-yr, 3-hr storm for 0056-W, 00746, MSD0057-LS	Flow Diversion	$66,000	2016	No Change	Flow Diversion	$66,000	2016	No Change	10-yr, 3-hr storm for 0056-W, 00746, MSD0057-LS	Flow Diversion	$83,200	2016
23	Anchor Estates PS Elimination Phase 2: Vannah Way PS Elim. *S_MI_MF_NB06_M_01_A_A_1*		10-yr, 3-hr storm for 01106	, Flow Diversion	$2,275,000	2011	No Change	, Flow Diversion	$3,878,900	2011	No Change	10-yr, 3-hr storm for 01106	, Flow Diversion	$3,878,900	2011
24	Hurstbourne I/I Investigation & Rehabilitation *S_MI_MF_NB07_S_07_C*	Hurstbourne Creek	2-yr, 3-hr storm for 01793	I/I Reduction	$569,000	2011	No Change	I/I Reduction	$773,200	2011	No Change	2-yr, 3-hr storm for 01793	I/I Reduction	$773,200	2011
SOUTHEASTERN DIVERSION AREA															
25	Parkview Estates I/I Investigation & Rehabilitation *S_SD_MF_NB03_S_07_C*	South Fork Beargrass Creek	2-yr, 3-hr storm for 47250	I/I Reduction	$302,000	2011	No Change	I/I Reduction	$29,600	2011	No Change	2-yr, 3-hr storm for 47250	I/I Reduction	$29,600	2011
26	Klondike Interceptor *S_SD_MF_NB04_S_01_B_A*	South Fork Beargrass Creek	5-yr, 3-hr storm for 25676, 26650, 26651	Pipe Upgrades	$666,000	2014	No Change	Pipe Upgrades	$2,231,000	2014	No Change	5-yr, 3-hr storm for 25676, 26650, 26651	Pipe Upgrades	$2,231,000	2014
27	Sutherland Interceptor *S_SD_MF_NB05_M_01_A*	South Fork Beargrass Creek	10-yr, 3-hr storm for 16649	Pipe Upgrades	$623,000	2023	10-yr, 3-hr storm for 16649	Pipe Upgrades	$623,000	2023	2021.Revised completion date to December 31, 2030.	10-yr, 3-hr storm for 16649	Pipe Upgrades	$1,065,300	2030
28	Beargrass Interceptor Rehabilitation Phase 2 *S_SD_MF_NB06_S_13_C*	South Fork Beargrass Creek	2-yr, 3-hr storm for 51594	Pipe Rehabilitation	$59,000	2010	2-yr, 3-hr storm for 51594	Pipe Rehabilitatio n	$29,700	2010	No Change	2-yr, 3-hr storm for 51594	Pipe Rehabilitatio n	$29,700	2010
POND CREEK AREA															

Table ES.1.1-6 Final SSDP Projects Including Project Modifications

	FINAL SSDP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2009 TECH AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 SSO(S) ELIMINATED & APPROVED LEVEL OF PROTECTION	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
29	Charleswood Interceptor Extension *S_PO_WC_PC03_M_01_C*	Fishpool Creek	2-yr, 3-hr storm 25477, 25478, 25480, MSD0130-PS	Pipe Upgrades	$886,000	2015	2-yr, 3-hr storm 25477, 25478, 25480, MSD0130-PS	Pipe Upgrades	$1,213,400	2015	No Change	2-yr, 3-hr storm 25477, 25478, 25480, MSD0130-PS	Pipe Upgrades	$1,213,400	2015
30	Cinderella PS Elimination *S_PO_WC_PC04_M_01_C*	Fishpool Creek	2-yr, 3-hr storm 60679, MSD1013-PS, 35309	Flow Diversion	$3,395,000	2025	2-yr, 3-hr storm 60679, MSD1013-PS, 35309	Flow Diversion	$1,500,000	2025	2021.Revised completion date to December 31, 2025.	2-yr, 3-hr storm 60679, MSD1013-PS, 35309	Flow Diversion	$1,500,000	2025
31	Lantana PS I/I Investigation & Rehabilitation *S_PO_WC_PC05_M_07_C*	Pennsylvania Run	2-yr, 3-hr storm 25484, 93719, MSD0101-PS	I/I Reduction	$21.000	2011	2-yr, 3-hr storm 25484, 93719, MSD0101-PS	Investigation Complete	$164,000	2011	No Change	2-yr, 3-hr storm 25484, 93719, MSD0101-PS	Investigation Complete	$164,000	2011
32	Government Center PS Elimination *S_PO_WC_PC06_M_01_C*	Pennsylvania Run	10-yr, 3-hr storm for MSD0180-PS	Flow Diversion	$1,909,000	2011	10-yr, 3-hr storm for MSD0180-PS	Flow Diversion	$353,600	2011	No Change	10-yr, 3-hr srm for MSD0180-PS	Flow Diversion	$353,600	2011
33	Avanti PS Elimination *S_PO_WC_PC07_M_01_A*	Little Cedar Creek	2-yr, 3-hr storm for 21229-W	Flow Diversion	$32,000	2009	2-yr, 3-hr storm for 21229-W	Flow Diversion	$32,000	2009	No Change	2-yr, 3-hr storm for 21229-W	Flow Diversion	$32,000	2009
34	Lea Ann Way System Improvements *S_PO_WC_PC08_M_01_C*	Fern Creek	2-yr, 3-hr storm 19360, 19369, 29933, 29948, 29943, 31083, 31084, 79076, MSD1010-PS	Pipe Upgrades	$987,000	2015	2-yr, 3-hr storm 19360, 19369, 29933, 29948, 29943, 31083, 31084, 79076, MSD1010-PS	Pipe Upgrades	$4,863,900	2015	2012. Combined SSES projects and performed additional sewer inspection and rehabilitation.	2-yr, 3-hr storm 19360, 19369, 29933, 29948, 29943, 31083, 31084, 79076, MSD1010-PS	Pipe Upgrades	$4,863,900	2015
35	Caven Ave PS Elimination & Offline Storage Phase 1: Caven Ave PS Elimination *S_PO_WC_PC09_M_09B_C*	Fishpool Creek	2-yr, 3-hr storm for 27116, MSD0133-PS	Offline Storage	$1,672,000	2016	2-yr, 3-hr storm for 27116, MSD0133-PS	Flow Diversion	$2,923,000	2016	2012. Elimination of nearby WQTC allowed for PS elimination instead of offline storage.	2-yr, 3-hr storm for 27116, MSD0133-PS	Flow Diversion	$2,923,000	2016
E	Caven Ave PS Elimination & Offline Storage Phase 2: Outer Loop Storage *S_PO_WC_PC09_M_09B_C*		2-yr, 3-hr storm for 70212, 17724	Offline Storage	Cost combined with Phase 1	N/A	2-yr, 3-hr storm for 70212, 17724	Project Eliminated	N/A	N/A	2012. Project eliminated due to new flow monitoring and model re-calibration.	2-yr, 3-hr storm for 70212, 17724	Project Eliminated	N/A	N/A
36	Leven PS Elimination *S_PO_WC_PC10_M_01_C*	Pennsylvania Run	2-yr, 3-hr storm for 36419, MSD1019-PS	Flow Diversion	$352,000	2022	2-yr, 3-hr storm for 36419, MSD1019-PS	Flow Diversion	$352,000	2022	2021.Revised completion date to December 31, 2025.	2-yr, 3-hr storm for 36419, MSD1019-PS	Flow Diversion	$720,000	2025
37	Edsel PS I/I Investigation & Rehabilitation *S_PO_WC_PC11_M_07_C*	Fern Creek	2-yr, 3-hr storm for 92098, MSD1048-PS	I/I Reduction	$389,000	2011	2-yr, 3-hr storm for 92098, MSD1048-PS	I/I Reduction	$1,289.800	2011	No Change	2-yr, 3-hr storm for 92098, MSD1048-PS	I/I Reduction	$1,289.800	2011
OHIIO RIVER FORCE MAIN (ORFM) AREA															
38	Mellwood System Improvements, PS Eliminations, Phase 1: Mellwood PS *S_OR_MF_NB01_M_01_B*	Muddy Fork Beargrass Creek	5-yr, 3-hr storm 26752, 41374, 41416, MSD0007-PS, MSD0010-PS, 24472, MSD0023-PS, 24152-W, MSD0024-PS	PS Replacement	$2,369,000	2012	5-yr, 3-hr storm 26752, 41374, 41416, MSD0007-PS, MSD0010-PS, 24472, MSD0023-PS, 24152-W, MSD0024-PS	Flow Diversion, PS and Pipe Upgrades	$2,369,000	2012	No Change	5-yr, 3-hr storm 26752, 41374, 41416, MSD0007-PS, MSD0010-PS, 24472, MSD0023-PS, 24152-W, MSD0024-PS	PS Replacement	$3,275,800	2012
39	Mellwood System Improvements, PS Eliminations, Phase 2: Mockingbird Valley & Winton PS *S_OR_MF_NB01_M_01_B*			Flow Diversion, PS and Pipe Upgrades	$1,302,000	2024		Flow Diversion, PS and Pipe Upgrades	$1,302,000	2024	2021.Revised completion date to December 31, 2030.		Flow Diversion, PS and Pipe Upgrades	$2,516,100	2030

Table ES.1.1-6 Final SSDP Projects Including Project Modifications

	FINAL SSDP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2009 TECH AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 SSO(S) ELIMINATED & APPROVED LEVEL OF PROTECTION	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
40	Leland Road SSO Investigation *S_OR_MF_NB02_A_13_C*	Cherrywood Creek	N/A storm for 96020	Condition Assessment	N/A	N/A	N/A	Condition Assessment	N/A	N/A	2012. One overflow documented at this location. MSD cleaned sewers in the vicinity and had no documented overflows for more than 3 years.	N/A	Assessment Completed	N/A	2012
41	Derington Ct. PS I/I Investigation & Rehabilitation *S_OR_MF_NB03_S_07_C*	Goose Creek	2-yr, 3-hr storm for MSD0095-PS	I/I Reduction	$290,000	2012	2-yr, 3-hr storm for MSD0095-PS	I/I Reduction	N/A	2012	No Change	2-yr, 3-hr storm for MSD0095-PS	I/I Reduction	Included in FY12 I/I Budget	2012
42	Prospect WQTC Elimination, Harrods Creek PS, ORFM System Improvements Phase 1: WQTC Eliminations *S_OR_MF_NB04_M_3_B_B*	Little Goose Creek	5-yr, 3-hr storm 40870, 40871, 40872, 42680, 65633, 65635, 22436, MSD0123-PS, MSD1044-PS, MSD0183-PS, MSD0192-PS, MSD0193-PS, MSD1063-PS, MSD0292	WQTC Elimination	$34,062,000	2015	5-yr, 3-hr storm 40870, 40871, 40872, 42680, 65633, 65635, 22436, MSD0123-PS, MSD1044-PS, MSD0183-PS, MSD0192-PS, MSD0193-PS, MSD1063-PS, MSD0292	WQTC Elimination	$34,062,000	2015	No Change	5-yr, 3-hr storm 40870, 40871, 40872, 42680, 65633, 65635, 22436, MSD0123-PS, MSD1044-PS, MSD0183-PS, MSD0192-PS, MSD0193-PS, MSD1063-PS, MSD0292	WQTC Elimination	$1,941,900	2015
43	Prospect WQTC Elimination, Harrods Creek PS, ORFM System Improvements Phase 2: HCPS & FM *S_OR_MF_NB04_M_3_B_B*			PS and Pipe Upgrades		2015		PS and Pipe Upgrades		2015	No Change		PS and Pipe Upgrades		2015
44	Prospect WQTC Elimination, Harrods Creek PS, ORFM System Improvements Phase 3: ORFM System Improvements *S_OR_MF_NB04_M_3_B_B*			Flow Diversion, PS and Pipe Upgrades		2016		Flow Diversion, PS and Pipe Upgrades		2016	2015. Replaced Muddy Fork Interceptor Upsizing with Muddy Fork Offline Storage Basin.		Flow Diversion, PS Upgrade, Offline Storage Basin		2016
MILL CREEK AREA															
45	Shively Interceptor *S_MC_WC_NB01_M_01_A*	Lynnview Ditch	10-yr, 3-hr storm 04498, 04542, 81814-W, MSD0047-PS, MSD0050-PS	Pipe Upgrades	$19,034,000	2012	10-yr, 3-hr storm 04498, 04542, 81814-W, MSD0047-PS, MSD0050-PS	Pipe Upgrades	$11,473,500	2012	No Change	10-yr, 3-hr storm 04498, 04542, 81814-W, MSD0047-PS, MSD0050-PS	Pipe Upgrades	$11,473,500	2012
46	East Rockford PS Relocation *S_MC_WC_NB02_S_03_C*	Mill Creek	2-yr, 3-hr storm for 04699-W	PS Replacement and Relocation	$1,488,000	2012	2-yr, 3-hr storm for 04699-W	PS Replacemen t and Relocation	$541,300	2012	No Change	2-yr, 3-hr storm for 04699-W	PS Replacement and Relocation	$541,300	2012
SMALL WQTC AREA															
E	Lucas Lane PS Inline Storage *S_FF_NB01_S_09A_C_A*	Goose Creek	2-yr, 3-hr storm for MSD0199-LS	Inline Storage	$261,000	2021	2-yr, 3-hr storm for MSD0199-LS	Inline Storage	$320,000	2021	2021. Project eliminated due to more detailed model calibration.	2-yr, 3-hr storm for MSD0199-LS	Project Eliminated	N/A	N/A
47	Riding Ridge PS Improvements *S_HC_HN_NB02_S_03_C_A*	Harrods Creek	2-yr, 3-hr storm for MSD1060-LS	PS Upgrades	$31,000	2014	2-yr, 3-hr storm for MSD1060-LS	PS Upgrades	$31,000	2014	No Change	2-yr, 3-hr storm for MSD1060-LS	PS Upgrades	$19,200	2014
48	Gunpowder PS Inline Storage *S_HC_HN_NB02_S_09A_C_B*	Harrods Creek	2-yr, 3-hr storm for MSD1055-LS	Inline Storage	$251,000	2021	2-yr, 3-hr storm for MSD1055-LS	Inline Storage	$251,000	2021	2021.Revised completion date to December 31, 2025.	2-yr, 3-hr storm for MSD1055-LS	Inline Storage	$800,000	2025
E	Fox Harbor Inline Storage *S_HC_HN_NB03_S_09A_A_A*	Harrods Creek	10-yr, 3-hr storm for 62769	Inline Storage	$468,000	2021	10-yr, 3-hr storm for 62769	Inline Storage	$468,000	2021	2019. Project eliminated due to more detailed model calibration.	10-yr, 3-hr storm for 62769	Project Eliminated	N/A	N/A

Table ES.1.1-6 Final SSDP Projects Including Project Modifications

	FINAL SSDP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2009 TECH AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 SSO(S) ELIMINATED & APPROVED LEVEL OF PROTECTION	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
49	Fairway View PS Improvements *S_FF_LF_NB01_S_03_C_A*	Harrods Creek	2-yr, 3-hr storm for MSD1065-PS	PS Upgrades	$101,000	2014	2-yr, 3-hr storm for MSD1065-PS	PS Upgrades	$101,000	2014	No Change	2-yr, 3-hr storm for MSD1065-PS	PS Upgrades	$359,500	2014
50	Lake Forest PS SSO Investigation *S_FF_LF_NB01_S_13_C_A*	Chenoweth Run	N/A storm for MSD1169-LS	Monitor	$650,000	2012	N/A storm for MSD1169-LS	Monitor	$650,000	2012	No Change	N/A storm for MSD1169-LS	Monitor	$650,500	2012
51	St. Rene Rd PS Inline Storage *S_FF_CH_NB01_S_09A_C_A*	Chenoweth Run	2-yr, 3-hr storm for 94187	Inline Storage	$43,000	2014	2-yr, 3-hr storm for 94187	Inline Storage	$43,000	2014	2015. Project changed to PS Elimination	2-yr, 3-hr storm for 94187	Flow Diversion	Included in Jeffersontown WQTC Elimination	2014
COMBINED SEWER SYSTEM AREA															
52	Sonne PS I/I Investigation *S_OR_MF_42007_S_07_C*	Paddy Run	2-yr, 3-hr storm for MSD0042-PS	I/I Reduction	$281,000	2011	2-yr, 3-hr storm for MSD0042-PS	I/I Reduction	$846,500	2011	No Change	2-yr, 3-hr storm for MSD0042-PS	I/I Reduction	$846,500	2011
53	Camp Taylor System Improvements, Phase 1: SSES *S_SF_MF_30917_M_09_A*	Muddy Fork Beargrass Creek	10-yr, 3-hr storm 08717, 13931, 13943, 36763, 44396, 44397, 66349, 104223, 104231	SSES	$37,927,000	2014	10-yr, 3-hr storm 08717, 13931, 13943, 36763, 44396, 44397, 66349, 104223, 104231	SSES		2011	2012. Modification combined Phases 2 & 3 and expanded overall area	10-yr, 3-hr storm 08717, 13931, 13943, 36763, 44396, 44397, 66349, 104223, 104231	SSES	$12,367,100	2011
54	Camp Taylor System Improvements, Phase 2: Replace & Rehabilitate Sewers *S_SF_MF_30917_M_09_A*			Sewer Replacement & Rehabilitation				Sewer Replacement & Rehabilitation		2017			Sewer Replacement & Rehabilitation	$29,345,500	2013
55	Camp Taylor System Improvements, Phase 3: Replace & Rehabilitate Sewers *S_SF_MF_30917_M_09_A*			Sewer Replacement & Rehabilitation											2017
56	Camp Taylor System Improvements, Phase 4: Offline Storage *S_SF_MF_30917_M_09_A*			Offline Storage				Offline Storage		2024	2021.Revised completion date to December 31, 2035. Future: Monitoring on-going – project may not be necessary		Offline Storage	$23,972,300	2035
57	Hazelwood PS I/I Investigation & Rehabilitation *S_MC_MF_55665_S_07_C*	Manslick Branch	2-yr, 3-hr storm for 55665	I/I Reduction	$184,000	2011	2-yr, 3-hr storm for 55665	I/I Reduction	$382,000	2011	No Change	2-yr, 3-hr storm for 55665	I/I Reduction	$382,100	2011
INTERIM SSDP															
1	Hikes Lane Interceptor and Highgate Springs	South Fork Beargrass Creek and Wedgewood Ditch	2-yr, 3-hr storm for 18134, 18298, 18302, 18483, 18595, 49224, 49236, 49672, 49673, MSD0012-PS	New Sewer	$23,183,000	2012	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$13,821,500	2012
2	Southeastern Diversion Structure & Interceptor	South Fork Beargrass Creek	8426, 8427, 8430, 8431, 18654, 30680, 30681, 30701, 30702, 30704, 49647, 63779, 72571-X	Diversion Structure	$1,906,000	2012	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$8,589,600	2012
3	Northern Ditch Diversion Interceptor	Northern Ditch	MSD0271	New Sewer	$21,639,000	2011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$14,104,600	2011

Table ES.1.1-6 Final SSDP Projects Including Project Modifications

	FINAL SSDP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2009 TECH AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 SSO(S) ELIMINATED & LEVEL OF PROTECTION	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 SSO(S) ELIMINATED & APPROVED LEVEL OF PROTECTION	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
4	Sinking Fork Relief Sewer	Middle Fork Beargrass Creek, Upper Sinking Fork	21103, 25012, 63319	New Sewer	$1,741,000	2010	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$1,437,300	2009
5	Beechwood Village Sanitary Sewer Replacement	Upper Sinking Fork	2-yr, 3-hr storm for 21061, 21089, 21101, 21153, 21156	Sewer Replacement, Rehab	$12,519,000	2011	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$7,982,100	2010
6	Derek R. Guthrie WQTC	Ohio River, Black Pond Creek, Alvey Ditch, Mendora Branch, Mill Creek	10-yr, 3-hr storm for wet weather SSOs	100 MGD High Rate Treatment Facility	$122,000,000	2012	N/A	N/A	N/A	N/A	N/A	N/A	N/A	$96,358,900	2012

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Appendix A Acronyms and Abbreviations

AACE	Association for the Advancement of Cost Engineering
ACD	Amended Consent Decree
AM	Asset Management
AO	Agreed Order
AAOV	Annual Average Overflow Volume
BG	Billions of Gallons
BGC	Beargrass Creek
BMP	Best Management Practice
BOD	Biological Oxygen Demand
CAH	Cold Water Aquatic Habitat
CAP	Morris Forman WQTC Action Plan
CD	Consent Decree
CDS	Continuous Deflection Separator
CFU	Coliform Forming Unit
CHP	Combined Heat and Power
CIP	Capital Improvement Plan
CMMS	Computerized Maintenance Management System
CMOM	Capacity, Management, Operation, and Maintenance Program
CPE-CCP	Comprehensive Performance Evaluation-Composite Correction Plan
CRCC	Customer Relations Call Center
CRRP	Critical Repair and Replacement Plan
CSO	Combined Sewer Overflow
CSOP	Combined Sewer Operational Plan
CSS	Combined Sewer System
CSSA	Continuing Sanitary Sewer Assessment
CWA	Clean Water Act
D/T	Dilution to Threshold
DAFT	Dissolved Air Flotation Tanks
DMR	Discharge Monitoring Report
DRGWQTC	Derek R. Guthrie Water Quality Treatment Center

DRI	Drainage Response Initiative
DTPD	Dry Tons Per Day
DWF	Dry Weather Flow
DWS	Domestic Water Supply
EAP	Early Action Plan
EPA	United States Department of Environmental Protection
FEPS	Morris Forman WQTC Final Effluent Pump Station
FM	Force Main
FOG	Fats, Oils, and Grease
FPSs	Flood Pump Stations
FY	Fiscal Year
GIS	Geographical Information System
GPM	Gallons Per Minute
I/I	Infiltration and Inflow
IBI	Index of Biotic Integrity
IOAP	Integrated Overflow Abatement Plan
ISSDP	Interim Sanitary Sewer Discharge Plan
JCPS	Jefferson County Public Schools
KDEP	Kentucky Energy and Environment Cabinet
KDOW	Kentucky Department of Water
KPDES	Kentucky Pollution Discharge Elimination System
LF	Linear Feet
LOC	Level of Control
LOJIC	Louisville and Jefferson County Information Consortium
LOP	Level of Protection
LS	Lift Station
LTCP	Long Term Control Plan
LTMN	Long Term Monitoring Network
M	Millions of Dollars
MCC	Motor Control Center
MG	Millions of Gallons
MGD	Millions of Gallons per Day

ML	Milliliter
MOPs	Modeled Overflow Points
MSD	Louisville-Jefferson Metropolitan Sewer District
MS4	Municipal Separate Storm Sewer System
MW	Megawatt
NASSCO	National Association of Sewer Service Companies
NMC	Nine Minimum Controls
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
O&M	Operations & Maintenance
ORFM	Ohio River Force Main
ORFPS	Ohio River Flood Protection System
ORSANCO	Ohio River Valley Water Sanitation Commission
OSRW	Outstanding State Resource Water
PACP	Pipeline Assessment and Certification Program
PCCM	Post Construction Compliance Monitoring Program
PCR	Primary Contact Recreation
PLC	Programmable Logic Controller
POTW	Publicly Operated Treatment Works
PS	Pump Station
QAPP	Quality Assurance Project Plans
QA/QC	Quality Assurance/Quality Control
R&R	Renewal & Replacement
RAS	Return Activated Sludge
RCP	Reinforced Concrete Pipe
ROW	Right-of-Way
RTC	Real Time Control
S&F	Solids and Floatables
SAMP	Strategic Asset Management Plan
SCAP	Sewer Capacity Assurance Plan
SCR	Secondary Contact Recreation
SEP	Supplemental Environmental Projects

SIU	Significant Industrial User
SOPs	Standard Operating Procedures
SORP	Sewer Overflow Response Protocol
SSDP	Sanitary Sewer Discharge Plan
SSES	Sanitary Sewer Evaluation Studies
SSO	Sanitary Sewer Overflow
SSOP	Sanitary Sewer Overflow Plan
SSS	Sanitary Sewer System
SWMM	Stormwater & Wastewater Management Model
TAMP	Tactical Asset Management Plan
TDH	Total Dynamic Head
THP	Thermal Hydrolysis Process
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
UAA	Use Attainability Analysis
UMF	Upper Middle Fork
UofL	University of Louisville
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
UV	Ultraviolet Radiation
VFD	Variable Frequency Drive
WAH	Warm Water Aquatic Habitat
WAS	Waste Activated Sludge
WASP5	Water Quality Analysis Simulation Program Version 5
WDRs	Wastewater and Stormwater Discharge Regulations
WEF	Water Environment Federation
WIFIA	Water Infrastructure Finance and Innovation Act
WIN	Waterway Improvements Now
WQT	Water Quality Tool
WQTC	Water Quality Treatment Center
WWT	Wet Weather Team
WWTPs	Wastewater Treatment Plants

APRIL 30, 2021

Safe, clean waterways

2021 IOAP MODIFICATION

VOLUME 2 FINAL LTCP, CHAPTER 1

METROPOLITAN SEWER DISTRICT

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

There are no appendices associated with this Chapter.

Chapter 1: INTRODUCTION

Special Note – 2021 IOAP Modification: This chapter was developed in 2009. The statistical data for the CSO's reported, specifically related to individual CSO volumes in a typical rainfall year, were derived from the hydraulic model calibrated in 2007. Since then, a more detailed calibration and validation effort has adjusted the average annual overflow volumes in the Typical Year. The data presented in this and subsequent chapters represents the 2008 initial system conditions. Project modifications due to improved system characterization data, hydraulic model recalibration and other changed conditions are described in Chapters 3 and 4. A crosswalk summarizing changes made for the 2021 Modification of the Volume 2 Final Long-Term Control Plan (LTCP) is provided in Table 1.1-1. As with the 2012 IOAP submittal, Volume 2, Chapter 1 does not have any appendices.

Table 1.1-1 2021 IOAP Modification Final LTCP Crosswalk

CRITERIA	DESCRIPTION	VOLUME 2 CHAPTERS OR SECTIONS	2012 IOAP SUBMITTAL	2021 IOAP MODIFICATION
LTCP Projects	Work Progress	1.3.1.4 LTCP activities 4.1, LTCP revised dates Table 4.1-6 storage	Work through 2012 was noted	Added summary of work performed 2009 - present
	Minor Project Modifications	Table 4.0-1 Appendix 4.0-1 Appendix 4.0-2	Information was accurate through 2012.	Revised LTCP table to include all project modifications and provide copies of letter modifications and certifications.
New Information Since 2012 IOAP Submittal	Clarified which information is from 2009, 2012, 2021	Multiple places throughout Chapters 1, 2, 3, and 4	Process and data remain valid and accurate	New note added at the front of each chapter
	Progress since the 2012 IOAP Submittal	2.4.2 AAOV by stream 2.5.2.3 Beargrass CSOs 2.6.2.3 Ohio River CSOs 2.6.2.6 Ohio River CSOs 4.1.2.2. final gray projects	Tables were labeled as outdated and referred to Volume 2, Chapter 5	Deleted the tables and the references to Volume 2, Chapter 5
		Chapter 5	New Chapter 5 added for 2012 modifications	Chapter 5 deleted, and information integrated into Chapters 3 and 4
		1.3.1.4 LTCP activities 1.3.4.2 ORSANCO 2.4.3.1 rain gauges 2.4.4 model 2.4.4.4 flow monitors 2.4.4.5 water quality 2.4.6.4 model 2.4.6.5 model 2.9.1 water quality 3.2.3.1 RTC Phase 1 3.2.5.9 dry well projects 3.2.5.10 green projects 4.1.2.1green projects	N/A	New information added to reflect work or pertinent information since the 2012 IOAP submittal
	Verb Tense	Multiple places throughout Chapters 1, 2, 3, and 4	No change to content	Verb changed to past tense for work that been performed

CRITERIA	DESCRIPTION	VOLUME 2 CHAPTERS OR SECTIONS	2012 IOAP SUBMITTAL	2021 IOAP MODIFICATION
Presumption Approach	Clarification	2.9 receiving Waters Chapter 3 Introduction 3.1.1 approach 4.4 measures of success	N/A	Added language clarifying the 2021 Final LTCP exceeds the requirements of the Presumption Approach for 85% capture.
Consolidated Information	Consent Decree Background	1.1. background	Reduced text added reference to Volume 1	Information about Consent Decree deleted and consolidated into Volume 1, Chapter 1.
	Public Information	1.3.2 public participation 1.3.4 NMC-8 3.1.1.3 public participation 4.2 public participation	Reduced text added reference to Volume 1	Consolidated the Public Participation into Volume 1, Chapter 3
	Level of Control	Table 4.1.1	LOC noted in Tables	Previous tables deleted and information added to Table 4.0-1

1.1. BACKGROUND

Refer to Volume 1, Chapter 1, Section 1.1 for background information and an overview of MSD's Consent Decree, Amended Consent Decree (ACD), and the Second ACD. The background information included in this section relates specifically to the Final LTCP and MSD's measures to mitigate combined sewer overflows (CSOs).

1.1.1. HISTORY OF CSO CONTROL POLICY

The CSO Control Policy published by EPA on April 19, 1994, provided guidance to permittees with CSOs, National Pollutant Discharge Elimination System (NPDES) authorities and State water quality standards authorities on coordinating the planning, selection, and implementation of CSO controls that meet the requirements of the CWA. The policy contains provisions for developing appropriate, site-specific NPDES permit requirements for all CSS that overflow due to wet weather events and allows for public involvement during the decision-making process.

Four key principles of the policy ensure that CSO controls are cost effective and meet the requirements of the CWA. These principles are as follows:

- Provide clear levels of control that would meet appropriate health and environmental objectives.
- Provide sufficient flexibility to municipalities, especially financially disadvantaged communities, to consider the site-specific nature of CSOs and to determine the most cost-effective means of reducing pollutants and meeting CWA objectives and requirements.
- Allow a phased approach for implementation of CSO controls considering a community's financial capability.
- Review and revise, as appropriate, water quality standards and their implementation procedures when developing CSO control plans to reflect the site-specific wet weather impacts of CSOs.

The CSO Control Policy became law in December 2000 and establishes two main objectives for permittees: implementation of the Nine Minimum Controls (NMCs), and the development and implementation of a LTCP.

A separate report entitled "NMC Compliance Report" details the implementation and status of the NMCs and was originally submitted by MSD to the regulatory authorities in February 2006 and ultimately approved in 2007.

The CSO Control Policy directs the permittee to develop and implement a LTCP based on system characterization, water quality and quality monitoring, and stream and sewer system modeling of the CSS. To develop a comprehensive plan, the LTCP should consider the site-specific nature of CSOs and utilize a public participation process involving stakeholders such as the ratepayers, industrial users, persons residing downstream of CSOs, and other interested parties. The CSO Policy also requires that the plan give highest priority to controlling overflows in sensitive areas.

A major part of the LTCP is the CSO alternatives. To develop and evaluate the alternatives, MSD conducted a review of the current and proposed water quality standards to define the levels of pollutant load reductions that are required to meet water quality standards, and thus set the performance expectations for the CSO controls.

General indications of past water quality studies throughout the United States show that CSOs are only one of several sources that can significantly affect the pollutant concentrations in the receiving waters. Control of CSOs alone may not be sufficient to achieve the standards or restore the water bodies to their designated uses. Various wet weather source discharges also exist within the MSD service area. Under the Continual Planning Process in the CWA, an appropriate approach for dealing with these complex combinations of pollutant sources is to evaluate the effectiveness of controls and, from time-to-time, the appropriateness of the water quality standards.

As MSD implements CSO controls and conducts post-construction compliance monitoring of the Final LTCP, review and revision of the water quality standards may be appropriate as indicated by the EPA 2001 Guidance: "Coordinating CSO Long-Term Planning with Water Quality Standards Reviews" (EPA-833-R-01-002). The Ohio River Sanitation Commission (ORSANCO) also adopted a provision in its water quality standards for the Ohio River allowing for development and application of alternative criteria if CSO communities have submitted a LTCP and a Use Attainability Analysis (UAA) (ORSANCO, 2006). Therefore, the intent of MSD is to implement the controls recommended in the updated LTCP and then evaluate whether developments of a UAA or additional CSO or other pollutant source controls are warranted.

1.1.1.1. KEY ELEMENTS OF CSO CONTROL POLICY

EPA developed guidance documents to assist agencies in preparing LTCPs in compliance with the CSO Policy. MSD's Consent Decree requirements generally follow existing EPA guidance, with the inclusion of additional requirements to address specific MSD issues, such as overflows from the flood pump stations. The Consent Decree specifies that MSD's LTCP shall achieve the following three goals:

- Ensure that if CSOs occur, it is only as a result of wet weather (this goal shall include addressing those discharges resulting from MSD's compliance with the requirements of the United States Army Corps of Engineers' {USACE} "Ohio River Flood Protection System Pumping Operations Manual," dated 1954 and revised 1988).
- Bring wet weather CSO discharge points into 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.

Additionally, as specified by the Consent Decree, the MSD Final LTCP shall include, at a minimum, the following elements:

- **Characterization & Selection of CSO Controls**: The results of characterization, monitoring, modeling activities, and design parameters as the basis for selection and design of effective CSO controls (including control to address those discharges resulting from MSD's compliance with the requirements of the USACE's "Ohio River Flood Protection System Operations Manual," dated 1954 and revised 1988.
- **WQTC Peak Flow Treatment Capacity**: The results of an evaluation of WQTC peak flow treatment capacity for any WQTC, other than Morris Forman WQTC, that will receive additional flow based on the MSD LTCP project. Such evaluation shall be consistent with the EPA publications "Improving POTW Performance Using the Composite Correction Approach," (EPA CERI, October 1984), and "Retrofitting POTWs," (EPA CERI, July 1989).
- **Public Participation**: A report on the public participation process.
- **Sensitive Areas**: Description of how the MSD Final LTCP addresses sensitive areas as the highest priority for controlling overflows.
- **Cost Analysis**: A report on the cost analyses of the alternatives considered.
- **Operational Planning**: Operational plan revisions to include agreed-upon long-term CSO controls.
- **Capacity Maximization**: Maximization of treatment and evaluation of treatment capacity at Morris Forman WQTC.
- **Implementation Schedule**: Identification of and an implementation schedule for the selected CSO controls.
- A post-construction compliance monitoring program adequate to verify compliance with water quality-based CWA requirements and ascertain the effectiveness of CSO controls.

1.1.1.2. GUIDANCE TO SUPPORT IMPLEMENTATION OF THE CSO CONTROL POLICY

Implementation of the Consent Decree program and both the LTCP and the SSDP, will continue for many years. Recognizing the need for consistent, long-term direction for the Consent Decree, along with planning, coordination, and reporting activities, MSD initiated Project WIN (Waterway Improvements Now). As presented in Volume 1, Project WIN's mission is to provide oversight and guidance of the activities required to comply with the terms and conditions of the Consent Decree. This requires initiating, organizing, coordinating, and managing a diverse set of elements, programs, and projects to successfully discharge all Consent Decree obligations.

Project WIN's goals are as follows:

- Identify, design, and implement projects and programs that reduce CSO events and mitigate their impact to comply with the CWA and the CSO Policy.
- Identify, design, and implement projects and programs that eliminate unauthorized discharges in both the separate SSS and the CSS, providing the level of protection indicated by the selected design event.
- Select projects and programs that satisfy the Consent Decree requirements, and at the same time support and protect a broad spectrum of community values.

- Implement the projects and programs in a manner that will efficiently use MSD's available resources while creating benefits related to Louisville Metro's community values.

1.1.2. MSD'S FINAL LTCP

Over the last 150 years, MSD's sewer system has extended into a network of both sanitary and combined sewers, diversion structures, and other flow control devices. In the combined sewer system (CSS), dry weather flows are conveyed to the Morris Forman WQTC for treatment prior to discharge into the Ohio River. During wet weather events, when the total combined sewage flow exceeds the capacity of the sewer, a mixture of sewage and stormwater runoff is discharged to the South Fork of Beargrass Creek, Middle Fork of Beargrass Creek, Muddy Fork of Beargrass Creek, and the Ohio River. The CSS service area is approximately one-third of the Morris Forman WQTC service area and encompasses approximately 37 square miles of area. Presently there are 102 active combined sewer overflows (CSO) within the MSD area.

To address the wet weather overflows, MSD initiated a CSO abatement program in 1991 dedicated to developing a comprehensive understanding of the CSS and an approach to reducing CSOs. MSD continues to enhance and expand the resources and a significant amount of work has been conducted including characterization of the system, development of hydraulic computer models, compliance with the U.S. Environmental Protection Agency's (EPA) Nine Minimum Controls (NMC), and implementation of various CSO Long-Term Control Plan (LTCP) elements. Figure 1-1 illustrates most of MSD's major activities over the last 15 years that have provided a foundation for the development of this Final LTCP.

Figure 1-1 CSO Abatement Program Accomplishment Timeline
This figure is provided at the end of this chapter.

MSD's initial efforts at CSO abatement occurred before the EPA issued the final CSO Control Policy in 1994. MSD performed model development and flow monitoring during the early 1990s to help better understand how the CSS functioned during periods of wet weather. In addition, MSD investigated preliminary CSO controls by evaluating potential CSS best management practices (BMP). The implementation of BMPs and NMCs during the mid to late 1990s, provided additional reductions in the frequency of occurrence and volume of CSO discharges, at relatively low capital cost.

Since 1998, MSD has devoted additional resources to more capital-intensive projects such as Real Time Control (RTC), pump station improvements, sewer separation, construction of storage basins, solids and floatable (S&F) removal facilities, and the elimination of several CSOs. Completion of these projects demonstrates the significant impact MSD's CSO initiative of the 1990s has had on the overall progress of the CSO Abatement Program and poises MSD for successful completion of the Final LTCP.

A significant undertaking that has become the foundation of the current LTCP is the Real Time Control (RTC) Program. The objective of this ongoing program is to maximize the existing in-line storage capacity of large conduits for cost-effective reduction of CSOs within both the Beargrass Creek and Ohio River basins. The RTC Program is an application of advanced technology which uses available meteorological data and sewer capacity information monitored over the sewer network, and predicted by the Radar Rainfall Data System, to determine the best flow management strategy.

Along with the RTC Program, MSD has implemented other CSO controls, including demonstration programs, to establish the applicability and effectiveness of various CSO technologies.

Design and installation for CSO controls has been completed, and facilities are in operation for the following:

- Established a voluntary plumbing modification program to develop public support for removal of downspouts, sump pumps, etc.
- Installed screens, baffles, and bar racks to capture S&F at individual CSOs.
- Installed an inflatable dam within the Sneads Branch Relief sewer, an 11-foot diameter semi-elliptical drain that recaptures CSS flows from eleven CSOs and pumps the flow back into the sewer for treatment at Morris Forman WQTC.
- Installed a combination of inflatable dams and control gates in the Southwestern Outfall sewer that provides retention of wet weather flows in the system from a large portion (about 7,500 acres) of the CSS in southwestern Louisville Metro.
- Separated combined sewers in several CSO drainage basins, to eliminate CSOs.
- Installed two earthen storage basins for both CSO and surface flooding control with a combined storage volume of 33 million gallons (MG) on the grounds of the Kentucky Fair and Exposition Center.
- Installed three million gallons per day (MGD) screening devices at two CSO locations and a 32 MGD Continuous Deflection Separator (CDS) at one CSO location to screen the CSO discharge.
- Reconstructed a 140 MGD CSO pump station, reducing CSO volume by 70 MG per year.
- Modified flood control protocols for the Ohio River Flood Protection System Infrastructure to reduce CSOs.
- Installed thousands of backwater valves on residential laterals to prevent basement backups.
- Additional activities from 2009 through 2020 within the CSS are described in MSD Quarterly and Annual Reports posted on the Project WIN website at http://msdprojectwin.org/.

Two other key, long-standing, planning projects that have been active for several years and critical to MSD's LTCP planning process for 2008 include the (ORSANCO water quality study and the Beargrass Creek Total Maximum Daily Load (TMDL) project. The ORSANCO water quality study includes a preliminary analysis of the bacterial impacts of CSO on the Ohio River and the Beargrass Creek TMDL project uses the Water Quality Tool (WQT) to determine TMDL allocations for bacteria. Both of these projects play important roles in the development of the Final LTCP.

MSD completed and submitted a draft LTCP for the Beargrass Creek area in 1996 and a draft LTCP for the Ohio River area in 1997. Both plans were required by the EPA CSO Guidance Policy of April 1994. These plans presented the current plan to address CSOs within the MSD service area. Upon submittal of these plans, MSD appropriately began initiating implementation of the LTCP.

This document is the Final LTCP, which is a major modification of the 1996 and 1997 draft LTCPs and an expansion of the Interim LTCP submitted in September 2006 and the 2012 Final LTCP. The term Final LTCP will refer to the 2021 version of the Final LTCP. When referencing to prior versions of the LTCP submittal years are included to provide specific references As its name implies, the Final LTCP defines the long-term objectives of MSD's CSO control objectives, the analyses undertaken to arrive at the appropriate CSO control solution, a detailed description of the various measures recommended for implementation, and a schedule of implementation based on MSD's financial capability and compliance needs.

1.2. CSO LTCP DOCUMENT ORGANIZATION

As the second volume of the IOAP, the Final LTCP focuses on the control and mitigation of CSOs. The LTCP outline as well as a brief description of each chapter is given below. The second volume of the IOAP focuses on the control and mitigation of the CSOs.

1.2.1. CHAPTER 1 INTRODUCTION

This chapter includes a history of MSD's control policy for CSOs and a summary of the policy's key elements. Also provided are general descriptions of the current CSO control efforts, control processes, and criteria for success.

1.2.2. CHAPTER 2 SYSTEM CHARACTERIZATION

This chapter provides extensive analysis of CSO areas. Analysis includes existing baseline conditions of the CSO area, monitoring of CSO flows, CSO quality sampling, and combined modeling of the sewer system and receiving waters.

1.2.3. CHAPTER 3 DEVELOPMENT AND EVALUATION OF ALTERNATIVES FOR CSO CONTROL

This chapter discusses the approach and factors used to identify, develop, evaluate, and select projects that make up the recommended projects and programs in the Final LTCP.

1.2.4. CHAPTER 4 SELECTION OF THE LONG-TERM CONTROL PLAN

This chapter includes an explanation of the values-based risk management process used to select and prioritize the Final LTCP alternatives. Issues discussed include community values, benefit/cost analysis, environmental impact, technical concerns, prioritization of projects, and implementation schedules compatible with the Consent Decree requirements.

Note: In the 2012 IOAP submittal, a Chapter 5 was included that provided a summary of project modifications to the IOAP between 2009 and 2012. The 2012 project modifications, in addition to schedule modifications as part of the 2021 IOAP submittal, have been incorporated into Chapters 3 and 4 of this Volume 2, and Chapter 5 has been removed.

1.3. LTCP PLANNING APPROACH, PROGRAMS, AND STUDIES

This section provides a summary of previous and ongoing programs relative to CSO control. These studies and MSD's combined sewer system (CSS) hydraulic model serve as the foundation for the Final LTCP.

1.3.1. LTCP ACTIVITIES THROUGH 2020

Since the development of MSD's initial LTCP, MSD has been implementing plan elements to reduce the pollutant load on receiving streams from CSOs. The following sections provide a summary of LTCP Implementation accomplishments through December 2008.

1.3.1.1. JANUARY 1991 TO DECEMBER 1992

During 1991 and 1992, MSD's CSO program focused on characterization, monitoring, and modeling activities to assist in the selection and design of effective CSO controls. Specific activities included the inventorying of CSS assets and developing the tools required to move forward with the development of a LTCP.

The accomplishments achieved during this period included:

- **Maintenance Programs for CSS Assets**: Development of a detailed inventory that determined the operational status of all assets.
- **System Evaluated**: Evaluation of CSS included pump stations, overflows, and regulators.
- **Flow Monitoring Program**: Conducted a program to provide calibration data for the CSO Stormwater and Wastewater Management Model (SWMM) model and developed a SWMM model of the CSS.
- **CSO and Stream Sampling Program**: Executed a CSO and stream-sampling program to quantify the impact of CSOs on the receiving streams.
- **CSO Nutrient Release Estimates**: Estimated annual CSO nutrient release to quantify the impact of CSOs on the receiving streams.
- **CSS Flooding Analysis**: Performed a flooding analysis associated with the CSS focused on the Ohio River North and Ohio River West regions.
- **Evaluated Impacts to CSS**: Evaluated major stormwater impacts and industrial loadings to the CSS.
- **Public Education Program Summary**: Summarized MSD's public education program relative to the CSS.

1.3.1.2. JULY 1993 TO NOVEMBER 1998

During this period, MSD continued to focus on the development and implementation of a long-term capital program for planning, design, and construction of new facilities and the improvement of existing facilities and systems to minimize the frequency and volume of CSS overflows.

MSD evaluated alternatives in its plan based on cost, performance in meeting the programmatic objectives, contribution toward attainment of water quality standards, and operational performance. The prioritized projects were incorporated into a rolling five-year Capital Improvement Program and budget. Specific program accomplishments from 1993 - 1998 relative to implementation of the LTCP are summarized below:

- **LTCP for Beargrass Creek Region** developed.
- **LTCP for the Ohio River North and Ohio River West Regions** developed.
- **System Flow Monitoring and Sampling**: Setup at selected CSO outfalls.
- **Evaluated localized surface flooding issues**: Evaluations at various locations throughout the CSS that were typically a result of limited inlet capacity.
- **CDS Unit at CSO050 for Solids and Floatables (S&F) Control:** Constructed and installed a CDS which is a liquids-solids separation technology typically used for stormwater management. The facility began operations in February 1998 and is used for S&F control.

- **Wheeler Avenue CSO/Flood Control Basin**: Constructed the basin to provide flooding relief for the area and to reduce overflows at CSO015. The project was accomplished by constructing a 4.9 MG flood control basin, constructing a 553,000-gallon CSO Basin inside the flood control basin, providing 1.1 MG of storage in the 78-inch combined sewer, regulating the rate of flow to the Mill Creek Trunk and preventing the Mill Creek Trunk from backing up into the area. The conveyance pipe for Wheeler Avenue storage basin is operated as part of the RTC System. The RTC component of the Wheeler Avenue storage basin conveyance was completed in December 2008.
- **Plumbing Modification Program**: Implemented on a countywide basis. The Plumbing Modification Program was initially intended to provide protection to designated critical areas in the CSS experiencing chronic problems due to basement backups. A major accomplishment was the minimization of public health concerns resulting from the combined and sanitary sewer systems backing up into customer basements. The program resulted in the removal of downspouts directly connected to the CSS thereby reducing storm flow into the CSS. To-date over 17,992 backflow prevention devices have been installed. This program is currently being implemented on a priority area and evaluated need basis.

1.3.1.3. DECEMBER 1998 TO SEPTEMBER 2009

During this period, MSD's LTCP continued to focus on program development and implementation to achieve compliance with the CSO policy through the continued evolution and development of its LTCP efforts. Below is a summary of specific accomplishments during this period.

- **CDS Unit**: Installed a CDS Unit as a demonstration project for S&F control on CSO108. This liquids-solids separation technology had typically been applied to stormwater management. The CDS facility project became part of an EPA and National Sanitation Foundation International partnership with the Environmental Technology Verification Program and Water Quality Protection Center program to verify commercial-ready technologies that protect surface waters from contamination.
- **Screenings Facility**: Installed gross screenings facility at Beargrass Creek using two diversion booms and two trash baskets to collect S&F from the creek. This concept differed from other S&F control facilities because it screened the entire stream channel. The objective was to remove S&F within the stream channel, capture S&F originating from point and non-point sources and create a more aesthetically pleasing environment suitable for recreation.
- **Sewer Separation on CSO206, located in Cherokee Park**: Evaluated, designed, and initiated construction for sewer separation on CSO206. The field investigation was completed during October 1999. Recommendations included a three-phased sewer separation project for the elimination of CSO206. Projects included reconnection of sanitary and storm sewers to their proper conveyance pipe, manhole remodeling, downspout disconnection, relining of sanitary sewers and relining of home services that run under the parallel storm sewers. Design of the sewer separation for the CSO206 area was initiated in 1999. The CSO206 Project was separated into 15 sub-areas, the design was completed, and construction began in 2000. Sub-areas 1 through 9 were completed by 2005 and remaining sub-areas will be completed by March 31, 2009.
- **CSO211 In-line Storage Project**: Constructed the CSO211 In-line Storage Project located at the main diversion structure. The goal of this project was to reduce overflow volume and maximize flows to the Morris Forman WQTC (up to the full Morris Forman WQTC capacity) from the Southern Outfall during wet weather. To provide treatment for the maximum flow possible, an inflatable gate was placed at the overflow from the main diversion structure. The gate provides the ability to raise the water level to

provide sufficient head to provide the short duration peak 350 MGD flow rate to the Morris Forman WQTC. The gate reduces the annual overflow volume at CSO211. Operation of the gate will ultimately be incorporated into the RTC effort for achieving in-line storage of wastewater.

- **Eliminated CSO209 through Sewer Separation**: The 105-acre area served through CSO209 consists of approximately 350 residential properties. The system was separated and the CSO permanently closed in September 2005 following completion of the related downspout removal project.
- **Constructed the Sneads Branch Relief In-line Storage Facility**: The facility uses the Sneads Branch Relief Drain as a CSO storage facility via the operation of an inflatable rubber gate. The gate is located approximately 200 feet from the outlet of the Sneads Branch Relief Drain to the South Fork of Beargrass Creek channelized section. The storage capacity of this facility when the gate is fully inflated is approximately 2.5 MG. The facility is designed to capture flows from the eleven CSOs tributary to the Sneads Branch Relief Drain and pump the stored volume to the Beargrass Interceptor to be conveyed to the Robert J. Starkey Pumping Plant (formerly known as the Buchanan Street Pump Station) and then on to the Morris Forman WQTC for treatment. Cleaned the Northeastern Sanitary Trunk Sewer: Cleaning increases the sewer's carrying capacity and reduce overflows. The Northeastern Sanitary Trunk Sewer Cleaning project involved the removal of an estimated 15-inch of deposition within the 5.5-foot diameter Northeastern Sanitary Trunk Sewer. The cleaning restored full capacity to the Northeastern Sanitary Trunk Sewer and greatly increased usable storage volume for smaller, more frequent storm events.
- **Expanded the Robert J. Starkey Pumping Plant**: The expanded plant increased pumping capacity from 125 MGD to 140 MGD and reduced overflows at CSO020 and CSO062. Estimates show this project resulted in a reduction of approximately 70 MG in the average annual overflow volume (AAOV). The upgraded pumping plant included a new wet well adjacent to the old wet well; four new variable speed, submersible pumps capable of handling 35 MGD each; two channel grinders with hydraulic motors for screening; hydraulically operated slide and sluice gates for control of flow through the pump station; a new electrical substation; new instrumentation and control, and included provisions for telemetry.
- **Constructed the Upper Dry Run Trunk Storage Basins (Executive Inn and Brady Lake Basins):** Basins provide flooding relief and reduce overflows at CSO015. The project included the construction of two earthen basins (17.3 MG and 15.3 MG) on the Kentucky Fair and Exposition Center property, and the construction of 1,922 linear feet of 60" diameter sewer. Both the Executive Inn Basin and the Brady Lake Basin are operated as part of the RTC System.
- **Implemented Phase One of the RTC Program**: The initial phase of RTC consisted of remotely controlling five sites by means of a centralized-decision-making system. The objectives for this program are a better use of the existing in-line storage capacity, a decrease of CSO volumes in the Beargrass Creek and Ohio River Watersheds, and an increase of the wastewater volume conveyed to the Morris Forman WQTC. The RTC approach is both global and predictive, which means that the decision-making system will use available information monitored on the sewer network, and predicted by the Radar Rainfall Data System, to determine the best flow management strategy. The initial phase included the setup of a centralized decision-making system, a radar rainfall data system to predict weather over a two-hour window, and remote control of five sites within the CSS. The initial five sites included Southeastern Diversion Structure, Nightingale Pump Station (CSO018), Southwestern Pump

Station (CSO015), Upper Dry Run Trunk Storage Basins (CSO015), and Sneads Branch Relief In-line Storage Project.

- **Developed Radar Rainfall Data System**: The intent of the Radar Rainfall Data System project is two-fold: to calibrate Next-Generation Radar (NEXRAD) radar with rain gauge data, and to provide predictive rainfall data two hours in advance of rainfall. The information provided by the Radar Rainfall Data System is utilized by the RTC system in an effort to better utilize the in-line storage capacity of the existing CSS.
- **Remediated the 11th Street and Rowan Street Connections**: The project corrected improperly connected property service connections tied to the storm sewer system near the intersection of 11th Street and Rowan Street, and the sanitary services located at the 10th Street Flood Pump Station.
- **Completed Riverside Area Sewer Reconnection Project**: Separate storm and sanitary sewers were provided at the area west of the Beargrass Creek Pump Station, east of Second Street and inside the floodwall. However, 27 commercial and residential properties were left connected to the storm sewer resulting in dry weather overflows. These properties were successfully reconnected to the sanitary sewer in 1997 and the dry weather overflows were eliminated.

Other accomplishments through 2009 include:

- Installed S&F controls on CSO109, CSO113, CSO126, CSO127 and CSO166 using Copa Cross Wave Static Screens. The static screen reduces the volume of S&F within the overflow stream.
- Installed S&F controls on CSO028, CSO030, CSO034, CSO054, CSO082 and CSO119 using Copa Cyclone Screen. The device is a low maintenance S&F screen.
- Installed S&F controls on CSO125 and CSO144 using Hydro International Wave Static Screens. Both of the CSOs utilized static screens to reduce the amounts of S&F within the overflow stream.
- Eliminated CSO123 through sewer separation.
- Reduced the AAOV at CSO088 through sewer separation. The original combined sewer was transformed into a sanitary sewer and a new storm sewer was constructed.
- Eliminated CSO080 through sewer separation.
- Upgraded wet weather capacity at Morris Forman WQTC which was completed in 2000.
- Modified the headworks at Morris Forman WQTC which was completed in 2000.
- Eliminated CSO209, CSO087 and CSO147 through sewer separation by transforming the existing combined sewer into a sanitary sewer and a new storm sewer.
- Replaced the four Northern Ditch Pump Station Pumps with new 14,000 gallons per minute (gpm) submersible tubular casing pumps. These renovations of the pump station greatly increase the station reliability and improve the functioning of the RTC system.
- Eliminated CSO030, CSO032, CSO033, CSO081 and CSO194 based on quick closure effort.
- Willow Pond Disconnection Project at CSO127 in progress.
- CSO131 S&F control device replaced baffle with cyclone screening device.
- CSO206 sub-areas 10-15 sewer separation completed.

1.3.1.4. OCTOBER 2009 THRU DECEMBER 2020

Activities completed during this time period are included in MSD's Quarterly and Annual Reports, which can be found at **http://msdprojectwin.org** Activities related to the first years of IOAP implementation such as project completion green implementation are detailed in these reports as well as various CMOM and NMC related activities.

Select accomplishments since October 2009 include, but are not limited to:

- **Right-sized storage basins** via Basin Balancing Evaluation (2012)
- **Project Modifications** were made to several LTCP projects as documented in Executive Summary Table ES-1.3.
- **Completed construction** of 24 of the 25 LTCP projects (refer to Volume 2, Chapter 4)
- **Expanded rain gauge network** to 46 gauges, including some gauges outside of its service area to better predict incoming storms
- **Expanded long-term flow monitoring network.** MSD currently has long-term sewer flow monitors in place at each of its CSO outfalls (where feasible), as well as some in-system meters.
- **Determined several CSO flow monitors were affected by backwater levels** from the receiving streams causing a discrepancy with actual overflow volume, along with other potential variables at some locations and implemented a corrective action program. Updated SOP and equations were developed.
- **Implemented extensive in-stream monitoring** effort for tributary streams and emergency spill responses, including ambient monitoring at 28 Long Term Monitoring Network (LTMN) locations across Jefferson County to monitor multiple physical and biological parameters in accordance with the MS4 permit.

1.3.2. PUBLIC PARTICIPATION

To meet the requirements of the CWA, the public program as required by the CSO Control Policy was based upon two concepts: public notification and public participation. The CSO Policy (NMC 8) requires public notification of overflows. Public participation includes public engagement in the decision-making process and selection of long-term controls. Volume 1, Chapter 3 of the IOAP presents a detailed description of the public participation program.

In addition to the requirements of the CSO Policy, MSD considered the public participation program essential to ensure public acceptance of the Final LTCP priorities and projects and to ensure there is public willingness to pay for the infrastructure program over a long time period. Additionally, the public needs to be informed that the Final LTCP will not eliminate all overflows under all conditions nor will it guarantee that no harmful pollutants will be discharged to Beargrass Creek and the Ohio River under certain conditions.

temporary overflow warning signs, email notification of events (public and regulators), and Web page notification.

1.3.3. COORDINATION WITH STATE WATER QUALITY STANDARDS AUTHORITY

Water quality standards are intended to protect human health, aquatic life and its habitat, and recreational use of the nation's waterways. CSOs can cause water quality standards exceedances because of the pollutants that are present in sanitary sewage and stormwater runoff. The CSO Policy requires permittees to evaluate whether CSOs are causing exceedances of the water quality standards and to develop “clear levels of control that would be presumed to meet appropriate health and environmental objectives” (59 Federal Register 18689). The CSO Policy also recognizes the site-specific challenges that CSO communities can face in determining cost-effective controls to meet water quality standards at all times, under all conditions.

A key principle of the CSO Policy is the “[r]Eview and revision, as appropriate, of water quality standards and their implementation procedures when developing CSO control plans to reflect site-specific wet weather impacts of CSOs” (59 (Code of Federal Register {CFR} 18689). Coordinating CSO Long-Term Planning with Water Quality Standards Reviews (US EPA, 2001) provides guidance on conducting these reviews. Some states, such as Indiana (IDEM, 2008); Massachusetts (MassDEP, 2007), and Maine (MDEP, 2003), have established revisions to their water quality standards to specifically address the challenges associated with CSO control.

If current standards cannot be met in a reasonable timeframe with cost-effective levels of control, permittees will work with the state water quality standards authority (KDEP) to determine the appropriate mechanism for ensuring that the LTCP will meet water quality standards. The role of the Kentucky water quality standards authority is to review standards in CSO-impacted receiving water bodies; coordinate the review with the LTCP development; and revise the standards as appropriate. These revisions can include development of site-specific criteria modification of the designated use or establishing a temporary variance.

This approach is consistent with the Continual Planning Process contained in the CWA, as shown in Figure 1-2. This figure shows how the CWA framework result in appropriate water quality standards and reasonable TMDLs, NPDES permit limits, and nonpoint source controls.

The first step is to start with appropriate water quality standards, and monitoring and assessing whether a water body is meeting these standards. If not, a TMDL is required to establish allowable loads for point sources (such as WQTCs, CSOs, or stormwater discharges) and nonpoint sources (like agriculture runoff).

A watershed or implementation plan is then developed to identify how to achieve these load reductions. This can be challenging since load reductions, particularly for bacteria, can often be 90 percent (or more) of current loads because of the existing water quality standard. If the load reductions are not feasible, then the process for establishing achievable and appropriate water quality standards is the UAA, which is shown at the top of Figure 1-2.

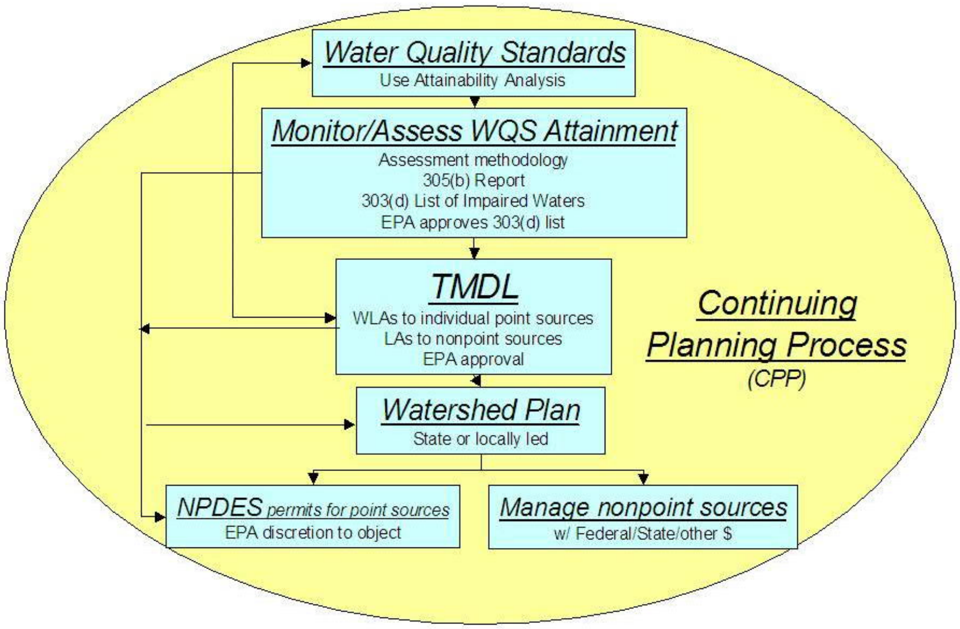


Figure 1-2 Use Attainability Analysis in the Continual Planning Process (USEPA, 2006)

As MSD implements CSO controls and conducts additional updates to its LTCP, review and revision of the water quality standards may be appropriate. ORSANCO adopted a provision in its water quality standards for the Ohio River allowing for development and application of alternative criteria if CSO communities have submitted a LTCP and a UAA (ORSANCO, 2006). MSD intends to implement the controls recommended in the updated LTCP and then evaluate whether development of a UAA or additional CSO or other pollutant source controls are warranted.

1.3.3.1. KENTUCKY'S WATER QUALITY USE CLASSIFICATIONS

Kentucky's Water Quality Regulations establish surface water use classifications for all waters of the Commonwealth (refer to Table 1.3-1).

Table 1.3-1 Kentucky's Water Quality Regulations Surface Water Use Classifications

KENTUCKY'S WATER QUALITY REGULATIONS	SURFACE WATER USE CLASSIFICATIONS
WAH	Warm Water Aquatic Habitat
CAH	Cold Water Aquatic Habitat
PCR	Primary Contact Recreation
SCR	Secondary Contact Recreation
DWS (Domestic Water Supply)	Applicable at existing points of public water supply disposal
OSRW	Outstanding State Resource Water

Table 1.3-2 summarizes the designated stream uses for the surface water bodies within the Ohio River near Louisville Metro and the Beargrass Creek Basin.

Table 1.3-2 Stream Use Designations

STREAM	USE DESIGNATION
Ohio River - Main Stem	WAH, PCR, SCR, DWS
South Fork Beargrass Creek and Tributaries	WAH, PCR, SCR
Middle Fork Beargrass Creek and Tributaries	WAH, PCR, SCR
Muddy Fork Beargrass Creek and Tributaries	WAH, PCR

For warm water aquatic habitat, the water quality standards require the following:

- The dissolved oxygen is to be maintained at a minimum concentration of 5.0 milligrams per liter (mg/l) daily average; the instantaneous minimum shall not be less than 4.0 mg/l.
- Total dissolved solids and total suspended solids (TSS) are not to be changed to the extent that the indigenous aquatic community is adversely affected.
- The addition of settleable solids that may alter the stream bottom and adversely affect productive aquatic communities is prohibited.
- The concentration of un-ionized ammonia shall not be greater than 0.05 mg/l at any time in-stream after mixing.

For recreational waters that are designated for primary contact recreation, the fecal coliform or Escherichia Coli (E. Coli) shall not exceed 200 colonies/100 milliliter (ml) or 130 colonies/100 ml, respectively, as a geometric mean based on not less than five samples taken during a 30-day period. Further, the fecal coliform concentration shall not exceed 400 colonies/100 ml in 20 percent or more of all samples taken during a 30-day period, or 240 colonies/100 ml for E. Coli. The above limits apply to the recreational season defined as May 1st to October 31st.

For the non-recreational period from November 1st to April 30th, the fecal coliform concentration criteria are the same as the criteria for secondary contact recreation. These criteria require that the fecal coliform content be no greater than 1,000 colonies/100 ml as a 30-day geometric mean, and no greater than 2,000 colonies/100 ml in 20 percent or more of the samples taken during a 30-day period.

For the main stem of the Ohio River, the dissolved oxygen is to be 5.0 mg/l or higher per day and shall not be less than 4.0 mg/l, except during the August 15th through June 15th spawning season when a minimum of 5.1 mg/l is to be maintained.

Kentucky Department for Environmental Protection (KDEP) 2004 303(d) listing of impaired water in Kentucky provides additional insight into the ability of these surface waters to meet its designated uses and lists the pollutants of concern that are the likely causes of the impairments (refer to Table 1.3-3).

Table 1.3-3 2004 Kentucky 303(D) List

STREAMS	PRIORITY	IMPAIRED USE	POLLUTANT OF CONCERN
Beargrass Creek of Ohio River (mile 0.0 to 1.5)	First	Aquatic Life (Nonsupport)	Metals, Organic Enrichment/Low dissolved oxygen
Middle Fork of Beargrass Creek (mile 0.0 to 2.3)	First	Aquatic Life (Nonsupport) Swimming (Nonsupport)	Organic Enrichment/Low dissolved oxygen, Habitat Alteration (other than flow), Metals (Cadmium), Pathogens
Middle Fork of Beargrass Creek (mile 2.3 to 15.2)	First	Aquatic Life (Partial support) Swimming (Nonsupport)	Metals (Cadmium), Pathogens
Muddy Fork of Beargrass Creek (mile 0.0 to 6.9)	First	Swimming (Nonsupport)	Pathogens
South Fork of Beargrass Creek (mile 0.0 to 2.7)	First	Swimming (Nonsupport) Aquatic Life (Partial Support)	Metals (Cadmium), Pathogens, Organic Enrichment/Low dissolved oxygen
South Fork of Beargrass Creek (mile 2.7 to 14.6)	First	Aquatic Life (Partial Support) Swimming (Nonsupport)	Pathogens, Organic Enrichment/Low dissolved oxygen
Ohio River (main stem) (mile 317.1 to 981.0)	Second	Fish Consumption (Partial Support)	Chlordane
Ohio River of Mississippi River (mile 609.7 to 617.6)	Second	Swimming (Partial Support)	Pathogens
Ohio River of Mississippi River (mile 606.8 to 609.7)	Second	Swimming (Nonsupport) Fish Consumption (Partial Support)	Pathogens, Poly-chlorinated Biphenols (PCBs), Dioxin
Ohio River of Mississippi River (mile 617.6 to 629.9)	Second	Swimming (Nonsupport), Fish Consumption (Partial Support) Domestic Water Supply (Nonsupport)	Pathogens, PCBs, Dioxin

1.3.3.2. OHIO RIVER CONSIDERATIONS

ORSANCO conducted a study of wet weather impacts on the Ohio River beginning in 2000, concluding with a final report in late 2004. The report is entitled, “Wet Weather Impact Study on the Ohio River - Louisville/Southern Indiana Area, 2004.” This study examined on a preliminary basis the impacts on water quality from wet weather discharges from major tributaries, WQTCs and CSOs in Kentucky and Indiana. The study area lay within the McAlpine Locks and Dams and Cannelton pools of the Ohio River, with the major communities of Louisville Metro, Kentucky, and Jeffersonville, Indiana being the major communities in the study area. The following is a summary of the major conclusions from the ORSANCO study.

- CSO sources account for about 18 percent of the fecal coliform load and 22 percent of the E. Coli load to the Ohio River on an annual basis. Louisville Metro’s share of the total annual fecal coliform load was 15.7 percent, and 16.9 percent of the annual E. Coli load.
- CSOs cause the pathogen criteria to be exceeded between five percent and 10 percent of the days during the recreation season. Although other days exceeded criteria, sources other than CSOs (tributary and upstream loads) were believed to be the causes.
- The ORSANCO model was believed to be very useful as a planning tool but was not well-suited for use as a predictor of absolute concentrations in the river.
- The report indicated that the most realistic CSO reduction scenario (control of most, but not all CSOs) would have very little benefit in reducing the frequency of days that exceed the single sample maximum water quality standard. Although, the report noted that the alternative would have a noticeable benefit in reducing peak in-stream concentrations.

- Eliminating CSOs appeared to be less beneficial than eliminating upstream and tributary sources (by five to 10 percent). It appears that either CSOs or tributaries alone will cause water quality exceedances because removing either one alone will not significantly reduce the days of exceedances; rather, reducing both would achieve significant benefits. This supports the watershed approach to achieving water quality standards.

The 2008 ORSANCO study also showed that controlling CSOs by 100 percent could reduce the number of days exceeding the fecal coliform and instantaneous maximum criterion from 60 percent to 40 percent, a 20 percent reduction. Data was presented for the removal of the total CSO load (without stormwater), and for the removal of only the sanitary component of the wet weather load (with stormwater). The latter includes the wet weather stormwater runoff loads that would continue to discharge to the river if sewer separation were implemented. Comparison of the two options indicate that sewer separation would be of negligible benefit, since the number of days exceeding the instantaneous maximum would be nearly the same for the sewer separation case as it is for the existing condition case. Thus, the 20 percent reduction seems to be achievable only if both the CSO and stormwater loads of bacteria were substantially reduced (>95 percent).

MSD continues to receive Ohio River water quality data from ORSANCO. During the contact recreation season, ORSANCO regularly samples for E-coli and fecal coliforms. On a weekly basis ORSANCO samples for river conditions and E-coli. On a bimonthly basis, ORSANCO samples for various water quality parameters to evaluate attainment of established water quality criteria. Every two years, ORSANCO completes the Ohio River Water quality Conditions 305(b) Report to confirm the river is of sufficient quality for its intended uses. Every ten years, ORSANCO evaluates water quality trends including ecological conditions. Information and result of ORSANCO's water quality programs is found at www.ORSANCO.org.

1.3.3.3. BEARGRASS CREEK WATERSHED

Many efforts have been undertaken since 1999 to obtain better information on the pollutant load characteristics being discharged into Beargrass Creek from CSOs, sanitary sewer overflows (SSOs), and stormwater discharges. One effort included a sampling program in 1992 and 1993 in which samples were taken at several CSOs and at several locations in-stream. Other sources of data were included in The Synthesis Report of 1999, which summarized sampling results taken in the Beargrass Creek Basin over several years.

Beginning in 2005, a significant monitoring and modeling effort was undertaken to support the development of TMDLs as well as development of a WQT model. The continuous monitoring effort consisted of 14 in-stream, "continuous" monitors collecting water temperature, pH, dissolved oxygen, dissolved oxygen saturation (percent dissolved oxygen), and specific conductance at 15-minute intervals. Ammonia data were also collected using continuous monitors at some locations. Three United States Geological Survey (USGS) gauges monitored "continuous" (15-minute interval) stream flow data. Discontinuous data was collected during both dry and wet weather conditions. Sampling occurred within the stream, at CSO locations, and from runoff from specific land uses according to the Quality Assurance Project Plans (QAPPs) developed specifically for the Beargrass Creek WQT/TMDL project.

An additional discrete event sampling project was conducted to support the WQT Model calibration/validation. Eight CSOs in the Beargrass Creek watershed were selected based on a sample population of 15 percent of the total CSO population. Each of these sites was sampled for E. Coli, total phosphorus, total nitrogen, TSS, and biochemical oxygen demand. The eight sites also had flow meters in place recording flow and probes were in place measuring temperature, conductivity, pH, and dissolved oxygen. The maximum CSO samples collected per site is nine, included eight grab samples and one event composite at a time interval of 15 minutes for the first hour and every two hours up to six hours.

In-stream samples were collected to define background loading as well as to characterize the individual impacts of the CSOs on the receiving waters of Beargrass Creek. A total of 23 sites were sampled for the same parameters as CSOs.

MSD continues to collect water quality samples from 16 sites along Beargrass Creek. MSD staff compiled bacteria and flow data collected near the Big 4 sites used to compute Event Mean Concentrations (EMCs) for 4 wet weather sample events: October 2010; September 2013; July 2014; and June 2017. It was determined that the June 2017 event too much antecedent rain to be considered a qualifying event. Details regarding MSD's current water quality sampling program are provided in Chapter 2, Section 2.4.5.

1.3.3.4. CSO DISCHARGES AND WATER QUALITY ISSUES

The ORSANCO study showed that CSOs are a significant source of bacteria loadings to the Ohio River. However, other sources, such as tributaries and stormwater discharges, also contribute substantially to the bacteria loadings. Further definition of the relative significance of these sources has been undertaken during the development of the Final LTCP. Dissolved oxygen was not identified as a concern in the 303(d) listing for the Ohio River (refer to Table 1.3-3).

In the Beargrass Creek watershed, the presence of pathogens, organic enrichment, some metals, and low dissolved oxygen, is common in all the tributaries. The Beargrass Creek TMDL effort currently under way in the watershed will identify the respective contributions of CSOs, stormwater discharge loads, and potential other sources, and develop a strategy for controlling the varied sources to meet water quality standards, if possible.

1.3.4. INTEGRATION OF CURRENT CSO CONTROL EFFORTS

In accordance with Paragraph 24a of the Consent Decree, MSD was required to implement an Early Action Plan (EAP). The purpose of the EAP is the immediate reduction of overflow events through improved operation and control of MSD's collection, conveyance, and treatment system.

As outlined in Volume 1, Chapter 4, MSD's EAP for CSO Program is based on the EPA document, "Combined Sewer Overflows Guidance for Nine Minimum Controls", plus capital improvements and SSO related initiatives. The NMC are technology-based actions or measures designed to reduce the number of CSO events and to mitigate their effects on water quality. As required by the Consent Decree, MSD submitted a NMC Compliance Report to the EPA and the KDEP on February 10, 2006. MSD received an approval letter dated February 22, 2007, for the NMC Compliance Report.

The following is an overview of MSD's implementation of the NMCs.

<u>NMC 1- Proper Operation and Maintenance Program</u>

MSD established an integrated program to train responsible staff on the inspection and maintenance of critical assets of the CSS system to allow for their effective operation. These critical assets included the collection system, catch basins, CSO structures, pump stations, and the Morris Forman WQTC.

<u>NMC 2- Maximization of Storage in the Collection</u>

MSD maximized the in-system storage capacity of the existing CSS, thereby reducing the discharge volume, frequency, and duration of CSO events. MSD achieved compliance by documenting actions that increased the usable storage capacity of the CSS. Examples of maximizing in-system storage capacity included installation of flap gates on selected CSO outfalls tributary to Beargrass Creek and the Ohio River and raising the dams and weirs of selected CSO structures to achieve an increase in available storage capacity. Other actions taken by MSD to reduce the flow of water into the CSS included the repair of a leaking water reservoir and the installation of pervious pavement to reduce the volume of stormwater runoff entering the CSS during wet weather events. Additionally, the Plumbing Modifications Program was expanded to increase the removal of direct downspout and sump pump connections from the CSS. A significant increase of in-system storage capacity was also achieved with the implementation of the Supervisory Control and Data Acquisition (SCADA) and RTC systems that allow MSD to maximize the storage capacity of the CSS by predicting wet weather events, and monitoring and controlling the flow through the CSS.

NMC 3- Review and Modification of Pretreatment Requirements

MSD routinely inventories and inspects the facilities of private businesses within its service area when necessary, evaluates feasible modifications to the existing Pretreatment Program, Hazardous Materials Ordinance/Spill Prevention and Control Plan and the Industrial / Commercial Plumbing Plan Review Program.

NMC 4- Maximization of Flow to the Publicly Owned Treatment Works for Treatment

Using the RTC system to divert wet weather flow from CSO locations to the Morris Forman WQTC, MSD developed and implemented a program to increase the wet weather treatment capacity of the Morris Forman WQTC. The wet weather treatment capacity of the Morris Forman WQTC was increased from 225 MGD to a short duration peak flow capacity of 350 MGD with a sustainable capacity of 325 MGD via construction completed in 2000. In addition, MSD increased the capacity of select pump stations to convey additional wastewater flow to the Morris Forman WQTC. Upgrades and modifications of certain pump stations have allowed MSD to further increase wet weather flow to the Morris Forman WQTC. Typical modifications at these pump stations included increasing their wet well volume or raising the dam levels to allow more wastewater to be stored in-system. The stored wastewater is then pumped to the Morris Forman WQTC as capacity becomes available.

NMC 5- Elimination of CSOs during Dry Weather

MSD reviewed and assessed the causes of previous dry weather overflows and took immediate corrective actions necessary to remediate each occurrence. Examples included mechanical repairs or upgrades at the WQTCs and pump stations, installment of back-up power generators, increasing the elevation of overflow dams, and removal of CSS blockages. To prevent the occurrence of additional dry weather overflows, MSD uses a variety of programs such as routine inspection and maintenance of the CSS as well as computer models simulations of the CSS to predict the location of potential DWOs and evaluate cost-effective solutions.

NMC 6- Control of Solids and Floatable Materials in CSOs

MSD evaluated modifying in-line controls such as dams and weirs and installing end-of-pipe control devices to remove S&F materials from CSO discharges. In-line control devices function by keeping S&F within the CSS, thereby preventing them from exiting the system and entering the receiving waters. End-of-Pipe control devices also remove S&F but are placed external to the CSS. MSD has installed appropriate S&F controls on CSOs including constructed steel screen/cages placed over the discharge points as well as constructed baffles immediately upstream of the CSO dam. MSD personnel maintain manual cleaning of the S&F devices on a regular basis to maintain the effectiveness. MSD routinely cleans approximately 30,000 catch basins in the CSS per year. Additionally, MSD partnered with the Louisville Metro Government and other community organizations to implement watershed level activities to reduce S&F from entering the CSS.

NMC 7- Pollution Prevention Programs to Reduce Contamination in CSOs

MSD administers several programs to address pollution prevention. These include the Erosion Prevention and Sediment Control Program and the Hazardous Materials Ordinance Program. MSD also takes an active role in administering the Industrial Pretreatment Program and the distribution of educational materials discussing BMPs for fats, oils, and grease (FOG) and mercury disposal. Wet weather flow minimization and water conservation are also relevant factors to this minimum control because they can reduce the frequency, volume, and duration of CSO events. MSD promotes water conservation by providing incentives for significant industrial users to reduce their discharge volumes and promotes and financially supports rain barrel and rain garden programs. MSD also supports and participates in numerous public education programs that target pollution prevention, including mass media campaigns and involvement with the Beargrass Creek Watershed Council, and the Youth Environmental Leadership Institute.

NMC 8- Public Notification

To ensure the public is aware of potential and actual overflows, MSD informs the public as to the location of existing CSO outfalls, as well as ongoing programmatic outreach and educational activities. Event based activities are initiated when a CSO event occurs or is likely to occur. Examples of event-based notification activities include door hangers, verbal, and e-mail alerts, as well as a Sewer Overflow Advisory Level on MSD's website. Programmatic outreach and educational activities vary in an effort to reach the public and include warning signs posted at all CSO outfalls and at public access areas that are downstream of CSO outfalls. Lastly, MSD mails and posts on its website newsletters to notify, inform, and update the public as to the progress of various programs and efforts of programs and projects to reduce the frequency, volume, and duration of CSOs. More details regarding MSD's Public Notification programs is provided in Volume 1, Chapter 3.

NMC 9- Monitoring to Characterize CSO Impacts and the Efficacy of CSO Controls

MSD updates infrastructure mapping and databases to record the geographical locations and physical conditions of existing CSS and CSO structures. In addition, MSD collects an extensive number of measurements and stores this data in a database. The measurements taken describe the quantity of CSO, and the quantity and quality of both the CSS waste stream and the receiving waters. Measured values include flow rates, nutrients, pH, biochemical oxygen demand, chemical oxygen demand, TSS, temperature, and dissolved oxygen. Using this information, MSD is able to assess the effectiveness of previously implemented CSO control measures. An important outcome of such extensive monitoring and documentation are the production of computer simulations of the existing CSS. The computer simulations allow MSD to estimate the impact of CSO events upon the receiving waters, and to predict the effect of implementing various alternatives upon the frequency, volume, and duration of CSOs.

1.3.5. WATERSHED APPROACH TO CSO CONTROL PLANNING

MSD has promoted the use of a watershed approach for improving water quality. The watershed approach, as it is commonly defined, provides a holistic framework for managing all the factors that influence water quality with a specific drainage area. MSDs watershed overall approach is described in Volume 1 of the IOAP.

For the Final LTCP, the watershed approach is multi-scale, ranging from a site-specific end-of-pipe solution to a regional scale source reduction program. The watershed approach incorporates both "gray" technologies and "green" infrastructure solutions as well as other solutions that bridge the separate SSS and CSS.

1.3.5.1. INTEGRATION OF SSS AND CSS

The current CSS baseline condition receives approximately 45 percent of the total sanitary flow conveyed to Morris Forman WQTC from the separate SSS. Six boundary points separate sanitary flows that contribute to the CSS.

The boundary points are shown on the system map in Chapter 2, Figure 2.4.27 and are as follows:

- Beargrass Creek Interceptor, downstream of Southeastern Diversion Structure
- Goldsmith Lane Trunk Sewer
- Middle Fork Trunk Sewer at Park Boundary Road
- Northern Ditch Pump Station
- Ohio River Force Main (ORFM)
- Mellwood Trunk Sewer

The approach taken to integrate the SSS and the CSS for development of the Final LTCP was to apply the benefit/cost analysis to projects at or near these six boundary points. Chapter 3 details a comprehensive list of projects developed at the onset of the LTCP process. Some projects evaluated included benefit for both the SSS and the CSS. Examples of solutions developed within the SSS that also benefited the CSS included traditional end of pipe control technologies and separate SSS projects that off-loaded flow upstream of the CSS. Likewise, CSS projects, which reduced the inflows, created capacity in the interceptor pipe and thus benefit the SSS projects. As presented in Chapter 4, several of these projects were selected as the best alternatives.

1.3.5.2. GREEN INFRASTRUCTURE INITIATIVE

Throughout the public outreach program, MSD received a recurring appeal to integrate green technologies to reduce the frequency and volume of CSO discharges. Because of this encouragement and the dedication of leadership, MSD made a commitment to integrate green technologies into the Final LTCP.

Green opportunity evaluations were performed on each sewershed that contained an active CSO. This process was a coarse evaluation to determine potential opportunities to implement green infrastructure within each sewershed. The goal of this exercise was to identify strategies to reduce the amount of stormwater runoff that enters the CSS, thus reducing overflow frequency, duration, and volumes. This evaluation led to the identification of specific green projects and programs that could be implemented throughout the combined system.

The system-wide evaluation led to a recommendation to develop and implement a series of Green Infrastructure Programs that includes downspout disconnection, residential rain gardens, a rain barrel program, and green roof incentives. In an effort to estimate conservatively the net benefits of these programs in terms of CSO mitigation, MSD considered only the reductions from the proposed downspout disconnect program in the modeled reduction in runoff volume.

To determine the impact of the disconnection program on CSO activity, each sewershed was evaluated in terms of the anticipated number of downspouts that could reasonably be expected to be removed. This value was translated into a total impervious area removed from the CSS. This reduction was then applied uniformly across each sub-sewershed in the model, resulting in an estimated reduction in CSS activity. It is important to note that very conservative estimates were used in the basic assumptions from which these CSO reductions are derived. Chapter 3 Section 3.2.5 provides a detailed description of this analysis.

In addition to the proposed green programs, 19 green demonstration projects sites have been identified and evaluated. Project site locations were selected based on soils, geology, public visibility, property ownership, etc. For each proposed demonstration project, a project location and associated drainage area was determined. Each proposed project was then evaluated to estimate the effective reduction in impervious area for that particular site. This information was then input into the CSS model to evaluate the impact on CSO activity associated with the particular project.

It is important to note that the location of the project within the site drainage area as well as the overall size of the CSO drainage area has a significant bearing on the impact of the proposed project. For example, when evaluating the impact of a single project located within a large sewershed with an active CSO, the model may indicate little benefit in terms of reducing CSO activity. However, when this same project is evaluated on a site level comparing existing runoff to post development runoff using green infrastructure, significant reductions in loadings to the CSS are usually realized. In addition, cumulative effects of numerous site level reductions will, over time, result in overflow reductions. Therefore, when evaluating the benefits of green infrastructure, care should be taken in the interpretation of the results to ensure that a fair and accurate assessment is made.

Once the green demonstration projects and programs have been implemented, monitoring and modeling will determine the effectiveness of these controls on the reduction of stormwater runoff entering the CSS and the corresponding impact on CSO activity. The net result of the Green Infrastructure Program will potentially allow the proposed gray CSO controls, such as tanks and pipes, to be downsized or possibly eliminated due to the reduction in stormwater runoff entering the CSS.

1.3.6. SENSITIVE, PRIORITY, AND RECREATIONAL USE AREAS

EPA's CSO Control Policy requires a recreational use survey and a sensitive area study be performed in preparation of a LTCP. This work is to assist with identifying locations along the stream with the greatest potential for public contact and to prioritize implementation of CSO controls.

1.3.6.1. SENSITIVE AREAS

EPA's CSO Control Policy requires that sensitive areas be given the highest priority for implementation of CSO controls. Typically, identifying sensitive areas within the watershed of concern provides a framework for developing a cost-effective, phased approach to CSO control implementation and selection of abatement alternatives. However, all waters of Beargrass Creek within the CSS have been identified as sensitive, based on their designation as primary contact waters and their potential to contain species identified as threatened, endangered, or of special concern. Thus, additional prioritization was necessary to develop a phased approach to implementing CSO controls.

MSD conducted an ecological reach characterization of Beargrass Creek, in support of the CSO control decision-making process, to effectively implement a phased approach to CSO control in the Beargrass Creek watershed. A characterization framework for prioritizing sensitive areas was constructed based on the degree of benefit anticipated to be gained by various control measures. A summary of this work is below. A more detailed presentation of this work follows in Chapter 2, Section 2.2.8 of this Volume.

The basis of this characterization framework was to segment Beargrass Creek within the CSS into discreet stream reaches and rate them based on an ecologically sensitive, multi-parameter approach. This framework addressed ecological factors for evaluating CSO control project alternatives, which were then used in conjunction with the various other factors for overall control efforts prioritization. The rating scale reflects the ecological condition of each stream reach and the degree of benefit to be gained by water quality improvements.

"Ecological Condition" for these purposes was considered to be the existing, or realistic potential of, stream-related communities in terms of biological integrity, ecological function, and aesthetic/public health value. Based on this approach, reaches with high ratings would realize greater benefit from water quality improvements and, therefore, should be given higher priority during the CSO control and implementation decision process.

Ten parameters were identified to measure the ecological condition of each stream reach. A multi-parameter approach was necessary to accurately characterize existing/potential condition of stream reaches, especially in this highly urbanized environment. The parameters used for this characterization include:

- **Accessibility** – A measure of the potential for human contact with the creek. Data was obtained through field observations.
- **Threatened/Endangered Species** – A defined component of sensitive area study. This data was obtained from the Kentucky State Nature Preserves Commission.
- **Stream Rapid Bioassessment Protocol** – A method for assessing stream habitat quality and its ability to harbor a healthy ecological community.
- **Bank Erosion Hazard Index** – A measure of the potential for streambank erosion.
- **Index of Biotic Integrity** – An index developed for rating fish community assemblages as an indicator of the degree of impact from pollutants.
- **CSO AAOV** – Discharge modeled for each CSO for a synthetic typical year rainfall.
- **Land Use** – A classification system describing the types of human activities for a given area. For example, parks, residences, industrial uses.
- **Landcover** – Types of vegetative or manmade features covering a landscape.
- **Restoration Potential** – A qualitative assessment of benefits a stream reach may realize considering the level of effort required to restore aquatic/riparian habitat functions.
- **Reach Length** – The physical measurement of each reach.

Because CSOs impact a diverse set of constituents, numerous factors must be considered when prioritizing and evaluating CSO control alternatives. The ecological reach characterization is one component of a multifaceted decision process framework that was used in LTCP development. The tool provided a means for comparing individual stream reaches of Beargrass Creek within the CSS in terms of ecological condition. The results do not imply that stream reaches with high priority ratings should be the sole target for CSO abatement activities since all portions of Beargrass Creek must meet water quality standards. Results of this prioritization process and ecological reach ranking were one of several variables integrated into the Final LTCP projects selection process and implementation schedule.

1.3.6.2. RECREATIONAL USE

EPA's CSO Control Policy also requires that a Recreational Use Survey be performed to assist in identifying the locations with the greatest potential for public contact with sewer overflows. MSD conducted a Recreational Use Survey within the Beargrass Creek and Ohio River Watersheds (refer to Table 1.3-4). An overview of the study is below, and details are presented in Chapter 2, Section 2.7 of this Volume. The Beargrass Creek watershed was further subdivided into three forks: Muddy Fork Beargrass Creek; Middle Fork Beargrass Creek; and South Fork Beargrass Creek.

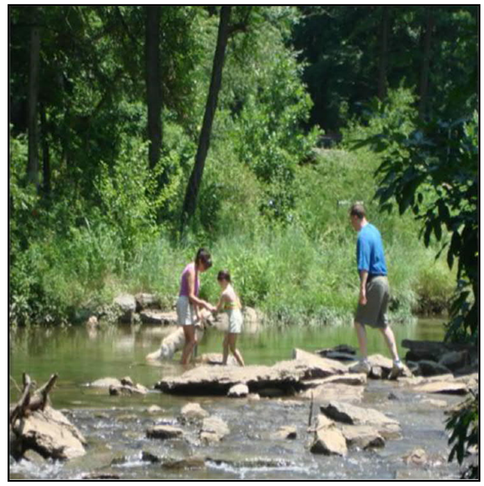
Table 1.3-4 List of Recreational Use Survey Sites (2009)

SITE NUMBER	SITE NAME	WATERSHED
1	Riverside, Farnsley-Moremen Landing	Ohio River
2	Riverview Park	Ohio River
3	Waterfront Park	Ohio River
4	Cox Park (Public Boat Ramp)	Ohio River
5	Louisville Soccer Park	Beargrass Creek Muddy Fork
6	Cherokee Golf Course	Beargrass Creek Middle Fork
7	Cherokee Park	Beargrass Creek Middle Fork
8	Seneca Park (Scenic Loop and Maple)	Beargrass Creek Middle Fork
9	Seneca Park (Big Rock)	Beargrass Creek Middle Fork
10	Seneca Golf Course (1-mile stretch)	Beargrass Creek Middle Fork
11	Brown Park	Middle Fork Beargrass Creek
12	Joe Creason Park	Beargrass Creek South Fork
13	Louisville Junior Academy	Beargrass Creek South Fork
14	Eva Bandman Park	Ohio River
15	Eva Bandman Park	Beargrass Creek Confluence
16	Beargrass Creek at Irish Hill	Beargrass Creek Middle Fork
17	Butchertown Trail	Beargrass Creek Confluence

The Recreational Use Survey was conducted from May 1, 2007, through November 29, 2007, to coincide with the Kentucky recreational season. During site visits, field data at each site was reported on a form entitled, "Field Data Sheet for Recreational Use Stream Survey." Additionally, a minimum of three photos were taken per site (upstream, downstream, and observed recreational activity). Field data reported on the form included:

- Site Information: Name, Location Description, Global Positioning Satellite (GPS) Coordinates
- Photo IDs
- Date and Time
- Personnel
- Current Weather Conditions
- Weather Conditions for Past Seven Days
- Number of People Observed
- Recreational Activities Observed
- Type of Water Contact

A summary sheet was created to summarize the field data for all the survey sites. Field data included on the summary sheets include the site description, number of people observed, recreational activities observed, and magnitude of water contact.



Results were divided in the following categories:

- Adults observed at the site
- Children observed at the site
- Adults observed participating in non-contact activities
- Children observed participating in non-contact activities
- Adults observed participating in contact activities
- Children observed participating in contact activities
- Contact observed

In order to provide assistance in evaluating and selecting overflow control approaches that protect public health, the recreational use survey site locations with the greatest potential contact with CSOs were identified and prioritized. The final results of this survey were used in the evaluation of overflow control measures.

The following four parameters were selected to rank and prioritize the survey site locations:

- Average number of people observed per site visit
- Percent contact observed
- Potential for water contact
- Percent children observed

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FIGURE 1.1.1
CSO PROGRAM ACCOMPLISHMENTS

MILESTONE:	YEAR:	CSO ABATEMENT PROJECTS:
MSD Initiated CSO Abatement Program	1991	1991–1993: • BMP Evaluations Conducted • Sewer System Flow Monitoring • CSO Inventory • CSO & Stream Sampling • CSO Model Developed
First Combined Sewer Operational Plan (CSOP) to KDOW	1993	
Yearly Reporting to KDOW	1994	1994–1998: • Solids & Floatables Demonstration Projects • Central Relief Drain Cleaning • BMP Evaluations • Increase Overflow Weir Height • CSO143 Elimination • CSO065 Elimination • CSO162 Elimination
CSO LTCP Submittal	1996	
Nine Minimum Controls	1998	1998–2001: • Sneads Branch In-Line Storage • Increase Overflow Weir Height • Upper Dry Run Trunk Storage • Wheeler Basin Storage • Robert J. Starkey Pumping Plant Modification • CSO108 CDS Facility • CSO123 Elimination • CSO088 Sewer Separation Project • CSO080 Elimination • CSO209 Sewer Separation Project • CSO147 Sewer Separation Project • CSO049 Elimination • CSO204 Elimination
	2000	
	2001	2001–2005: • Airport Deicing Project • Stormwater Drainage Improvements • Pumping Station Upgrades • Morris Forman WWTP Upgrade • MDS Inflatable Dam • Flow Maximized to Morris Forman WWTP • Real Time Control Studies • Real Time Control Phase I Improvements • Sewer Diversions • Solids & Floatables Facilities • Sewer Cleaning at NSTS • CSO080 Elimination • CSO145 Elimination
	2002	
	2004	
Entered Into Consent Decree	2005	2005–2006: • Prepared Consent Decree Documents • Real Time Control Phase I Implementation Project • CSO209 Elimination Project
Interim LTCP	2006	2006–2008: • Solids & Floatables Control - System Wide • CSO206 Sewer Separation Project (On-Going) • CSO147 Elimination Project • CSO087 Sewer Separation and Elimination Project • Real Time Control Phase II Implementation Project • CSO081 Elimination Project • CSO194 Elimination Project • CSO032 Elimination Project • CSO033 Elimination Project • CSO030 Elimination Project
	2008	

MSD Metropolitan Sewer District

PROJECT WIN Waterway Improvements Now

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APRIL 30, 2021

Safe, clean waterways

2021 IOAP MODIFICATION

VOLUME 2 FINAL LTCP, CHAPTER 2

METROPOLITAN SEWER DISTRICT

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLES

TABLES

FIGURES

FIGURES

FIGURES

FIGURES

APPENDICES

Note: Appendices shown in italic text were not revised for the 2021 IOAP and remain the same as the 2012 IOAP Modification. All appendices have been provided on a separate USB flash drive and are not included in this report.

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Chapter 2: SYSTEM CHARACTERIZATION

Special Note: This chapter was developed in 2009. The statistical data for the CSO's reported, specifically related to individual CSO overflow volumes in a typical rainfall year, were derived from the CSS model calibrated in 2007. Since then, a more detailed calibration and validation effort has adjusted the average annual overflow volumes and frequencies in the Typical Year. The general process described for hydraulic model building was followed to develop the 2009 Final LTCP, and the descriptions for the initial model building reflect 2009 system conditions. Any subsequent calibrations to the hydraulic models still follow the same procedures and guidelines discussed in this chapter. Project modifications and the changed conditions that resulted in project modifications are described in individual modification letters and are summarized in Chapters 3 and 4. The Volume 2, Chapter 2 appendices remain the same as those provided with the 2012 IOAP.

2.1. SYSTEM CHARACTERIZATION OBJECTIVES

The purpose of combined sewer system (CSS) characterization, monitoring, and modeling is to better understand the response of the system to various wet weather events, the characteristics of the overflows, and the water quality impacts that could result from combined sewer overflow (CSO) discharges. The CSS characterization information is imperative to developing a CSO control plan adequate to meet the Clean Water Act (CWA) and Amended Consent Decree (ACD) requirements. For the purposes of the Integrated Overflow Abatement Plan (IOAP), except where specifically noted otherwise, the term "Consent Decree" will be understood to mean the ACD as it was entered into Federal Court on April 15, 2009.

The major elements of a sewer system characterization are listed below with the description from the United States Environmental Protection Agency (EPA) Guidance: Combined Sewer Overflows Guidance for Long-Term Control Plan (EPA 832-B-95-002). Subsequent sections of this Volume describe major elements in more detail:

- **Rainfall Records** - "permittee should evaluate flow variations in the receiving water body to correlate between CSOs and receiving water condition"
- **CSS Characterization** - "permittee should evaluate the nature and extent of its sewer system through evaluation of available sewer system records, field inspections and other activities..."
- **Monitoring** - "monitoring program that measures the frequency, duration, flow rate, volume and pollutant concentration of CSO discharges and assesses the impact of the CSOs on the receiving waters." This includes the following: number of CSOs, locations of CSOs, frequency of CSOs, volume of CSOs, concentration and mass of pollutants discharged at CSOs, impacts of the CSOs on the receiving waters and their designated uses, and mathematical modeling.

The characterization of the Louisville and Jefferson County Metropolitan Sewer District's (MSD) CSS was performed as outlined above, through review of existing information, field investigation, monitoring, and mathematical modeling of the sewer system.

2.2. IMPLEMENTATION OF NINE MINIMUM CONTROLS

The EPA CSO Control Policy, published April 19, 1994, provides guidance to stakeholders for coordinating the planning, selection, and implementation of CSO controls that meet the requirements of the CWA.

Among other things, the Policy establishes two main objectives for permittees: implementation of nine minimum controls (NMC), and development and implementation of a Long-Term Control Plan (LTCP).

As the name implies, a LTCP is intended to be a far-reaching plan that presents a comprehensive approach to the identification, evaluation, and implementation of long-term, capital-intensive controls to reduce the impact of CSOs. The development and implementation of a LTCP can take several decades to complete.

Conversely, it was intended that the NMCs "reduce CSOs and their effects on receiving water quality, do not require significant engineering studies or major construction, and can be implemented in a relatively short period of time." [1] The EPA envisioned that "implementing the nine minimum controls is among the first steps a municipality should take to reduce combined sewer overflow impacts." [2] Similar to the intent of the LTCP, efforts undertaken for the NMCs are not considered as temporary measures. They should be integrated into a community's long-term efforts to control CSOs. The intent of the nine minimum controls is as follows:

- Proper operation and regular maintenance programs for the CSS and the CSOs
- Maximize use of the collection system for storage
- Review and modification of pretreatment requirements to assure CSO impacts are minimized
- Maximization of flow to the publicly owned treatment works (POTW) for treatment
- Elimination of CSOs during dry weather
- Control of solid and floatable materials in CSOs
- Pollution prevention programs to reduce contaminants in CSOs
- Operating Programs Public notification to ensure that the public receives adequate notification of CSO occurrences and combined sewer impacts
- Monitoring to characterize effectively CSO impacts and the efficacy of CSO controls

2.2.1. HISTORY OF NINE MINIMUM CONTROLS

MSD began the initial phase of a CSO abatement program in 1991, prior to the release of the EPA guidance. These initial efforts included work on both the NMC and the LTCP. This initial effort culminated in the development of a Combined Sewer Operational Plan, which is contained in two documents: Combined Sewer Operational Plan 1996 Update, and 1997 Update. Also, in 1997, MSD prepared the NMC Compliance Report, which summarized NMC activities completed to date, showing compliance with EPA's Combined Sewer Overflow Control Policy January 1997 deadline for NMCs. Since 1997, MSD has continued to implement the NMC program and has prepared regular updates to the original Combined Sewer Operational Plan. In June of 2003, MSD prepared the NMC Compliance Report Update, which summarized the continuation of implementation of NMC activities from January 1997 through June 2003.

Additionally, as part of the Consent Decree, another updated compliance report was required. This comprehensive report titled, "Nine Minimum Controls Compliance Report," dated September 15, 2006, contains an updated summary of NMC activities completed throughout the life of the program up to

[1] US EPA, Combined Sewer Overflows, Guidance for Nine Minimum Controls, EPA 832-B-95-003, 1995 § 1.6

[2] ibid., § 1.8

September 2006. This report is available on the MSD website https://www.msdprojectwin.org under the library page.

In addition to the compliance report requirement in the Consent Decree, there were specific NMC activity requirements. A summary of the NMC Early Action Plan (EAP) requirements completed, as required by Paragraph 24a of the Consent Decree, are summarized in Volume 1, Chapter 4, Section 4.1.4 of this IOAP.

2.2.2. CONTINUATION OF NINE MINIMUM CONTROLS

MSD continues its efforts for NMCs with a focus on high value and sustainable activities. An example is proper operation and sustained maintenance of the collection system through inspection and cleaning of catch basins and sewer mains. Another example is reducing the potential for dry weather overflows through increased inspection and maintenance of “hot spots,” such as areas impacted by fats, oils, or grease (FOG). These activities are managed through MSD’s Hansen Information Management System (Hansen). Other examples include pollution prevention efforts that are being expanded through greater enforcement of current pretreatment and hazardous materials ordinances, and increased interaction with non-domestic dischargers and significant industrial users.

Public notification is continually being enhanced through the “Project Waterways Improvement Now” (Project WIN) website, which is regularly updated to include current and pertinent information related to the implementation of the NMCs and LTCP. Moreover, the frequency of public meetings is increasing, and the content of these meetings is expanding with the implementation of the NMCs and development of the Final LTCP.

MSD continues to submit quarterly and annual status reports documenting the accomplishments of the NMC program as required by the Consent Decree. These reports are available on MSD’s website for the public to review.

Detailed examples of MSD's efforts for continuation of NMC activity as a long-term program include:

1. Proper operation and maintenance (O&M) programs
    - In-field inspection of CSOs
    - Regular cleaning and tele-inspection of CSS pipes and siphons
    - Regular updating of the CSO inventory which contains drawings and key physical data of each CSO asset
    - Work order management system (Hansen) for inspection, maintenance, and documentation of CSOs
    - Annual training for personnel who inspect and maintain CSOs; this training also includes topics such as coding of field data and overflow response
2. Maximize use of the collection system for storage
    - Regular hydraulic analysis of the CSO overflow structures, seeking new opportunities to remove regulators or raise dams for additional in-system storage
    - Evaluating and revising the operational set points of the Real Time Control (RTC) system to increase in-system storage
    - Maintaining a robust hydraulic computer model of the CSS as an evaluation tool for improvement to maximize storage options

3. Review and modification of pretreatment requirements to minimize CSO impacts
    - Field inspection of streams and creeks for illicit discharges
    - On-going quality and quantity monitoring of non-domestic discharges that discharge to the CSS
    - Notification to non-domestic discharges of upcoming rain events requesting "wet weather control strategies" be implemented for upcoming event
    - Required wet weather control strategies (that is, hold and release and/or delayed cleaning operations during and for a certain time after wet weather events of a defined level by receiving CSO) for new wastewater discharge permits issued to facilities discharging to the CSS
    - Evaluated green infrastructure opportunities for existing permittees undergoing expansions
4. Maximization of flow to the POTW for treatment
    - On-going tracking of flow at Morris Forman Water Quality Treatment Center (WQTC), striving for increased treatment at the plant
    - Regular analysis of the Morris Forman WQTC for operational changes to increase combined sewage flow treated
5. Elimination of CSOs during dry weather
    - Weekly inspections of CSOs to address potential dry weather overflows
    - On-going monitoring of possible dry weather overflow data to address recurring dry weather overflows situations programmatically
6. Control of solid and floatable materials in CSOs
    - Regular maintenance of installed solids and floatables (S&F) devices at the CSOs
    - Regular cleaning of trapped street curb inlets, to collect and remove trash and grit from street runoff
    - Commitment to install more robust S&F control technologies at LTCP projects
7. Pollution prevention programs to reduce contaminants in CSOs
    - Regular cleaning of trapped street curb inlets, to collect and remove trash and grit from street runoff
    - On-going coordination with Louisville Metro Public Works to maintain commitment to regularly clean streets and pick up litter
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and combined sewer impacts
    - Annual inspection and maintenance of overflow advisory signage along the Ohio River and forks of Beargrass Creek
    - Annual mailing of information about CSOs to customers within 500 feet of the Ohio River and forks of Beargrass Creek

- Maintaining the Project WIN website which includes public document repository of program outreach and documents and quarterly and annual reports
- Automatic email service that sends emails notifying customers of possible CSO events
- Publishing MSD "Streamline" newsletter which is sent to customers to inform them of various program activities. Examples include not pouring grease down the sink, and staying out of streams after a rain event, etc.

9. Monitoring to characterize effectively CSO impacts and the efficacy of CSO controls
   - Monitoring the largest CSOs for overflow volume and frequency
   - Monitoring streams to obtain data such as stream flow, pH, dissolved oxygen, and other environmental data
   - Expanding CSS flow monitoring as part of each of the Final LTCP projects
   - Maintaining the existing rain gauge network which covers the entire MSD service area

2.3. USACE FLOOD PUMP STATION OPERATIONS

MSD has the responsibility for the operation and maintenance of an extensive flood protection system that was developed by the US Army Corps of Engineers (USACE) in the 1950s. A significant portion of this flood protection system, 11 of 16 flood pump stations and 162 flood control gates, are associated with MSD's CSS. Therefore, the flood protection system and the CSS operate in an integrated manner when the flood protection system is activated as a result of elevated Ohio River levels. When the USACE developed the flood protection system, their focus was to protect the community from flood damage. The minimization of overflows from the CSS was not the priority.

As a provision under the Consent Decree, entered into Federal Court April 15, 2009, MSD is required to provide for the following outcomes:

- Paragraph 25b, (2) A. (i) - "The final Long-Term Control Plan shall meet the following goals: Ensure that if CSOs occur, they are only as a result of wet weather (this goal shall include addressing those discharges resulting from MSD's compliance with the requirements of the USACE' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);"
- Paragraph 26b, (2) B. (i) - "The final Long-Term Control Plan shall include, at a minimum, the following elements: The results of characterization, monitoring, modeling activities and design parameters as the basis for selection and design of effective CSO controls (including controls to address those discharges resulting from MSD's compliance with the requirements of the USACE' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);"

Pursuant to this requirement of the Consent Decree, the flood pump station projects identified by this evaluation process to eliminate dry weather overflows became a component of the selected plan and were not subject to a cost-benefit analysis.

The USACE designed and constructed two types of flood pump stations within the CSS. There are dual-purpose flood pump stations that serve as both a sanitary pump station that conveys dry weather flow (DWF) to the interceptor and a flood pump station that conveys wet weather flow to the river during elevated river stages. Also, there is single-purpose flood pump station that serves only to convey wet weather flow to the river during elevated river stages. The following describes the various modes of operation that can exist at a flood pump stations and the potential for them to result in a dry weather overflow.

- **Sanitary Mode** – this mode only applies to dual-purpose flood pump stations. Sanitary pumps at the flood pump stations are set to discharge DWF to the interceptor, flood pumps are deactivated, and flood control gates are positioned to discharge wet weather overflows directly to the Ohio River as a permitted CSO. The dual-purpose flood pump stations are in this mode until the river level reaches the elevation of the top of the CSO dam and before the river mixes with the DWF. This USACE prescribed mode of operation does not result in dry weather overflows.
- **Plant Idle Mode** – this mode is different for the two types of flood pump stations and can be defined for each as follows:
    - Single-Purpose flood pump stations – the plant idle mode for single-purpose flood pump stations means that the facility is inactive and that flood control gates are positioned to convey wet weather flows directly to the Ohio River as a permitted CSO. This USACE prescribed mode of operation does not result in a dry weather overflow.
    - Dual-Purpose flood pump stations - the plant idle mode for dual-purpose flood pump stations means that all pumping at the facility has stopped, the flood pump stations have been isolated from the CSS and all flow is conveyed to the river during both dry and wet weather. During dry weather periods this USACE prescribed mode of operation results in a continuous dry weather overflow. During wet weather it results in a permitted CSO.
- **Minor Flood Mode** – this applies to single-purpose flood pump stations and indicates a mode of operation between plant idle and flood mode which requires the repositioning of selected flood control gates. The flood pumps are deactivated during this mode. There is the potential that the USACE prescribed mode of operation can result in a dry weather overflow.
- **Flood Mode** – this mode is different for the two types of flood pump stations and can be defined for each as follows:
    - Single-Purpose flood pump stations – the flood mode for single-purpose flood pump stations means that the flood pumps have been activated (energized) and are available to pump wet weather flows to the Ohio River as permitted CSOs and that all flood control gates are positioned to prevent the river from backing up into the CSS due to elevated river levels. This USACE prescribed mode of operation does not result in dry weather overflows.
    - Dual-Purpose flood pump stations - the flood mode for dual-purpose flood pump stations means that the flood pumps have been activated (energized) and are available to pump both wet and dry weather flows to the Ohio River and all flood control gates are positioned to prevent the river from backing up into the CSS due to elevated river levels. During dry weather periods this USACE prescribed mode of operation results in a continuous dry weather overflow. During wet weather it results in a permitted CSO

Throughout the development of MSD's CSO Abatement Program, specific opportunities were identified where modifications in the original procedures outlined in the USACE's Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988 (USACE Manual) could be modified to reduce overflows from the CSS and still maintain the integrity of the level of flood protection provided by the system. During 2002, MSD modified operating parameters at three flood pump stations (4th Street Flood Pump Station, 34th Street Flood Pump Station and Paddy's Run Flood Pump Station) and respectively modified the USACE Manual upon approval from USACE. These modifications reduced the frequency and volume of CSOs at these locations.

The following flood pump stations within the CSS were evaluated to define specific physical and/or operational modifications necessary to ensure that the USACE prescribed modes of operation, as described above, do not result in dry weather overflows:

- 4th Street Flood Pump Station and 17 flood control gates
- 5th Street Flood Pump Station and 7 flood control gates
- 10th Street Flood Pump Station and 11 flood control gates
- 17th Street Flood Pump Station and 10 flood control gates
- 27th Street Flood Pump Station and 12 flood control gates
- 34th Street Flood Pump Station and 20 flood control gates
- Beargrass Creek Flood Pump Station and 13 flood control gates
- Paddy's Run Flood Pump Station, Sluice Gate Chamber, and 15 flood control gates
- Shawnee Flood Pump Station and 24 flood control gates
- Starkey Flood Pumping Station and 8 flood control gates
- Western Flood Pump Station and 25 flood control gates

Figure 2.3-1 provides a location map for the eleven flood pump stations evaluated.

Figure 2.3-1 Locations of Evaluated Flood Pump Stations
Figure is located at the end of this chapter.

Appendix 2.3.1 is a USACE Flood Pump Station Operation Modification Technical Memorandum which provides a detailed summary of the 2009 operational modes of each of the considered flood pump stations and recommendations for operational and/or physical modifications. The results of the evaluation revealed that six of the flood pump stations required operational modifications and five required physical modifications to ensure that dry weather overflows do not result from mandated operational procedures as outlined in the USACE Manual. To implement the projects identified in the Technical Memorandum the following actions were taken:

- Developed plans and specifications for each of the identified projects.
- Prepared revisions to the USACE Manual that reflects the operational and physical modifications proposed by this Technical Memorandum.
- Secured review and approval by the USACE. Coordination with, and approval by the USACE will be required prior to any modifications being made to the congressionally authorized flood protection works for Louisville, Kentucky. A reasonable amount of time for USACE involvement has been included in the scheduled completion dates for the proposed projects. However, although it is not anticipated, delays in USACE approval and responses beyond these time estimates could impact scheduled completion dates.

Appendix 2.3.1 USACE Flood Pump Station Operation Modification Technical Memorandum
Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

2.4. DESCRIPTION OF SYSTEM/COMPILATION OF EXISTING DATA

The objective of the system characterization is to understand the complete CSS and receiving water to establish the existing baseline conditions. This section presents a detailed description of the physical characteristics of the CSS and receiving stream watersheds, as well as a description of the pipe network flow monitoring and CSS water quality sampling.

2.4.1. OVERVIEW OF CSO SYSTEM AND WATERSHED/SEWERSHED MAPPING

The sewer system owned, operated, and maintained by MSD has evolved for almost a century and a half into an extensive network of both sanitary and combined sewers, diversion structures, mechanical regulators, and other flow control devices, WQTCs, and pump stations. The expanse of the overall separate sanitary sewer service area and the limit of the older combined sewer area are exhibited in Figure 2.4-1. Morris Forman WQTC Service Area. The combined sewer area encompasses 24,000 acres (37 sq. miles) which is about one-third of the Morris Forman WQTC service area. MSD has subdivided the combined sewer area into three regions for study and evaluation purposes. A detailed description of the CSS within each region is provided in the following section (refer to Figure 2.4-2). As part of the green infrastructure analysis, MSD performed additional characterization of the entire combined system along with more detailed evaluations of each sewershed with active overflows.

Figure 2.4-1. Morris Forman WQTC Service Area

Figure 2.4-2. Combined Sewer System Region

Figures are located at the end of this chapter.

An important element of this analysis was a detailed evaluation of the impervious area characteristics across the entire CSS. The goal of the exercise was to determine the distribution of impervious area, including roadways, rooftops, parking lots and sidewalks, in an effort to understand the major sources of stormwater runoff to the CSS.

This data was further analyzed to calculate the distribution of impervious areas within each of the following land use classifications.

- Residential
- Commercial
- Industrial
- Parks/Open Space
- Vacant Land
- Public Space

Based on this evaluation, green infrastructure programs were developed targeting specific land use types. For example, downspout disconnection, and rain barrel and rain garden programs focus on residential land uses. In addition, MSD evaluated each CSO sewershed with an active overflow for the following information:

- Total area of roadways

- Total area of rooftops
- Total area of miscellaneous transportation (parking lots and sidewalks)
- Area of public rooftops
- Area of public parking lots
- Number of catch basins
- Area of single-family rooftops
- Number of single-family homes
- Suitability for downspout disconnect

This higher level of characterization allows MSD to properly evaluate and select green infrastructure techniques for individual sewersheds as well as the entire CSS. For specific results and a more elaborate explanation of this characterization effort, please refer to Chapter 3, Section 3.2.5.

2.4.2. COLLECTION SYSTEM UNDERSTANDING

2021 Update: As implementation of the IOAP continues, the CSS models are routinely reviewed, and calibration updated based on changing conditions and obtaining new and additional data. This section was written in 2009 based on 2007 model calibration. Updates to Typical Year performance are provided in the Annual Reports submitted as part of the Consent Decree. Previous tables showing 2009 AAOVs have been removed.

In the CSS, DWFs are conveyed to the Morris Forman WQTC to remove pollutants before discharging to the Ohio River. During wet weather conditions, when capacity of the CSS is exceeded, the excess flow, a mixture of sewage and stormwater runoff, is discharged to the South Fork Beargrass Creek, Middle Fork Beargrass Creek, Muddy Fork Beargrass Creek, and the Ohio River. The typical system constrictions are presented schematically and graphically in Figure 2.4-3 through Figure 2.4-6. The CSS receives flows from upstream separate sewer areas at six major boundary locations. Approximately 45 percent of the total sanitary flow conveyed to the Morris Forman WQTC is contribution from the upstream separate sewer system.

Figure 2.4-3. Typical System Constrictions Beargrass Interceptor Beargrass Creek Region

Figure 2.4-4. Typical System Constrictions Middle Fork Trunk Beargrass Creek Region

Figure 2.4-5. Typical System Constrictions Northwestern City Ohio River West Region

Figure 2.4-6. Typical System Constrictions Southwestern Outfall Ohio River West Region

Figures are located at the end of this chapter.

There are 106 active CSOs within the MSD service area. Figure 2.4-7 presents the distribution of CSO locations within each major geographical area: Ohio River North, West, and Beargrass Creek.

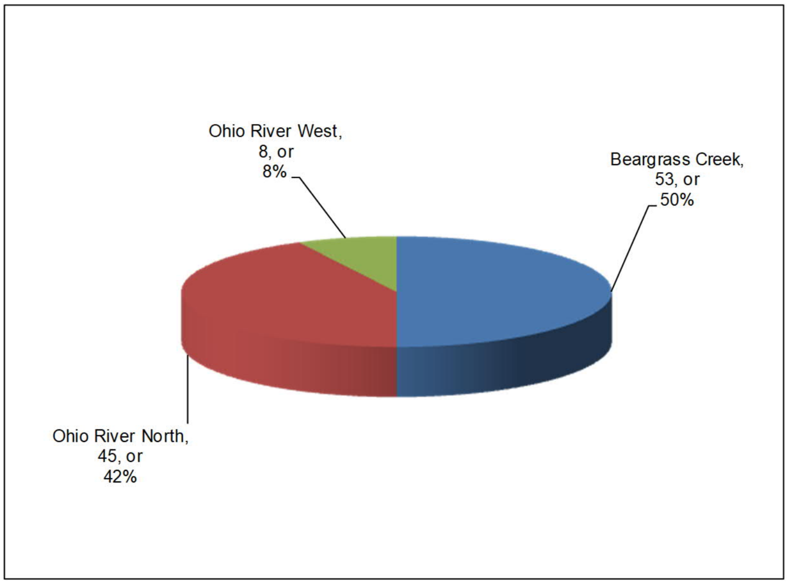


Figure 2.4-7 Number of CSOs per Region

A computer model was utilized to project the average annual hydraulic volume within the CSS. Figure 2.4-8 presents a summary of the Average Annual Overflow Volume (AAOV) by major geographical region, along with the percentage of the total CSO system volume by region (based on 2007 modeling data).

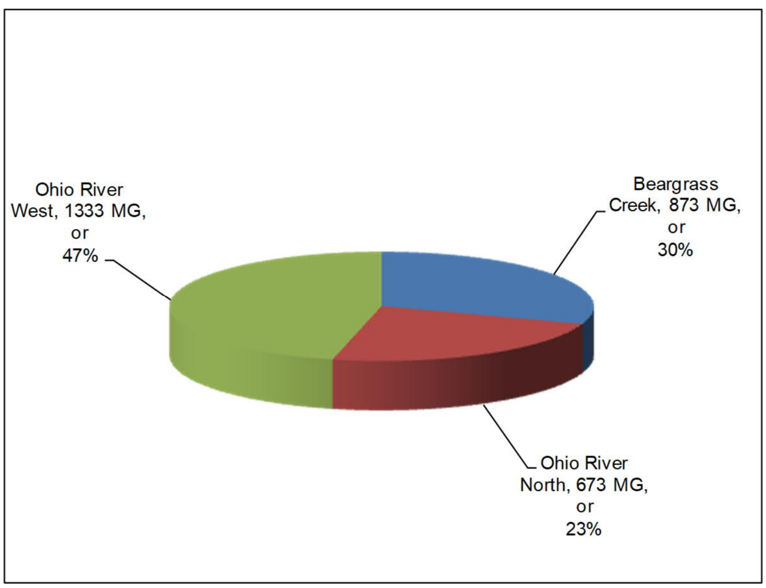


Figure 2.4-8 Volume of CSOs per Region (2009)

To project annual hydraulic loads, the following information was used:

- Typical rainfall year information described in Chapter 2, Section 2.4.3
- Calibrated computer simulation model described in Chapter 2, Section 2.4.6.

- Three United States Geological Survey (USGS) Stream Flow gauges were used to estimate the volume of stream flow on Beargrass Creek and Ohio River: USGS 03292500 South Fork of Beargrass Creek at Louisville, USGS 03293000 Middle Fork of Beargrass Creek at Old Cannons Lane, and USGS 03294500 Ohio River at Louisville.

2.4.3. RAINFALL MONITORING

Having accurate rainfall data is critical for proper CSS characterization, as well for performance monitoring of CSO controls that are in place. The EPA CSO Policy requires that the permittee evaluate flow variations in the receiving water body to correlate between CSOs and receiving water condition. This cannot be done without accurate rainfall monitoring.

2.4.3.1. RAINFALL MONITORING HISTORY

MSD has been monitoring rainfall since 1991. The initial rain gauges were installed in 1991 as a joint effort between MSD and the USGS and the information was to be used for MSD studies and USGS research.

In 1997, MSD took over sole responsibility for the rain gauge network. Because the data logger type rain gauges were non-telemetered, MSD personnel was required to download the information stored within each of the rain gauges. Though labor intensive, these rain gauges worked extremely well.

The rain gauges recorded total rainfall in five-minute increments. Eight of these gauges were located within or adjacent to the combined sewer drainage area and the data from these gauges were used in the model calibration process. The locations of these eight gauges are listed in and are shown in Table 2.4-1 and Figure 2.4-9 at the end of this chapter.

Figure 2.4-9 Original Rain Gauge Location Map

Figure is located at the end of this chapter.

Table 2.4-1 Original Rain Gauge Locations

RAIN GAUGE NO.	LOCATION
6	Seneca Golf Course along Bon Air Avenue
7	Louisville Water Tower at Zorn Avenue
9	Iroquois Golf Course along Taylor Boulevard
10	Morris Forman Treatment Plant along Algonquin Parkway
14	Standiford Field along Standiford Avenue
19	South Fork Beargrass Creek at Trevilian Way
20	USGS Office on Bradley Avenue
29	Downtown Louisville at MSD Headquarters, 6th & Cedar

Source: 1993 Combined Sewer Operational Plan

In 1997, 11 telemetry-equipped rain gauges were installed. The primary purpose of these rain gauges was to provide real-time data for emergency response and engineering support. The majority of these rain gauges were installed at MSD facilities located throughout Jefferson County. For the purposes of emergency response support, the rain gauges performed adequately. However, with the implementation of the RTC project, these telemetry-equipped rain gauges did not meet the requirements of RTC because the geographic distribution and the telemetry system used at the time were deemed insufficient to provide the needed information in a timely manner. In order to meet the goals of the RTC project and to provide better emergency response support, the telemetry-equipped rain gauge system required modification.

In the Spring of 2003, 15 new telemetry-equipped rain gauges, replacing original 11 gauges were installed throughout Jefferson County. Since 2003, MSD has further expanded its rain gauge network to 46 gauges, including some gauges outside of its service area to better predict incoming storms. This updated rain gauge system serves two primary functions - to calibrate weather service Next-Generation Radar (NEXRAD) with rain gauge data, and to assist in providing accurate two-hour predictive rainfall data. Currently, this information is utilized by MSD's RTC project and for emergency response preparation. The new rain gauge network also provides a better geographical coverage of Louisville Metro as shown in Figure 2.4-10.

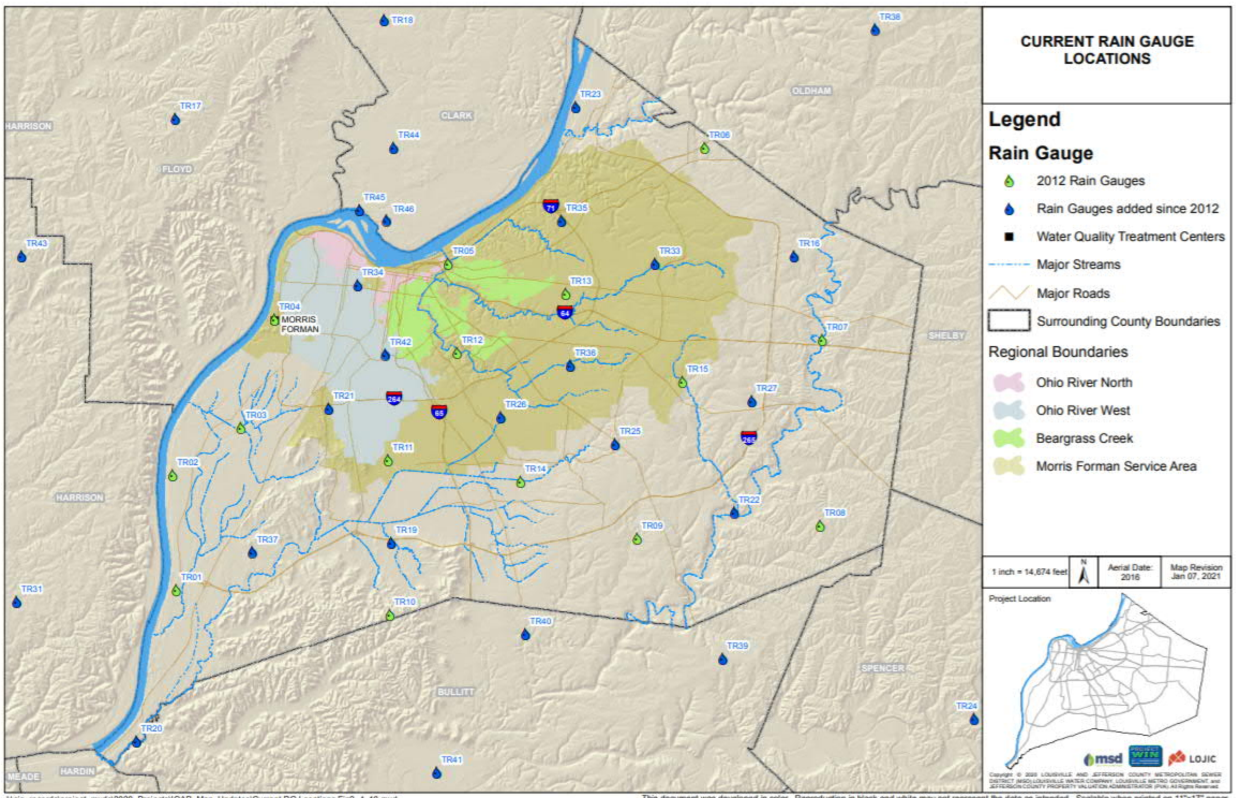


Figure 2.4-10 Current Rain Gauge Location Map, 2021

The majority of the storms approaching Louisville Metro approach from the northwest. Therefore, MSD established three additional satellite-enabled rain gauges in the Southern Indiana counties of Harrison, Floyd, and Clark. These rain gauges provide MSD with the ability to better calibrate rainfall predictions based on storms approaching from the northwest. Since the RTC project requires a two-hour predictive capability, rain gauges located outside Jefferson County provide MSD with the data needed to make these predictions. Figure 2.4-11 is a graphical presentation of radar rainfall.

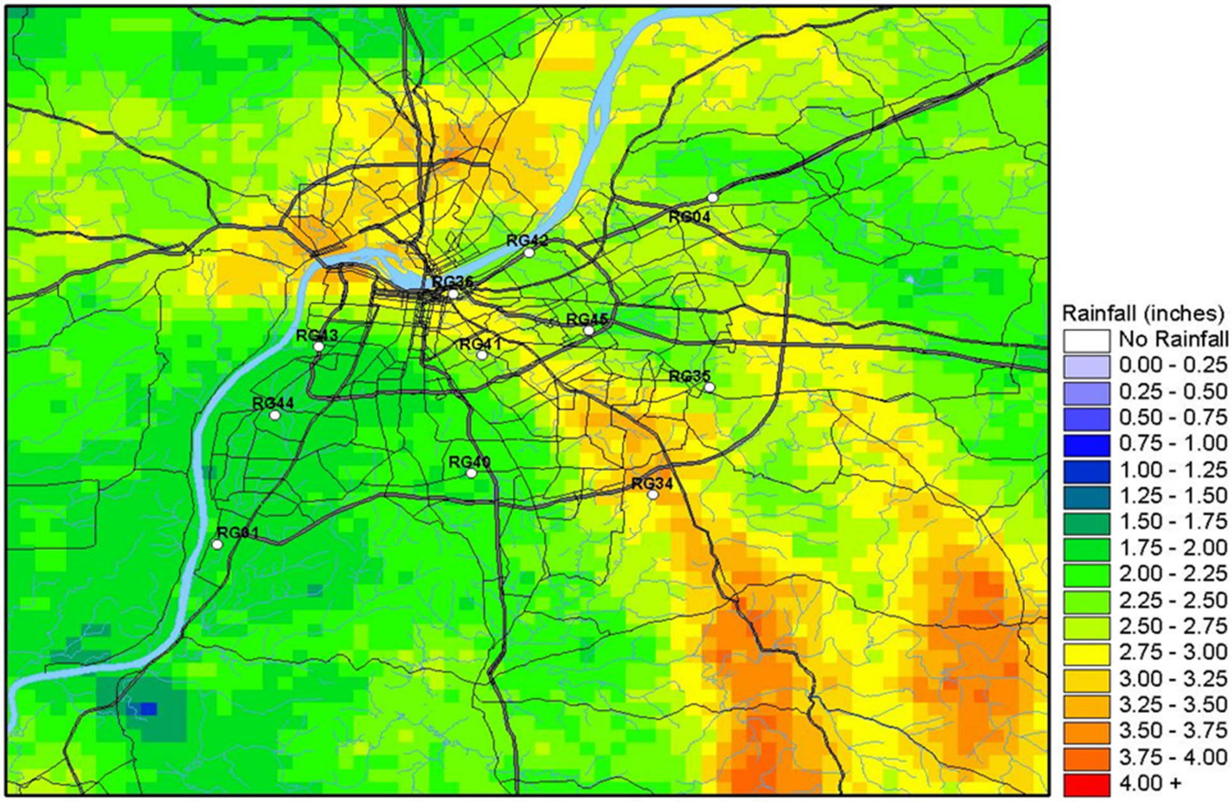


Figure 2.4-11 Example of Radar Rainfall

2.4.3.2. BASIS OF TYPICAL YEAR ANALYSIS

EPA's CSO Control Policy (1994) requires the effectiveness of CSO controls to be evaluated on a "system-wide, annual average basis." Identification of annual average rainfall conditions is a fundamental step in the LTCP process.

At the time of the initial model development (early 1990s), 31-years of rainfall records (1960 to 1991) were obtained from National Oceanographic and Atmospheric Administration (NOAA) as recorded at the National Weather Service (NWS) at Standiford Field. The rainfall records data was categorized by peak intensity, total rainfall, and duration.

Several approaches were available to analyze the performance of the CSS. Continuous simulation of long-term rainfall records was thought to provide more reliable predictions of overflow quantity on a regional basis than other methods considered at that time. However, due to limitations in computer processing time and data storage considerations that existed in the early 1990s, continuous simulation of an annual rainfall record was a significant limiting factor.

An alternate approach was developed which used detailed simulations for a number of discrete events. This approach allowed for generation of detailed model output (volumes, durations, peak rates) that would be useful for preliminary engineering planning, as well as data that would be useful for developing long-term overflow statistics. This approach was used in the initial stages of the project to estimate AAOVs.

A series of reference storms of varying return frequency were extracted from the NWS 31-year rainfall record based on a statistical analysis of key parameters in the rainfall record (total precipitation, intensity, duration). Ten actual historical storms were simulated using the sewer system model, and overflow volumes for each CSO and runoff volume for each drainage catchment were obtained. A mathematical regression of the data points provided predictive equations for overflow volume and runoff based on total rainfall for each storm in the historical record. The predicted volumes for all storms over the years provided an estimate of the AAOV for each CSO.

The combination of improvements in computer hardware technology and improvements in the model software since the early 1990s made continuous model simulation over long periods significantly more feasible. One of the many benefits from continuous simulation was that this technique automatically accounted for intermittent dry periods between rain events and for consecutive, closely spaced events. In 2004, MSD changed its method of calculating AAOV from a reference storm approach to a typical rainfall year approach using continuous model simulation. The analysis methodology currently being used is described in further detail in the following paragraphs.

A statistical analysis of a 54-year historical rainfall record (1948-2002) at KY4954 - Louisville Standiford Field gauge, was performed for the Jefferson County region in 2003 and updated in early 2008. The characteristics of a Typical Yearly rainfall that could be used for continuous simulation to obtain estimates of AAOV were determined. Individual rain events were sorted and ranked according to six characteristics: number of events, total precipitation, average intensity, maximum intensity, duration, and antecedent dry period.

Two different methods were used to determine the Typical Year. One method was to determine the Typical Year by selection of an entire historical year that most closely matched the average rainfall characteristic values from 54 years of record. Each individual year was compared to the average values for the six statistics noted above, and the year having values closest to the means was selected as the Typical Year. From this method, historical year 2001 was selected as the historical Typical Year.

Another method of establishing a Typical Year was also examined. This method consisted of “building” a year comprised of 12 individual months, wherein each month was extracted from the historical database based on matching the average characteristics on a monthly basis rather than an annual basis. The details of this analysis were provided in a Technical Memorandum in March 2008 Appendix 2.4.1 includes the Rainfall Selection Analysis Technical Memorandum with a full description of the methodology applied.

Appendix 2.4.1 Rainfall Selection Analysis Technical Memorandum

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

The overall 55-year mean for each of the six storm statistics, along with the mean statistics for 2001 and the monthly synthetic year as described above are presented below in Table 2.4-2.

Table 2.4-2 Overall Mean for 2001 and a Synthetic Year

PARAMETER	OVERALL MEAN 1948 - 2002	YEAR 2001	SYNTHETIC YEAR
Number of Events	92	91	91
Total Duration, Hours	530	516	568
Total Depth, Inches	41.25	42.83	40.84
Maximum Storm Average 60-Minute Intensity, Inch/Hour	1.19	0.83	0.84
Average Storm Intensity, Inch/Hour	0.08	0.08	0.07
Time From Last Event, Hours	92	91	89

Sewer system model simulations were conducted for both the Typical Years selected using each methodology described above. Ultimately, application of the 2001 historical precipitation event sequence was selected as the more appropriate method to use in evaluating CSO control alternatives for the following reasons:

- Represented a Typical Year of precipitation characteristics reasonably well, although not quite as well as a synthetic year might
- The receiving water models used for the Water Quality Tool (WQT) and Ohio River water quality impact analyses used the rainfall history and stream flow data from the same time, year 2001.
- Sewer system modeling required to establish baseline CSO loadings, size CSO control alternatives and evaluate their performance also utilized the 2001 rainfall year to:
- Maintain consistency between the CSO load projections and water quality impact analyses
- Maximize use of available overall system configuration and operating data for assessment of results
- Avoid potential confusion with regulatory agencies, stakeholders and the public that could arise by applying different precipitation records over different timeframes in the analyses.

2.4.4. FLOW MONITORING

Monitoring programs for CSO control planning serve many objectives, including those listed in the CSO Guidance for LTCPs (EPA, September 1995):

- Define the CSS hydraulic response to rainfall
- Determine CSO flows and pollutant concentrations/loadings
- Evaluate the impacts of CSOs on receiving water quality
- Support the review and revision of water quality standards, if necessary
- Support implementation and documentation of the NMC
- Support the evaluation and selection of long-term CSO controls
- Gain a thorough understanding of the CSS
- Adequately characterize the CSS response to wet weather events, such as the number, location, and frequency of the CSOs and the volume, concentration and mass of pollutants discharged
- Support a mathematical model to characterize the CSS
- Support the development of appropriate measures to implement the NMC
- Support LTCP development
- Evaluate the expected effectiveness of the NMCs and, if necessary, the long-term CSO controls

Achievement of these objectives requires both monitoring for flows and sampling for water quality characteristics. Flow monitoring in the combined sewer service area, including CSOs, is commonly used to refine understanding of the system and to calibrate and verify models used to evaluate impacts of potential CSO control alternatives. Water quality sampling in the CSS, including CSOs, is commonly used to characterize the contents of the combined sewer overflows, identify “hot spots” of higher strength sewage, and characterize the quality of CSO discharges.

The combination of flow monitoring and sampling is used to characterize pollutant loadings from CSOs into the receiving waters. Sampling in the receiving waters is used to evaluate impacts from CSOs relative to other pollutant loadings in the receiving waters and to calibrate and verify models for evaluation of alternative loading scenarios. These models and the associated evaluations provide the regulatory agencies the appropriate basis for determining that the use of the Presumption Approach is reasonable in light of the data and analysis conducted in the characterization, monitoring, and modeling of the system.

MSD flow monitoring includes data from receiving water flow monitoring stations operated by USGS, data from long-term sewer flow monitoring stations, and data from several study-specific short-term flow monitoring locations. The locations of the long-term sewer system and receiving water monitoring stations are located in the September 15, 2006, submittal of the NMC Compliance Report.

The sewer system flow monitoring data was coupled with episodic CSO flow monitoring to calibrate and verify models that both expand the characterization of CSOs and allow evaluation of the effectiveness of CSO control alternatives. Table 2.4-3 describes the locations of long-term CSO flow monitors active as part of the 2009 LTCP development.

Table 2.4-3 Summary of 22 Long-Term Sewer Flow Monitors - 2009

CSO NO	SITES	DESCRIPTION	RECEIVING WATER	INSTALLATION DATE
127	Etley Avenue	Etley Avenue	MF BGC	Jun-05
140	Locust Street	Locust Street	MF BGC	Jun-05
166	Lexington Rd @ I-64 Over Pass	Beals Branch Sanitary Diversion	MF BGC	Dec-06
206	Cherokee Park	Cherokee Park @ Spring Dr	MF BGC	Jun-05
125	Grinstead Dr & I-64 near entrance ramp	REG NO 24 - Grinstead Dr	MF BGC	Nov-07
132	Brownsboro Rd @ Storage Co.	REG NO 35 - Brownsboro Rd.	Muddy Fork BGC	Dec-06
019	34th Street & Rudd	34th Street Pump Station	Ohio River	May-05
105	Broadway & Western Pkwy	Western Outfall @ Broadway	Ohio River	Dec-06
189	Shawnee Park Pump Station	Northwestern Sanitary Diversion	Ohio River	Apr-06
190	Northwestern Pkwy	Seventeenth St Sanitary Diversion	Ohio River	Jul-06
191	Bells Lane	Southwestern Pump Station	Ohio River	Jul-06
210	Whayne Supply @ Diversion Structure	45th Street-Greenwood	Ohio River	Jul-06
211	Whayne Supply @ Diversion Structure	Main Diversion Structure	Ohio River	Jul-05
108	Newburg Road	REG No 1 - Newburg	SF BGC	Jun-05
117	Dry Run Sewer @ Beargrass Creek	REG No 11 - Dry Run	SF BGC	Jun-05
118	Broadway & Beargrass Creek	REG No 15 - East Broadway	SF BGC	Jul-06
151	Castlewood Avenue	REG No 5 - Castlewood	SF BGC	Jun-05
152	Ruffer Avenue	REG No 7 - Southeastern	SF BGC	Jun-05
182	Shelby & Burnett Street	SBR Shelby & Burnett	SF BGC	Jul-06
146	Swan Street South Fork of BGC	Sneads Branch Diversion	SF BGC	Mar-08
88	Brownsboro Rd @ Beargrass FPS	Mellwood Avenue Interceptor	SF BGC	Jun-06
110	Eastern Parkway	REG No. 3-Gross Avenue	SF BGC	Jul-05

The models use proven engineering principles, primarily hydrologic calculations, conservation of mass and conservation of energy, to estimate flows at unmonitored locations. In addition, the accuracy of flow monitors is highly dependent upon the ability to calibrate and verify the installed monitor for the range of flow conditions. Models are calibrated primarily using flow monitoring data, but standard hydrologic parameters and engineering judgement must also be used when analyzing flow monitoring data due to difficulty monitoring at some locations during certain flow regimes.

MSD performed flow monitoring specifically to calibrate the model during the years 1993, 2002, and 2007. The work done in 1993 was to provide data for the initial calibration of the model. In 2002 and 2007, flow monitoring was performed to re-calibrate the model. A discussion of the results of the flow monitoring and sampling programs is described later in this Chapter under the respective discussions of the Beargrass Creek regional facilities and the Ohio River regional facilities.

MSD maintains the long-term flow monitors to observe flow rates and to monitor changing system conditions in its systems. MSD operates six permanent, hard-wired monitors, four in the combined sewer area, and two in the west county area. The permanent monitors are integrated into the RTC systems. The monitors in the combined sewer area provide a strong base for quantifying the flows in the CSS and for calibrating hydraulic models of the combined sewer area. MSD deploys temporary monitors when necessary to further refine or confirm the understanding of the flows in the CSS. MSD will also deploy several simpler devices (floats, chalk lines) and post-storm inspections to confirm the frequency of CSOs.

MSD resolved to monitor all CSOs which have an estimated overflow exceeding 10 MG AAOV as predicted by the XP-SWMM model. MSD remains committed to monitoring flows from these sites where feasible. MSD will re-evaluate the CSOs which have overflows exceeding 10 MG AAOV, using InfoWorks CS model and develop a plan to monitor these locations.

As part of the adaptive management approach outlined in the 2009 IOAP, MSD has greatly expanded its long-term flow monitoring network, including monitors on the combined sewer outfalls. . MSD has been utilizing data from this network to recalibrate the hydrologic and hydraulic models used to size overflow abatement projects and refine individual project approaches and sizes based on an improved understanding of the sewer system operation and the relationship of certain overflows to one another.

2.4.4.1. FLOW MONITORING – 1992 PROGRAM

During the original development of the CSS model, flow monitoring was conducted in two phases due to the large combined sewer area and complexity of the system. For Phase I, the installation of the flow meters began in late November and early December 1991. By the first week of January 1992, 23 flow meters were installed at various locations in the central and western part of Louisville Metro and in the area around the Robert J. Starkey Pumping Plant, formerly known as the Buchanan Street Pump Station. The 24th flow meter was installed on the Northwestern Sanitary Trunk Sewer during the third week of January. The flow meter locations for Phase I are shown on Figure 2.4-12.

Figure 2.4-12 1992 Phase 1 Flow Monitoring Location Map

Figure is located at the end of this chapter.

Phase II of the flow monitoring program commenced in April 1992. For this phase, 17 of the 24 flow meters from Phase I were relocated from the western and central portions of the combined sewer area to the basins of the Middle and South Forks of Beargrass Creek. The flow meter locations for the Phase II flow monitoring are shown on Figure 2.4-13.

Figure 2.4-13 1992 Phase 2 Flow Monitoring Location Map

Figure is located at the end of this chapter.

This particular flow monitoring effort officially ended on June 20, 1992. Nine different storm events were chosen from the information obtained by the rain gauges and flow monitors during Phase I, and four different storm events were chosen from data recorded during Phase II for calibration purposes. A separate report, titled “Report on Combined Sewer System Flow Monitoring” (Tenney Pavoni Associates Inc., 1993) details the flow monitoring conducted on the CSS.

2.4.4.2. FLOW MONITORING – 2002 PROGRAM

During the year 2002, additional flow monitoring of the CSS was performed as a part of the model maintenance activity. A total of 19 flow meters were installed for the monitoring period of January 29, 2002, to April 11, 2002. Upon completion of this monitoring period, data from the flow monitors were analyzed to establish baseline flow(s) for DWFs characteristics in each basin. Additionally, wet weather and DWFs analyses were performed and the information was utilized to update the original model calibration. During the year 2002 monitoring period, five significant storm events (that is, rain events exceeding 0.5 inches) occurred. For calibration, the fourth and fifth events were selected for simulation. The fourth storm event, March 19, and the fifth storm event, March 25, recorded totals of 2.9 inches and 2.8 inches of rainfall, respectively. Figure 2.4-14 shows the flow meter sites. A separate report, titled “Flow Monitoring Report” (GRW Engineers Inc., 2002) details the flow monitoring conducted on the CSS.

Figure 2.4-14 2002 Flow Monitoring Location Map

Figure is located at the end of this chapter.

2.4.4.3. FLOW MONITORING – 2007 PROGRAM

During the year 2007, additional flow monitoring of MSD’s system was performed to support hydraulic modeling. Approximately 145 flow monitors were temporarily installed by a contractor beginning in January 2007 through mid-June 2007 throughout the MSD service area. Of the 145 monitors, 25 monitors were located within the CSS area. Upon completion of this monitoring period, data from the flow monitors were analyzed to establish baseline flow(s) and diurnal patterns for each basin. The flow monitor sites within the CSS area are exhibited in Figure 2.4-15.

Figure 2.4-15 2007 Flow Monitoring Locations

Figure is located at the end of this chapter.

2.4.4.4. FLOW MONITORING – CURRENT PROGRAM

MSD is in the process of finalizing and standardizing an expanded long-term flow monitoring program. According to the “Combined Sewer Overflows - Guidance for Monitoring and Modeling” (EPA, 1999) document, a CSS monitoring program will support in-depth system characterization and post-construction compliance monitoring that are central elements in the LTCP.

MSD currently has long-term sewer flow monitors in place at each of its CSO outfalls (where feasible), as well as some in-system meters. In 2016, MSD identified a potential for inaccurate volume reporting at some CSOs. This was identified by comparing measured overflow volumes against modeled overflow volumes for similar storms. It was determined that several CSO flow monitors were affected by backwater levels from the receiving streams causing a discrepancy with actual overflow volume, along with other potential variables at some locations. Furthermore, some preliminary inaccuracies in flow calculations were noted. MSD notified EPA and KDEP of data discrepancies on September 29, 2016.

A workgroup was established to review CSO flow monitoring and resolve potential over-reporting of overflow volumes. Initial findings indicated potentially significant discrepancies between modeling and monitoring data at 33 of MSD's 98 CSO locations. This set of 33 CSOs was established as the highest priority to review, correct data, document SOPs, and implement changes. For these CSO locations, MSD performed site visits including elevation surveys, performed detailed analysis, investigated equipment configurations, and investigated PLC programming or monitoring program logic. This led to the development of an SOP for each CSO that describes the existing monitoring equipment, configuration, and flow calculation in use as of December 31, 2016, and evaluated the effectiveness of the existing setup. If a more effective arrangement was recommended, MSD added the proposed arrangement to the SOP for implementation and determined if historical data could be updated. In cases where the historical data could be updated, MSD developed revised volumes for reporting. In some cases, historical volumes could not be recalculated based on the available data. For instance, CSOs influenced by river or creek elevation for which there was no available historic level data could not be recalculated for historical volumes but will be calculated or measured according to the revised SOP as they are implemented.

To-date, SOPs have been drafted and historical volume data corrections (where possible) have been made for all of the 98 CSO locations. Multiple SOPs required programming or equipment changes in order to implement the final SOPs.

CSO flow monitoring data is included as an appendix to each Consent Decree report. Regular meeting between Engineering and Operations Divisions will continue to occur. MSD will continue to update and refine changes to meter location and calculation algorithms as needed. Changes will continue to be made as new facilities come online, and new monitoring is implemented and tested. These changes will be documented in updated monitoring procedures. Figure 2.4-16 exhibits the locations of the in-system flow monitors currently installed. Refer to IOAP Volume 1 Chapter 6 titled "Post Construction Compliance Monitoring" for more details.

Figure 2.4-16 Flow Monitoring Locations

Figure is located at the end of this chapter.

2.4.5. CSO WATER QUALITY CHARACTERISTICS

2021 Update: This section describes MSDs water quality data collection procedures performed for the 2009 LTCP. The program continues to be modified to support other programs. A brief description of some of the updates is provided in this section, but the majority of the section describes the procedures used to gather and preliminarily assess data used in 2009.

Monitoring data available for CSO characterization and planning includes both monitoring for flows and sampling for water quality characteristics. Section 10.4 of the NMC Compliance Report (MSD, September 15, 2006) provides a summary of past flow monitoring and sampling activities, while the Post Construction Compliance Monitoring Plan addresses ongoing monitoring, sampling, and modeling activities in Volume 1 Chapter 6.3 of the IOAP.

This section describes MSD's water quality monitoring program. The goal of this program is to maintain an accurate, consistent record of water quality in receiving bodies of water. Monitoring results are used to determine the effect of effluent discharge and/or spills through the following monitoring programs: routine water quality, investigative water quality, and water quality monitoring for spill impact. Water quality monitoring data is also assessed and provided in the water quality synthesis report, called "State of the Streams', that summarizes water quality trends based on data MSD collects through its Long-Term

Monitoring Network. The latest report is available at **www.louisvillemsd.org/WaterQuality**. MSD continues to synthesize and trend water quality data in a report as required by the MS4 permit.

MSD's program has an extensive in-stream monitoring effort for tributary streams and emergency spill responses, including:

1. Ambient monitoring at 28 Long Term Monitoring Network (LTMN) locations across Jefferson County to monitor multiple physical and biological parameters in accordance with the MS4 permit.
2. Combined Sewer Overflows/Significant Industrial Users point sampling monitors the risk of water quality impairment to discharges associated with SIUs and General Discharge Permits through the NMC 3 Pretreatment Program.
3. CSO flow monitoring measures flow within the CSS to provide improved data input into hydraulic models.

2.4.5.1. CSS SAMPLING OF CSOS

Past sampling of CSOs in MSD sewers yielded a multitude of observations of numerous distinct analyses. The full range of analyzes and their observations are listed in a Technical Memorandum titled Interim LTCP Addendum in November 2006. Figure 2.4-17 shows the location of the CSO and CSS sites monitored to-date within the MSD system.

Figure 2.4-17 CSO and CSS Sampling Locations Map

Figure is located at the end of this chapter.

Most samples were collected by automated samplers using consistent sampling protocols that included more frequent sampling early in a storm, tapering off to less frequent through the remainder of the first three hours of the storm. This sampling protocol is biased toward the early "first flush" portion of the overflow hydrograph. Site storm samples were composited on a flow proportional basis prior to analysis; thus, each data point approximates an event mean concentration for that particular storm and event.

Table 2.4-4 summarizes the data collected through 2009in the CSOs for TSS, biochemical oxygen demand, and fecal coliform. As previously noted, the samples show a variability that is characteristic of environmental sampling, and even more prevalent in wet weather sampling. The standard deviation of the observations is the selected measure of the variability. If the data are normally distributed, one can be 68 percent confident that the average of the population is within one standard deviation of the average calculated from the observations. The significance of multiple observations at one site is commonly graphed as explained in Figure 2.4-18.

Table 2.4-4 Summary of CSO Data for Biochemical Oxygen Demand (BOD), Fecal Coliform and TSS

Table is located at the end of this chapter.

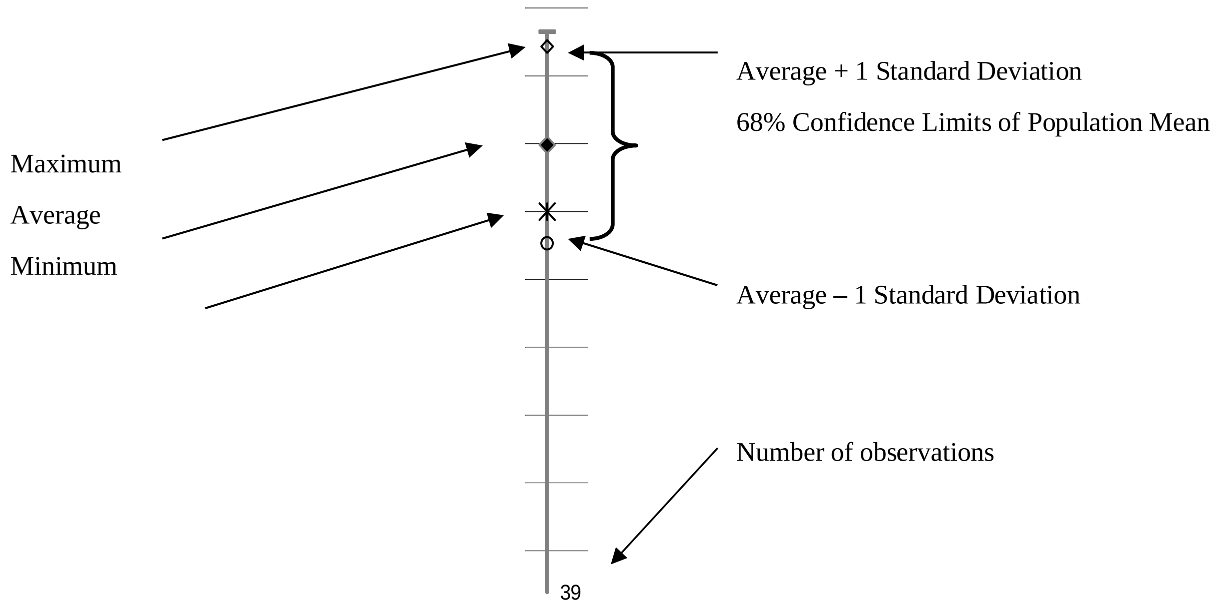


Figure 2.4-18 Variability Chart

Statistically, the population mean is somewhere within the confidence limits. Any value within those limits is not statistically different from the sample average. TSS, biochemical oxygen demand, and fecal coliform data are summarized here because of the perceived significance to LTCP planning. TSS are summarized because it is commonly of interest in wastewater impact evaluations and is used as a surrogate for pollutants known to 'attach' to sediments. Biochemical oxygen demand is summarized because it is commonly of interest in wastewater impact evaluations and because it is related to dissolved oxygen, one of the two parameters cited by Kentucky Department of Environmental Protection (KDEP) as out of compliance in the receiving waters. Fecal coliform is summarized because it is commonly of interest in wastewater impact evaluations and because it is cited by KDEP as "out of compliance" in the receiving waters.

Figure 2.4-19 illustrates that the TSS data in the CSOs show a high degree of variability. With the degree of variability evidenced, it is not possible to conclude that any site has a total suspended solids (TSS) concentration that is significantly different from any other site. CSO019 shows some evidence of a higher concentration, but with only six observations, it shows only weak evidence of a higher TSS concentration. Given the inherent variability evidenced in the data, it is unlikely that more samples would result in concentrations that show significant variation between the sites. All of the sites with more than six observations have data consistent with a mean event concentration of 200 million gallons per liter (mg/l) TSS. That is to say, 200 mg/l TSS is within one standard deviation of the mean for all sites with multiple observations.

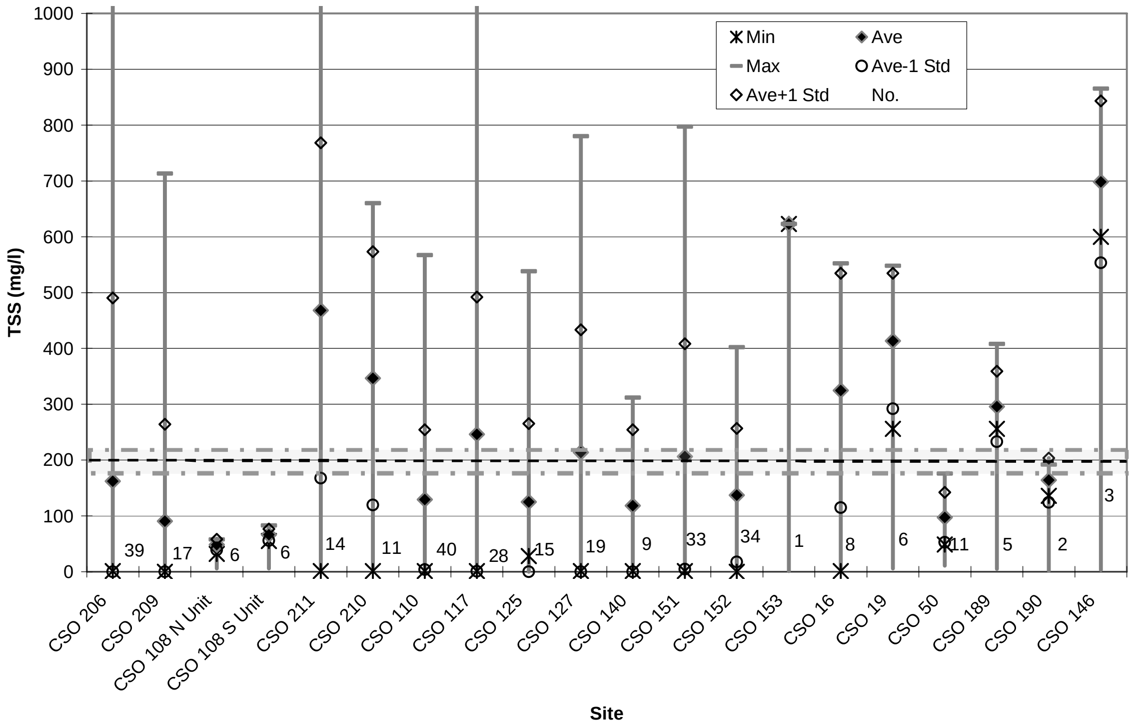


Figure 2.4-19 Summary of CSO Water Quality Data for Total Suspended Solids, 2006

Figure 2.4-20 illustrates that the biochemical oxygen demand data in the CSO samples show a high degree of variability as well. With the degree of variability evidenced, it is not possible to conclude that any site has a biochemical oxygen demand concentration that is significantly different from any other site. There is no statistically significant difference between sites draining highly commercialized or industrialized zones. Given the inherent variability evidenced in the data, it is unlikely that more samples would result in concentrations that show significant variation between the sites. Most of the sites, particularly those with more than six observations, are consistent with a mean event concentration of 75 mg/l biochemical oxygen demand. That is to say, 75 mg/l biochemical oxygen demand is within one standard deviation of the average for the sites. The exceptions would indicate that some sites (for example, CSO 140) might have lower average concentrations.

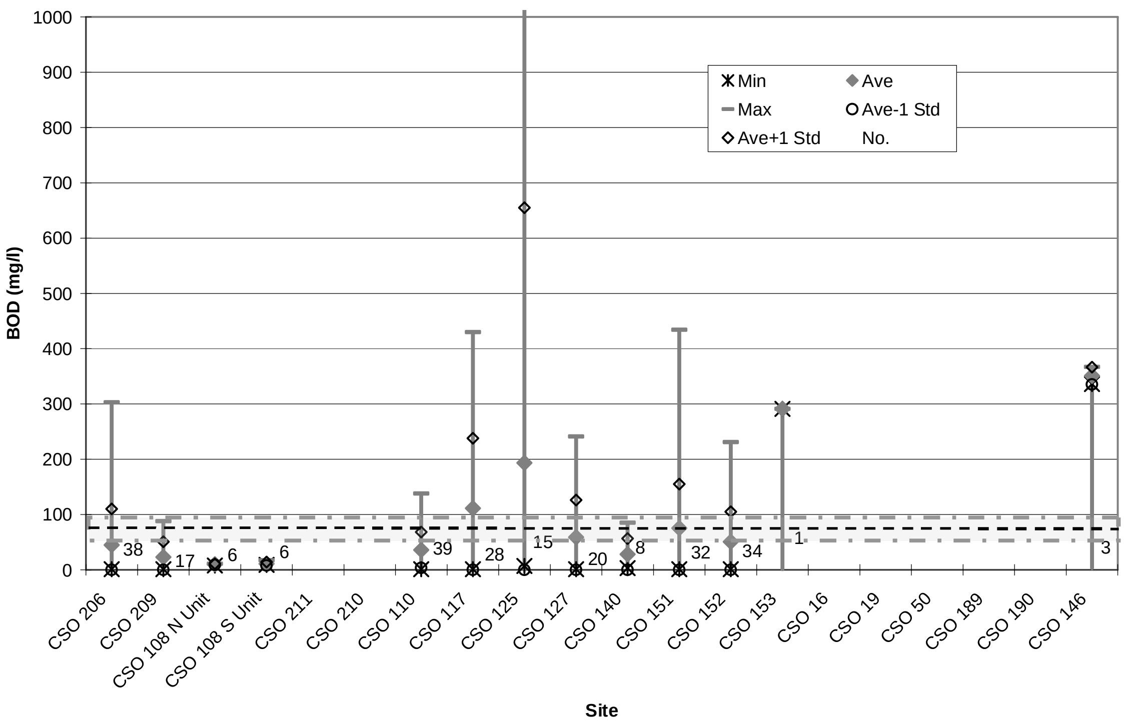


Figure 2.4-20 Summary of CSO Water Quality Data for Biochemical Oxygen Demand, 2006

Figure 2.4-21 illustrates that the fecal coliform data in the CSO samples show a higher degree of variability. Measurement of fecal coliform is itself imprecise, with expectations that duplicate measurements from one sample will often vary by an order of magnitude. Consequently, variations less than an order of magnitude are arguably insignificant. With the degree of variability evidenced in the CSOs, it is not possible to conclude that any site has a fecal coliform concentration that is significantly different from any other site. There is no distinguishable difference between sites draining highly commercialized or industrialized zones. Given the inherent variability evidenced in the data, it is unlikely that more samples would result in concentrations that show significant variation between the sites. All of the sites have observations consistent with an event mean concentration of 250,000 col/100 ml fecal coliform. That is to say, 250,000 col/100 ml fecal coliform is within one standard deviation of the mean for all sites.

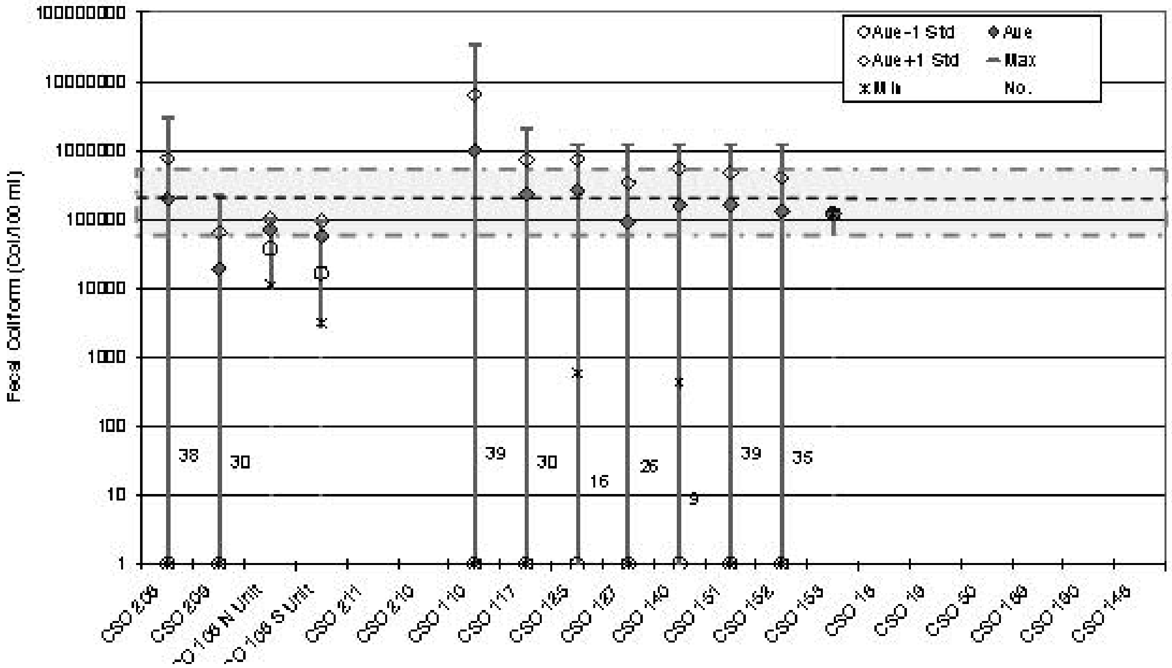


Figure 2.4-21 Summary of CSO Water Quality Data for Fecal Coliform, 2006

The extreme variability shown in the data is expected. Indeed, CSO long-term control planning in several municipalities (Bangor ME, Portland ME, New Haven CT, Narragansett Bay Commission RI, Milwaukee WI, and Atlanta GA) have observed similar variations and an inability to distinguish CSO concentrations from different land use areas. For example, Figure 2.4-22 shows TSS data from 12 New England sampling sites where all were deemed consistent with a single event mean concentration of 150 mg/l.

For purposes of analyzing loadings from CSOs, the mean concentrations cited above have been used for all CSO sites and all storm conditions. The data, and the precedents set in numerous other CSO planning studies, do not support varying the concentration estimates by site characteristics or by storm characteristics. That is not to say that variations do not exist. Even though the data do not show statistically valid higher concentrations for more urbanized sites, it is commonly assumed that more urbanized sites have a higher risk of spills of highly contaminated materials. Consequently, CSOs from highly urbanized sites may be prioritized for control independent of sampling data that demonstrate a higher strength discharge.

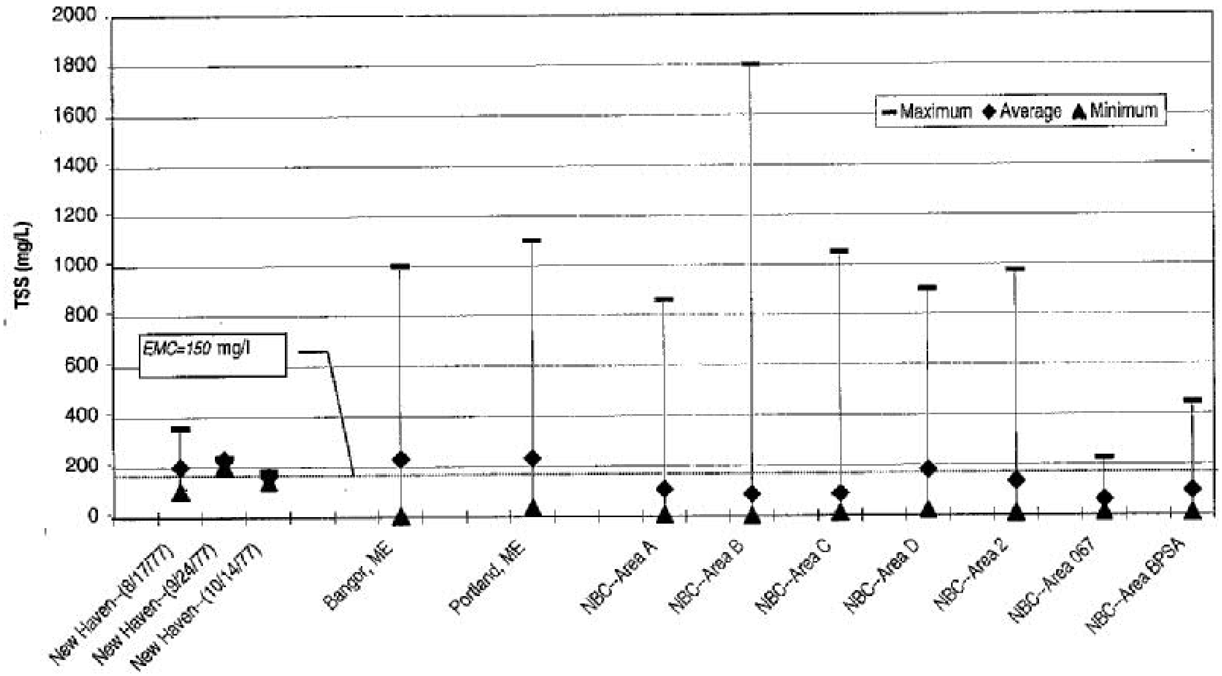


Figure 2.4-22 Summary of CSO Water Quality Data for Multiple New England Sites, 2006

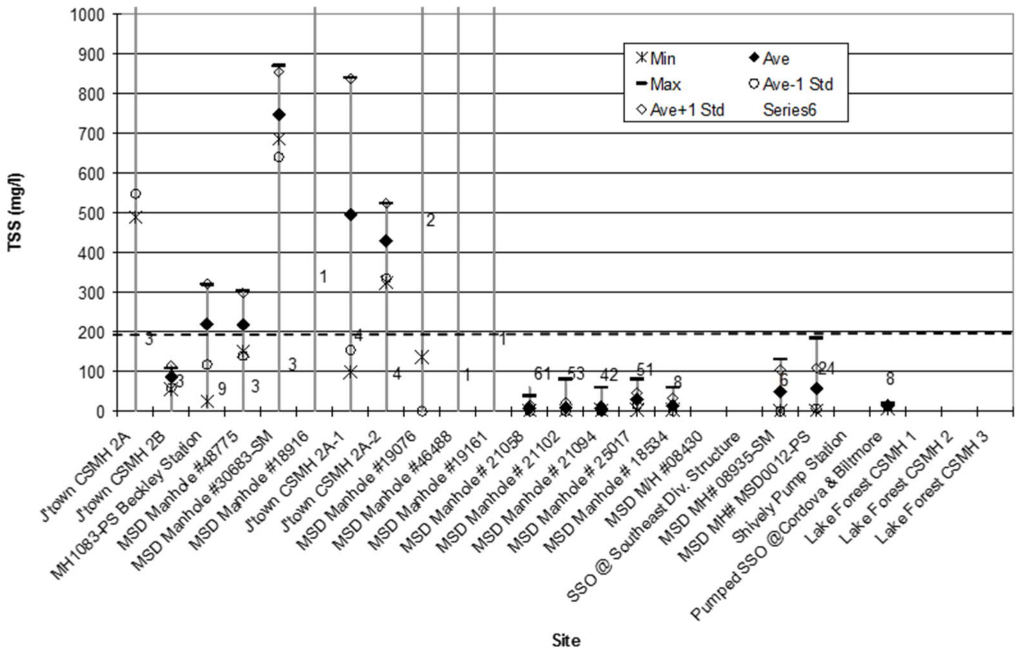
2.4.5.2. CSS SAMPLING OF NON-CSOS

Data for the non-CSO sites within the MSD combined sewer service were summarized in Technical Memorandum titled Interim LTCP Addendums. These data, too, show a high variability. The ranges of TSS, biochemical oxygen demand and fecal coliform data observed in the non-CSO CSS samples are charted in Figure 2.4-23, Figure 2.4-24, and Figure 2.4-25, respectively. The non-CSO CSS data are often higher than the means (dashed lines) used for the CSO data. The non-CSO CSS data include primarily observations during dry weather conditions that are far different from the conditions prevailing when the CSOs can be sampled. The non-CSO CSS samples, however, provide observations of the constituents that potentially could flush into the CSOs.

MSD continues to scrutinize the non-CSO sampling data to identify impacts, if any, from significant industrial dischargers or other non-domestic dischargers of concern that have been issued general discharge permits. The grab sample concentrations at these sites are highly variable and water quality modeling using continuous simulations was used to estimate the systematic impact of the proposed CSO control plan. Due to the sample variability, any particular grab sample or set of samples for one parameter is not reliable for direct application of a CSO control. The best available water quantity and quality models calibrated using the full environmental data set is relied upon for overflow control assessment. The additional data tables and possible uses of the data are described in Appendix 2.4.9.

Appendix 2.4.9 Non-CSO Sewer Sampling Data Characterization

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.



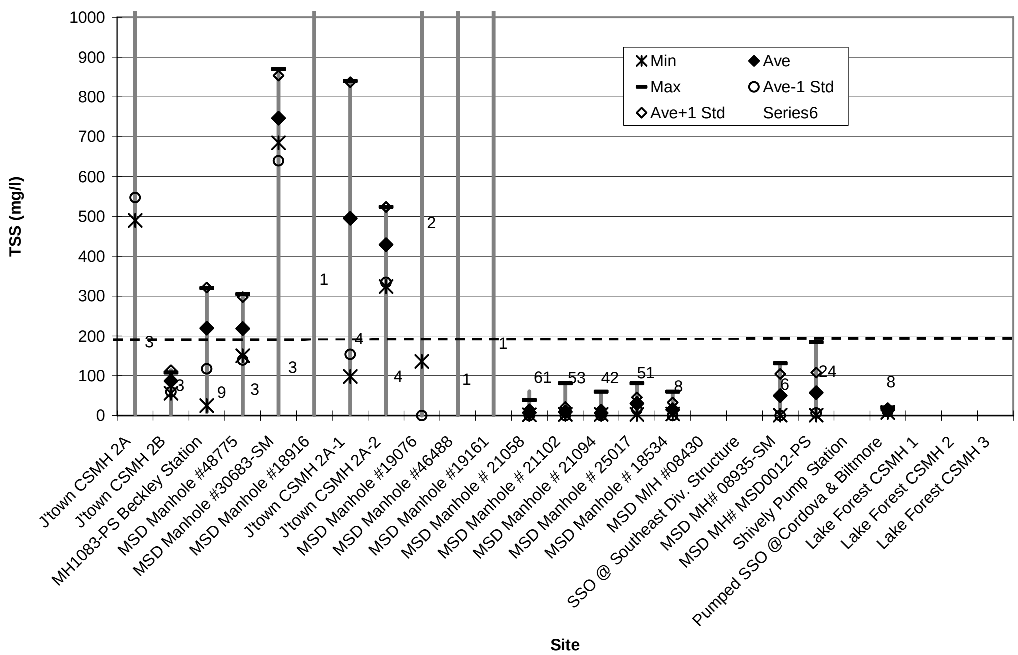
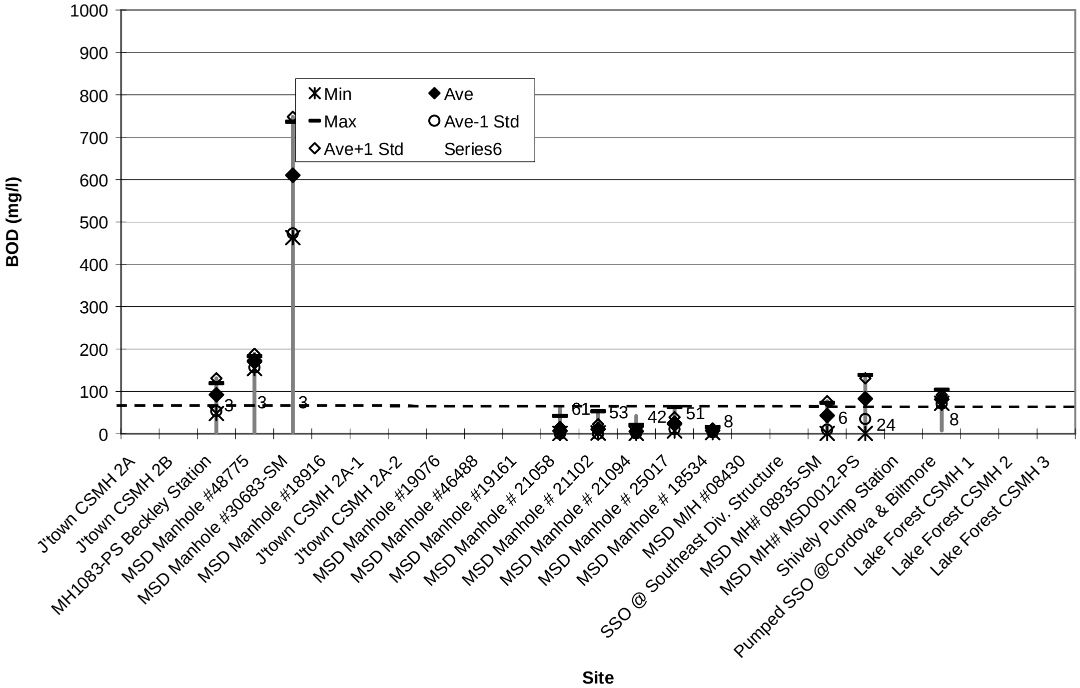


Figure 2.4-23 Summary of Non-CSO CSS Water Quality Data for TSS, 2006



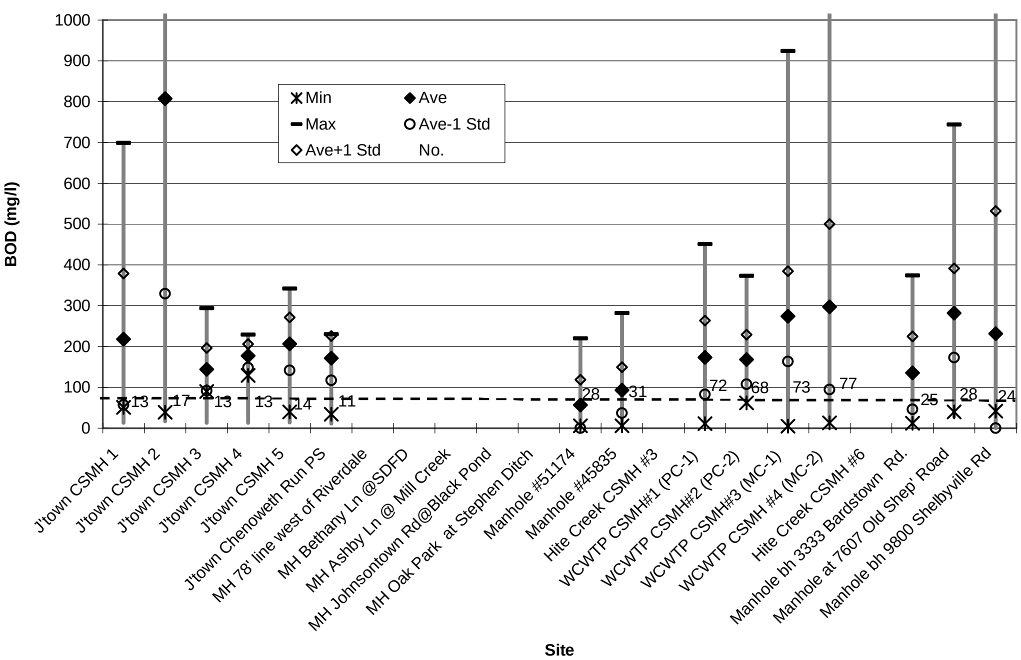
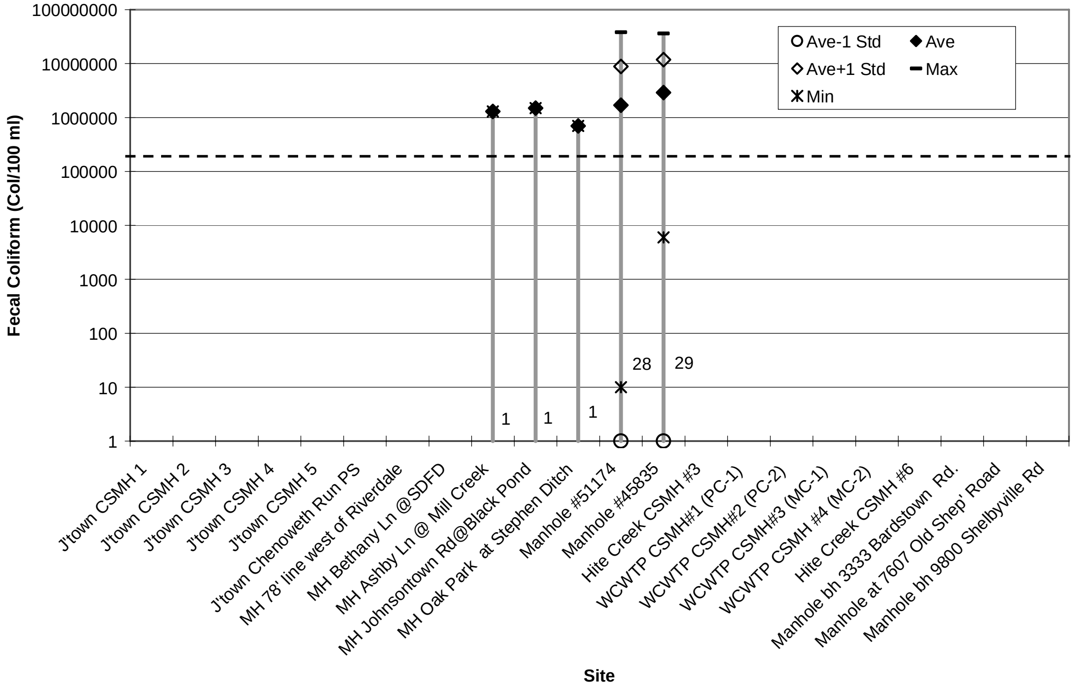


Figure 2.4-24 Summary of Non-CSO CSS Water Quality Data for BOD, 2006



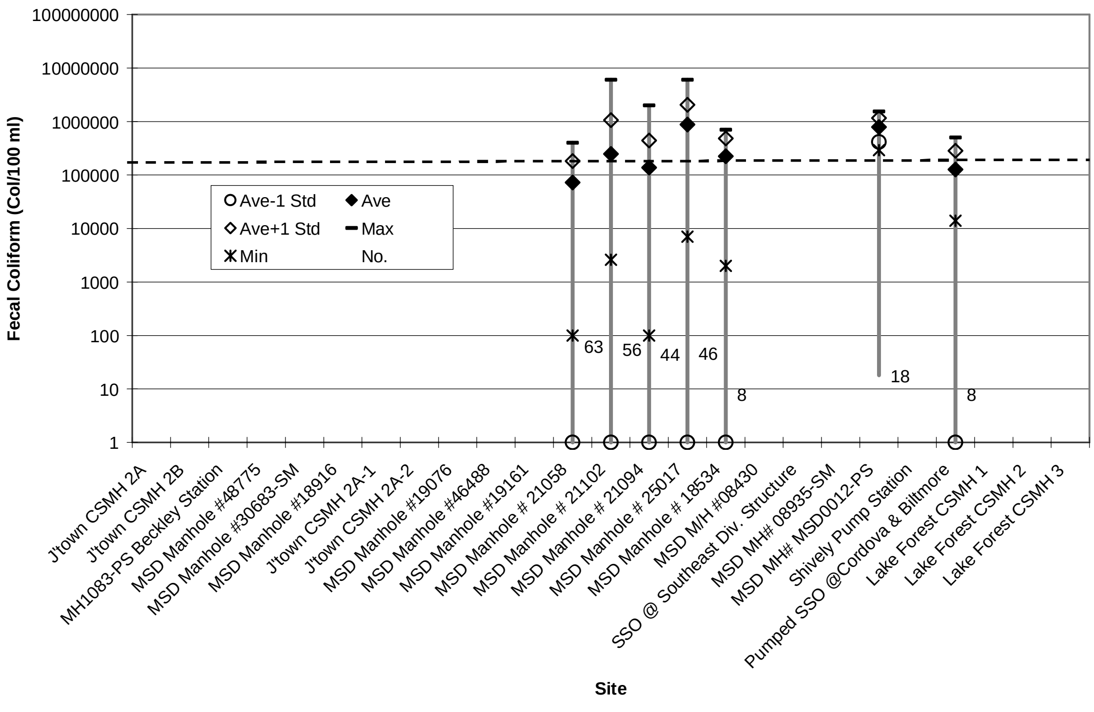


Figure 2.4-25 Summary of Non-CSO CSS Water Quality Data for Fecal Coliform, 2006

2.4.6. COMBINED SEWER SYSTEM MODELING

The CSO Control Policy describes modeling as a valuable tool for characterizing a CSS. EPA supports the proper and effective use of models. The sophistication of the model should relate to the complexity of the system to be modeled.

2.4.6.1. CSS MODELING OBJECTIVES

The development and calibration of the MSD CSS model was a part of early efforts associated with the CSO Abatement Program. The major objectives of the initial model development were to:

- Comply with CSO Policy Requirements
- Estimate CSO hydraulic and pollutant loads
- Assist in identifying the location of significant CSOs
- Assist in evaluating and prioritizing corrective actions

2.4.6.2. CSS MODEL SELECTION

The CSS model was originally developed in EPA Storm Water Management Model (SWMM) versions 4.05 and 4.3 as part of early efforts associated with the CSO Abatement Program in early 1990s. The selection of the hydraulic model for initial CSS model was based on the complexity and size of the MSD collection and conveyance system and the SWMM's ability to simulate full hydrodynamic equations. SWMM was a comprehensive water quantity and quality computer program available at the time of initial CSS model development.

In the late 1990s, the CSS model was converted from EPA's SWMM to proprietary XP-SWMM software for five primary benefits listed below:

- Useful graphical user interface
- Utilization of geographic information systems (GIS)
- Enhanced SWMM capabilities
- One simulation for entire CSO service area
- Fewer input/output boundary conditions to reconcile between simulations

The conversion of EPA-SWMM model to XP-SWMM model created one system-wide model to represent the CSS with approximately 2,000 nodes and 600 subcatchments. MSD continued to update the CSS model to reflect changing system conditions in the CSS by incorporating physical changes to various system features, and to take advantage of significant advances in computer hardware and software since the development of the model. The end product of this significant undertaking during the early 1990s and during 2004 was a working computer model of the CSS for use in predicting and analyzing the response of the system to various rain events.

MSD performed an extensive evaluation of commercially available computer models as well as the assessment of hydraulic sewer system modeling program and made a decision to convert all existing sewer models to InfoWorks Collection System (CS) format. In 2012, InfoWorks developed a new modeling software, InfoWorks ICM, which allowed for better data management, the potential for 2-D surface modeling, and enhanced integration with RTC. The CS models were migrated to ICM. The primary benefit of the model conversion was the decrease in run-time and ability to code in RTC rules to analyze the system benefit more accurately. The selection of InfoWorksICM model meets the criteria for selection of a CSS hydraulic model based on EPA Guidance: "Combined Sewer Overflows: Guidance for Monitoring and Modeling" (EPA 832-B-99-002). Criteria include:

- Ability to accurately represent CSSs hydraulic behavior
- Ability to accurately represent runoff in the CSS drainage basin
- Extent of monitoring
- Need for long-term simulations
- Need to assess water quality in CSS
- Need to assess water quality in receiving waters
- Ability to assess the effects of control alternatives
- Use of the presumption or demonstration approach
- Ease of use and cost

2.4.6.3. MODEL DESCRIPTION

The original CSS model was developed to include sewers larger than approximately 48 inches in diameter in general. However, in the Beargrass Creek, sewer sizes greater than 48 inches were very limited; therefore, sewer sizes as small as 12 and 24 inches were presented in the model to provide sufficient details for assessing CSO discharges. More detail information on original model development is documented in the 1993 "Combined Sewer Operational Plan," Chapter 5.

In late 1997, the existing six EPA SWMM models were converted to XP-SWMM. Upon completion of the conversion to XP-SWMM, the six individual models were combined into one XP-SWMM to create one system-wide model. After integration of the six models into one model, CSS model consisted of approximately 2,000 manholes and 600 subcatchment areas.

As part of the NMC, MSD frequently updates the CSS model to reflect changing system conditions in the CSS. During MSD's fiscal year 2004, the CSS model was updated and calibrated to reflect the following changes:

- Reflect changing system conditions within the CSS by incorporating physical changes to various system features.
- Take advantage of significant advances in computer hardware and software since the original model construction; and
- Modify the model to be able to simulate Typical Year rainfall (long-term) simulations

The general overview of MSD sewer modeling history is documented in Sewer Modeling History Report (2007) and available for review Appendix 2.4.2. In 2007, MSD developed a "Hydraulic Sewer System Modeling Guideline Manual" (see Appendix 2.4.3) to standardize model development and improve the detail, quality, and functionality of sewer models. MSD contracted two modeling experts to provide independent peer review of the modeling approach and the Modeling Guideline Report, Dry Weather Flow Memorandum, and the rainfall-derived infiltration and inflow (RDI/I) Flow Memorandum. The comments provided from the peer reviewers were incorporated into the draft final version of the Modeling Guideline

Manual. The Beargrass Creek Integrated Hydraulic Model Peer Review Report is available for review in Appendix 2.4.4.

Appendix 2.4.2 Louisville/Jefferson County MSD Sewer Modeling History Report

Appendix 2.4.3 Hydraulic Sewer System Modeling Guideline Manual

Appendix 2.4.4 Beargrass Creek Integrated Hydraulic Model Peer Review Report

Appendices are the same as the 2012 IOAP Modification and are provided on external USB storage drive.

2007 Model Conversion

The existing CSS model was converted to InfoWorks CS and upgraded in detail to meet the standards of modeling guideline document developed for MSD sewer system modeling. The model conversion and expansion were completed in 2007. Figure 2.4-26 is a diagram exhibiting the history of development of the CSS model. Key model inputs and sources of the data are listed in *Figure is located at the end of this chapter.*

Table 2.4-5.

Figure 2.4-26 Model History Diagram

Figure is located at the end of this chapter.

Table 2.4-5 CSS Model Key Inputs and Sources

TYPE	DATA	SOURCES
Hydrologic	CSO-Subcatchment area	Delineation using GIS and Field visits
	Surface Slopes	Estimated using GIS
	Roughness and percent imperviousness	Estimated using GIS
	Width	Estimated using GIS
	Rainfall Data	Hourly data from NWS gauge at Standiford Field Airport
		Ten-min radar rainfall data from 1-km pixel
		Five-min data from USGS/MSD rain gauge network
Hydraulic	Nodes and Conduits	GIS/ As built drawings/Surveying
	Diversion Structures	GIS/ As built drawings/CSO Inventory Records/Field visit/Survey
	Pump Stations	GIS/ As built drawings/Interview with operations/ Draw-down test
	Inflatable Dam /RTC operating scheme	As built drawings/ Rules developed by engineer
	Dry Weather Flow	Diurnal Pattern developed based on 2007 Flow monitoring data
	Inflow from Separate Sewer System	Flow monitoring data/ SSS model hydrographs

The expansion of the CSS model to include sewer sizes as small as 18 inches (except for the Beargrass Creek area where some pipe sizes were as small as 8 inches) was necessary to represent the CSS system more accurately. This was completed as part of conversion process. The current CSS model configuration includes approximately 12,000 nodes and 2,900 subcatchments compared to previous 2,000 nodes and 600 subcatchments in XP-SWMM model.

The newly updated CSS model includes the RTC rules of nine Phase I & II sites to model the system response accurately. Detailed descriptions of the model incorporation of RTC rules are provided for reference in Appendix 2.4.5 and Appendix is ***the same as the 2012 IOAP Modification and is provided on external USB storage drive.***

Figure 2.4-27 for the extent of CSS modeling area.

Appendix 2.4.5 RTC Incorporation Technical Memorandum

Appendix is the same as the 2012 IOAP Modification and is provided on external USB storage drive.

Figure 2.4-27 CSS Model Area Map

Figure is located at the end of this chapter.

2012 Model Conversion

The InfoWorks CS model was converted into a new software platform called the InfoWorks Integrated Catchment Model, which allows for 2-dimensional modeling. This conversion is intended to improve the hydrologic accuracy of the model and more truly mimic the interaction of the surface and the combined sewer system. As MSD continues to move forward with IOAP implementation, model calibration and CSO behavioral statistics will continue to improve and be used to further verify the projected performance of the overflow abatement projects.

2.4.6.4. MODEL CALIBRATION/VALIDATION

2021 Update: As implementation of the IOAP continues, the CSS models increasingly support critical planning and design decisions on sizing, location, and operation of new facilities as well as providing validation of Typical Year percent capture. MSD's model is calibrated to both in-system flow monitors as well as flow monitors on CSO outfalls. MSD continues to look for ways to improve the accuracy and precision of the model by performing field surveys and reconnaissance where additional details or other critical details need clarification to refine calibration of the models. This section describes the procedures and data to calibrate the models in 2007 for the 2009 Final LTCP. An extensive recalibration was performed for portions of the model prior to the 2012 IOAP. Continued calibration and validation have progressed for multiple project areas since the 2012 modification. A detailed discussion of model calibration and validation is provided in this section and impacts on model application is provided section 2.4.6.5. Changes to model calibration impacting projects are described in the minor modification letters submitted for each project.

Model calibration of the converted CSS model was completed from January through May 2007 to ensure the CSS model accurately represents the sewer system. Approximately 25 in-system locations were monitored to support hydraulic model calibration. In addition to the in-system monitors, overflow data from approximately 15 CSO sites were available for model calibration and validation. Figure 2.4-15 exhibits the location of flow monitors used for model calibration/validation purpose.

Based on review of the flow monitoring data, April 14, 2007, with a total rainfall depth of 1.3 inches was selected as the calibration event. April 12, through May 7, 2007, was selected as the validation period. It was recommended by independent peer reviewers to perform continuous calibration/validation rather than traditional independent event calibration and validation to better capture conditions during multiple rainfall events and inter-event dry weather period. The long-term calibration/validation approach was recommended because since the CSS model is used to perform annual simulations.

One of the most important input parameters in the sewer system modeling for calibration purposes is precipitation data. The precipitation data used for model calibration was 1-kilometer pixel size radar rainfall data provided by MSD. Using the radar rainfall data provided better spatial and temporal coverage of the modeling area during calibration period.

Dry Weather Flow

DWFs in the previous CSS models in XP-SWMM format were estimated from in-system flow monitoring data collected at a number of locations within the system, as well as available treatment plant and pump station flow rates. Based on an assumption that infiltration into the CSS is non-excessive, dry weather constant flow inputs (without diurnal pattern) were allocated to each subcatchment in the model based on the ratio of subdrainage area size to the total drainage area size upstream of the flow monitoring location.

Based on the modeling guideline document, the latest CSS model updated the representation of DWFs in the CSS model by distributing flows using census data and applying diurnal pattern developed based on flow monitoring data. The advantage of using this method is that the models would represent the DWF and wet weather flow capacity more accurately than previous methods used. Figure 2.4-28 and Figure 2.4-29 present two examples of diurnal patterns used in the model to predict sanitary flows in the system.

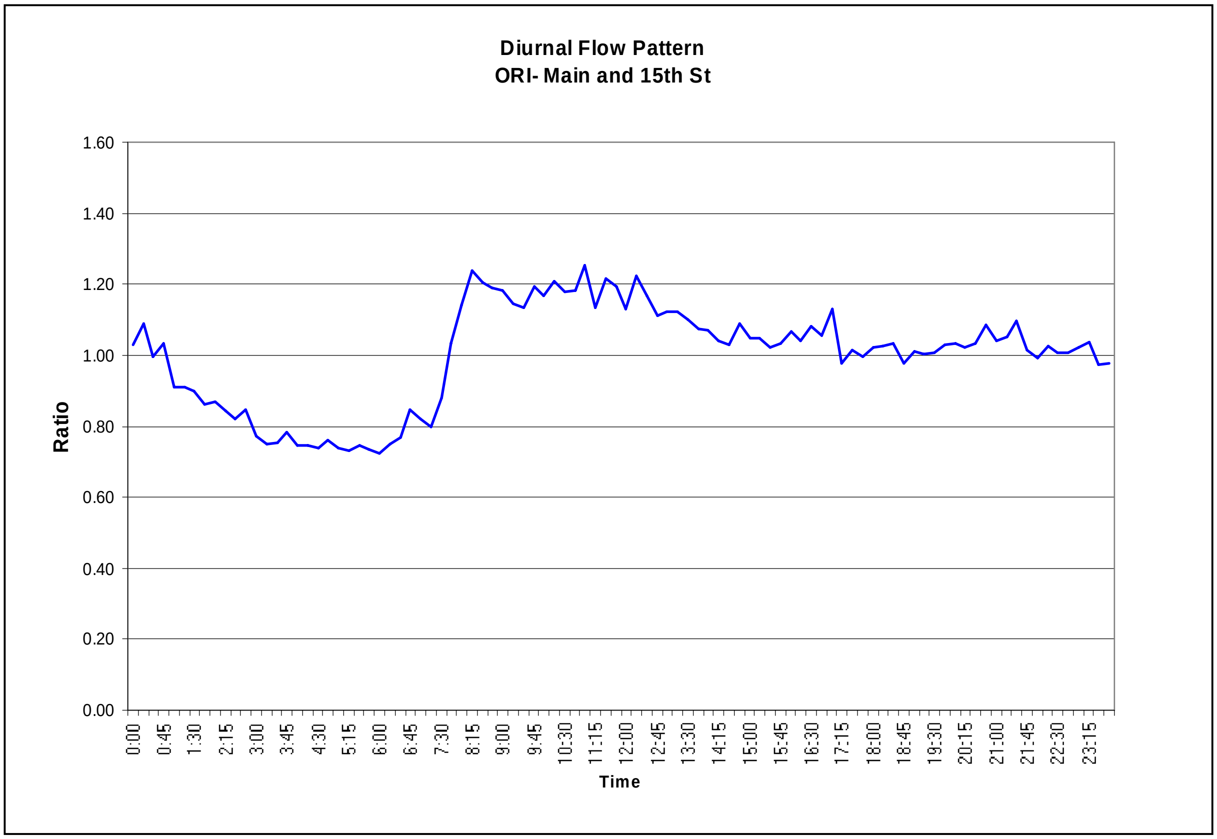


Figure 2.4-28 Diurnal Flow Pattern Ohio River Interceptor near Main and 15th Street, 2007

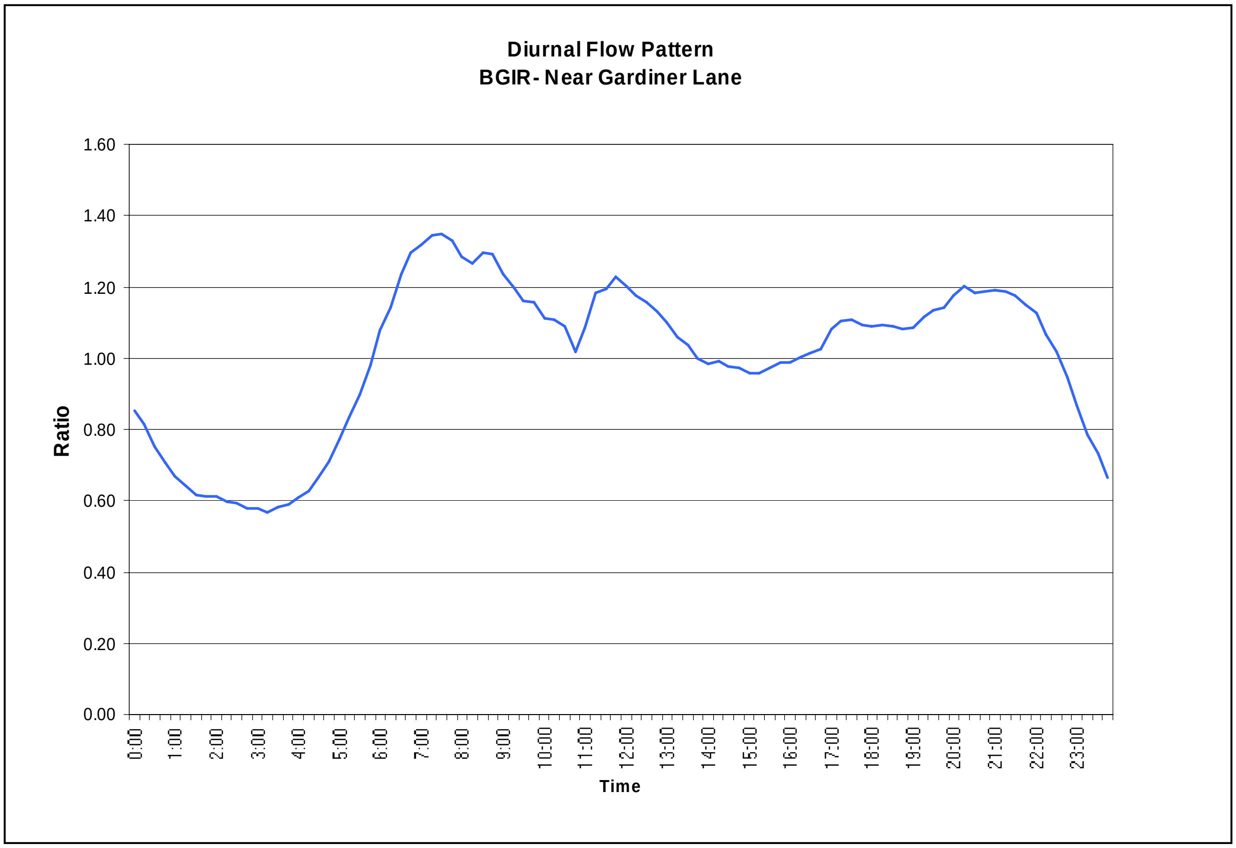


Figure 2.4-29 Diurnal Flow Pattern Beargrass Interceptor Relief near Gardiner Lane, 2007

DWF calibration was performed to ascertain that the model appropriately calculated the DWFs at various flow monitoring locations based on new methodology. Another aspect of DWF calibration is to understand the overflow structure configuration and/or other system configuration. Once the DWF simulation is successful, the model is then ready for wet weather calibration to determine the system response to a wet weather event.

Wet Weather Flow

The objective of the wet weather flow calibration is to simulate a series of wet weather events, by use of the best available data, and compare data predicted to actual data recorded at particular locations. Input variables are modified, within reason, to match observed conditions at flow monitoring locations.

Originally, in 1992, nine different storm events were chosen from the information obtained at the rain gauges and flow monitors during 1992 flow monitoring Phase I, and four different storm events were chosen from data recorded during 1992 flow monitoring Phase II for the wet weather calibration. The storm events were chosen because they represented a wide range of storm types. In most cases, a good correlation was achieved between two or three individual storm events at most sites, although some deviation between observed and predicted data was observed for another event. The Combined Sewer Operational Plan 1993, Chapter 5, details information from the original calibration.

The XP-SWMM version of CSS model was re-calibrated in 2004 using two different storm events: March 19 with a total of 2.9 inches of rain, and March 25 with a total of 2.8 inches of rain. The model was then executed using a two-week (March 15 to April 2, 2002) continuous simulation. The model predicted hydrographs within the system, which were compared to the monitored data, and a good correlation was found in most cases. The shapes and magnitudes of the hydrographs indicated that the original model was well calibrated for most of the service area. The updated XP-SWMM combined sewer model re-calibration, using 2002 flow meter data, was performed using the same method as outlined in the 1993 Combined Sewer Operational Plan.

The 2009 LTCP CSS model calibration in InfoWorks CS format was performed on April 14, 2007, and validation was performed on a continuous simulation. April 12, 2007 through May 7, 2007 was selected as a calibration and validation period to compare the model-predicted results to monitored data. In general, the plots of observed versus modeled depth and flow throughout the collection system demonstrated that the model simulated the actual collection system response reasonably well on an overall basis. **Error! Reference source not found.** presents a summary of the model wet weather flow calibration results for the major sewers. Calibration metrics that fell outside of MSD's modeling guidelines (10 percent) are shown in **Bold Red** text.

Table 2.4-6 Summary of Wet Weather Flow Calibration Results, 2007

NODE ID	SEWER NAME	METER SITE	MONITORED FLOW VOLUME (MG)	MODELED FLOW VOLUME (MG)	PERCENT ERROR (VOLUME)
Middle Fork Trunk (MFT) Sewer Area					
08769	MFT-Downstream end	Cabel St. & E. Washington St.	63.8	64.2	0.6%
24418	MFT-Lower Middle	Lexington Rd. & Bike Path	55.6	56.2	1.1%
45835	MFT-Upper Middle	Seneca Park Rd. and Alta Vista Rd.	48.0	43.8	-8.7%
24551	MFT-Upstream end	Seneca Park Rd. & Pee Wee Reese Rd.	43.5	43.2	-0.7%
Northeastern Sanitary Trunk Sewer (NSTS) Area					
08792	Mellwood	Mellwood Ave. & Delmont Ave.	3.3	3.4	1.2%
40248-X	NSTS	Louisville Metro Impound Lot	7.2	7.2	-0.6%
Beargrass Interceptor (BGI) and Beargrass Interceptor Relief (BGIR) Sewer Area					
08770	BGI	Buchanan St. & E. Washington St.	42.04	55.77	**32.8%**
08954	BGI	Near Nightingale Pump Station	40.6	31.2	**-23.1%**
27293	BGI [1]	Trevilian Way	NA	14.2	NA
16762	BGI	Downstream of SED	14.1	14.0	-0.4%
23214	BGIR	1718 Gardiner Ln.	17.2	17.4	-1.2%
50499	BGIR	Newburg Rd. & Trevilian Way	27.7	28.8	4.0%
71867	Tributary to BGI	937 S. Shelby St.	11.5	12.4	7.7%
08940	Tributary to CSO151	Castlewood Dell	2.3	2.6	**13.0%**
Southwestern Outfall Area					
10167	Cardinal Sewer	Union Ave. & Fayette Ave.	33.0	31.1	-5.7%
23167	Upper Dry Run Trunk	Lennox Ave. & S. Floyd St.	44.7	49.9	**11.5%**
50950	SW Branch	Bells Lane & S. 41st St.	198.3	175.1	**-11.7%**

Table 2.4-6 Summary of Wet Weather Flow Calibration Results, 2007

NODE ID	SEWER NAME	METER SITE	MONITORED FLOW VOLUME (MG)	MODELED FLOW VOLUME (MG)	PERCENT ERROR (VOLUME)
Ohio River Interceptor (ORI), Western Interceptor, Southern Outfall, and Northwestern Interceptor Area					
08843	CRD [2]	S. 8th Street & Magazine St.	2.2	0.2	**-88.9%**
08726-SM	Northwestern Interceptor	Shawnee Park Rd. & W. River Park Dr.	16.0	15.2	-5.1%
08112-SM	Western Interceptor	1366 S. 45th St.	22.1	22.5	1.8%
08635	Western Interceptor	4526 W. Broadway	9.7	10.6	9.3%
04250	38th Branch	W. Market St. & S. 38th St.	8.3	7.8	-6.0%
67892	Southern Outfall	Wilson Avenue & S. 12th St.	39.9	43.0	7.7%
08116	ORI	Fordson Way & Cecil Ave.	149.7	154.3	3.1%
08761-SM	ORI	Main St. & 15th St.	103.9	147.7	**42.4%**
Morris Forman WQTC					
Plant	MFWQTC Effluent Data [3]	Plant Inflow Hydrograph from CSS model	328.0	386.5	**17.2%**

Notes:

1. This meter location experienced data loss (4/15/07 through 4/26/07) during calibration/validation period.
2. Central Relief Drain (CRD) meter data not used for dry weather flow calibration. To simulate backwater condition, daily Ohio River level data provide by the USACE was applied.
3. Morris Forman WQTC influent data was not available. Effluent flow data was compared to modeled inflow data for general comparison purposes.

The following summarizes the results of the CSS model calibration efforts in 2007.

Middle Fork Trunk Sewer Area

A total of four calibration locations were available in the Middle Fork Trunk Sewer service area, including one upstream boundary location. After conducting the wet weather calibration efforts, all four sites exhibited good correlations between observed data and model-predicted data in flow, depth, and velocity. The total volume action level of 10 percent was met at all four of these locations.

Northeastern Sanitary Trunk Sewer Area

Two flow monitors (MH 08792 at Mellwood Avenue and MH 40248-x at the Louisville Metro Auto Impoundment Lot) were installed in the Northeastern Sanitary Trunk Sewer to characterize the inflow to the Robert J. Starkey Pump Station from the northeastern area. The hydrographs at both locations exhibited good correlation between the observed and model- predicted flows. The total volume action level of 10 percent was met at both locations.

Beargrass Interceptor and Beargrass Interceptor Relief Sewer Area

A total of eight calibration locations were available in the vicinity of the Beargrass Interceptor and Beargrass Interceptor Relief service area. For the most part, the model was able to predict the total volume of flow to meet the calibration criteria of 10 percent. Two (**MH 08770 and MH 08954**) of eight flow monitoring location calibration results will be improved by further investigation and continued analyses of operating strategy of the Nightingale Pump Station and Robert J. Starkey Pump Station. **MH 08940** calibration results were barely outside of the action level (13.0 percent or 0.2 MG). As part of continuing model maintenance activity, these sites will be closely monitored for next re-calibration task.

Southwestern Outfall Sewer Area

Three calibration locations existed in the service area of the Southwestern Outfall sewer, which is the largest pipe system in the MSD service area. The model reasonably predicted the flow rates measured and one of these calibration locations met the 10 percent action level while the other two locations (**MH 50950** and **MH23167**) were barely outside of the action level (11.7 percent and 11.5 percent). As the modeling program continues, this will be one area that will receive more focus to evaluate the calibration of the flow meters and monitor RTC responses.

Ohio River Interceptor, Western Interceptor, Southern Outfall, and Northwestern Interceptor Area

A total of seven flow monitoring locations were available for the wet weather flow calibration in the northwestern part of Louisville Metro, which includes service areas contributing to the Ohio River Interceptor, Western Interceptor, Southern Outfall and Northwestern Interceptor. As shown in **Error! Reference source not found.**, the model-predicted volumes were within the calibration action level of 10 percent, except for two locations discussed further below.

MH 08843: At this calibration/validation location flow was measured in the Central Relief Drain Sewer. This site was not considered for DWF calibration since Central Relief Drain does not carry sanitary flow. For wet weather flow calibration, this site experienced a backwater condition from the Ohio River due to an elevated river stage. Although the model-predicted volume at this location is significantly less than the observed data by percent error, the total volume measured is very small when compared to the flow at the Morris Forman WQTC (2.2 MG vs. 328.0 MG) and to other CSO locations. Further investigation of the Central Relief Drain system will result in a better understanding of the operating behavior in the service area. Furthermore, it would be beneficial to place temporary flow meters to monitor additional upstream characteristics. The investigation results will be used for re-calibration in the near future to improve calibration results of the model at this location.

MH 08761-SM: The Flow Meter at this calibration location measured the flow in the Ohio River Interceptor about midway between the Robert J. Starkey Pump Station and the Main Diversion Structure. The model-predicted volume at this location (148 MG) is about 42 percent higher than the observed volume (104 MG). This same trend was recognized during the DWF calibration. Based on other system calibration results and review of additional metering sites (downstream site shows 3.1 percent error by volume) modelers determined that additional flow monitoring and further investigation of the Robert J. Starkey Pump Station is required to improve calibration results of the model at this location.

Figure 2.4-30 and Figure 2.4-31 are example hydrographs of the good calibration/validation results. A detailed description of the model development and calibration/validation is provided for reference in Appendix 2.4.6.

Appendix 2.4.6 CSS Model Calibration/Validation Report

Appendix is the same as the 2012 IOAP Modification and is provided on external USB storage drive.

	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	3.490	1.200	0.006							
Obs.				1.430	4.815	5.201	44.653	537.989	0.510	5.180
... AreaRev_Rainfall				1.757	5.417	11.927	50.110	578.243	2.443	4.100

Figure 2.4-30 Hydrograph Middle Fork Trunk - Lexington Rd and Bike Path, 2007

	Rainfall			Depth (ft)		Flow (MGD)			Velocity (ft/s)	
	Depth (in)	Peak (in/hr)	Average (in/hr)	Min	Max	Min	Max	Volume (US Mgal)	Min	Max
Rain	3.690	1.260	0.006							
Obs.				0.466	2.300	0.676	28.457	230.741	1.280	5.980
... AreaRev_Rainfall				0.579	5.678	2.586	31.053	198.540	2.886	7.114

Figure 2.4-31 Hydrograph Cardinal Sewer - Union and Fayette Avenue, 2007

The calibrated and validated model was subject to a Quality Assurance/Quality Control (QA/QC) process. The QA/QC process involved peer review of the model, reporting discrepancies in a QA/QC checklist and a comments form. Full CSS Model QA/QC documentation is available for review in Appendix 2.4.7.

Appendix 2.4.7 CSS Model QA/QC

Appendix is the same as the 2012 IOAP Modification and is provided on external USB storage drive.

2.4.6.5. MODEL APPLICATION

The CSS model has been used as a tool to perform numerous analyses, such as flooding analyses and development analyses. Specific applications include evaluation to determine the AAOV and percent capture impact of the initial draft 1996 LTCP elements and compliance with NMC requirements.

During 2008, the CSS model was used to generate the hydraulic statistics to determine average annual CSO characteristics and establish the “baseline” condition of the system using 2001 rainfall data. The CSS model was used to generate the baseline AAOV and post LTCP AAOV or residual AAOV after the Final LTCP is completed. The summary report of LTCP characteristics, based on the 2007 modeling, is available for review in Appendix 2.4.8. The CSS modeling program enabled MSD to determine interceptor sewer conveyance and system storage capacities, characterize overflows and pollutant loads to receiving streams and to evaluate various CSO control strategies.

Appendix 2.4.8 LTCP Characteristics Summary Report

Appendix 2.4.9 Non-CSO Sewer Sampling Data Characterization

Appendices are the same as the 2012 IOAP Modification and are provided on external USB storage drive.

Subsequent Model Calibration/Validation

As part of the adaptive management process discussed in Volume 1, MSD continues to expand and update flow monitoring data as well as system geometric data. Based on new information, MSD modifies projects as necessary to design and construct projects that will ultimately meet the long-term goals of the LTCP and to meet community needs. As noted previously, MSD expanded the flow monitoring network to provide monitoring at each CSO site after the 2009 IOAP. As part of the 2012 submittal, significant geometric updates were made to portions of the model, and portions of the model were re-calibrated for certain project areas. After the 2012 IOAP, MSD continued to update the model and review calibrations for each project area in advance of proceeding with design for an individual project. The 2012 recalibration and modeling updates resulted in significant modifications to the 2009 LTCP. Subsequent modifications resulted in further modifications to the LTCP. The latest significant recalibrations were completed in advance of the final review of the 2015 project modifications. Project modifications are discussed generally in Chapter 4, and detailed information is provided in the minor modification letters submitted for each project.

2.5. COMPILATION EXISTING DATA – BEARGRASS CREEK

This section presents a detailed description of the physical characteristics of the Beargrass Creek Region of the CSS. The narrative summaries described are from the 2009 LTCP. The general descriptions are still relatively accurate. The statistical overflow information has been updated. New AAOV information for the current CSOs can be found in Chapter 3. Presented herein is an overview of the collections system mapping, an overview of the pipe network, major interceptors, all pumping stations, and a description of the individual CSOs.

2.5.1. BEARGRASS CREEK REGION OVERVIEW AND MAPPING

The combined sewer collection and conveyance system in the Beargrass Creek Region consists of those sewers contributing dry and wet weather flow to the Robert J. Starkey Pumping Plant, including the interceptors along the South and Middle Forks of Beargrass Creek, the Northeastern Sanitary Trunk, and related collector sewers. See Figure 2.5-1.

Figure 2.5-1 Beargrass Creek Regional Map

Figure is located at the end of this chapter.

Much of the interceptor network in this region has limited wet weather conveyance capacities. Although nearly all wastewater flows generated in the Beargrass Creek Region are tributary to the Robert J. Starkey Pumping Plant, two exceptions exist:

- Flows spilling into the Beargrass Interceptor Relief Sewer are subsequently pumped over to the Southwestern Outfall service area via the Nightingale Pump Station.
- Flows diverted from the Beargrass Interceptor to the Southeastern Interceptor and Northern Ditch Interceptor systems, via the Southeastern Diversion, upstream of the combined sewer area.

In 2009, 53 CSOs were located in the Beargrass Creek Region, with many discharge outlets located along much of the lengths of South and Middle Fork of Beargrass Creek. The slope of the interceptors serving these areas is marginal and requires a relatively high-water surface elevation to maintain flow in the sewers even under dry weather conditions.

2.5.2. COLLECTION SYSTEM UNDERSTANDING

This section presents an overview of the major assets within the CSS, including major sewers, major pumps stations and the CSOs. The system components are presented in group, aligned by reaches of Beargrass Creek.

2.5.2.1. BEARGRASS CREEK REGION MAJOR INTERCEPTORS/RELIEF SEWER DRAINS

The major interceptors included in the Beargrass Creek Region are designed to route sanitary flow and allotted quantities of diluted stormwater to the Morris Forman WQTC via either the Robert J. Starkey Pumping Plant or Nightingale Pump Station. A description of the major components of the CSS within the Beargrass Creek Region is presented below.

Beargrass Interceptor

The Beargrass Interceptor was originally constructed beginning in the early 1900s and has been reconstructed many times over the years. The line varies in size, shape and grade from a 6'-6" x 6'-1-1/2" basket-handle sewer with a 0.05 percent slope near its outlet end to a 36-inch circular sewer with a 0.073 percent slope just south of the Watterson Expressway (I-264). Estimated full flow capacities range between 74.4 million gallons per day (MGD) and 11.2 MGD, respectively.

Beargrass Interceptor Relief Sewer

The Beargrass Interceptor Relief Sewer was constructed in the 1960s and 1970s to relieve the surcharged Beargrass Interceptor. The Beargrass interceptor is located on the north side of the South Fork of Beargrass Creek, whereas the relief sewer is located on the south side of the creek between the Watterson Expressway and Nightingale Road. Most of the sewer tributaries to the Beargrass Interceptor from the south were connected to the relief sewer during its construction. The Beargrass Interceptor Relief is a 48-inch circular sewer with a varying grade. Based on a minimum slope of 0.037 percent and a maximum slope of 0.12 percent; estimated full flow capacities range from 16.5 MGD in the upstream sections to 31.1 MGD in the downstream sections.

Middle Fork Trunk Sewer

The Middle Fork Trunk Sewer serves the Middle Fork Basin of Beargrass Creek, is circular in shape and varies in size and grade throughout its length. At its outlet end, the 60-inch pipe on a slope of 0.095 percent has an estimated full flow capacity of 49.4 MGD. Typical daily DWF in the Middle Fork Trunk Sewer is about 16 MGD.

Northeastern Interceptor

The Northeastern Interceptor was originally a branch of the Beargrass Interceptor and is actually two sewers constructed in an over-under configuration. The upper Northeastern Sanitary Trunk Sewer was designed to collect sanitary flow from the northeastern portion of the city and convey it westward to the Beargrass Interceptor for discharge into the Ohio River. The lower Northeastern Storm Drain was designed to convey stormwater eastward for discharge into Beargrass Creek. After construction of these sewers, several sanitary sewers were erroneously connected to the Northeastern Storm Drain. Later, the construction of the McAlpine Locks and Dam raised the normal pool of the Ohio River from elevation 412.00 to 420.00. This submerged the Northeastern Storm Drain over most of its length and resulted in very low velocities that allowed septic conditions to develop in the sewer during dry weather periods. The Letterle Pump Station (formerly the Point Pump Station) was constructed to alleviate this condition by intercepting the Northeastern Storm Drain and discharging flow into the Northeastern Sanitary Trunk Sewer. During high flow periods, the pump station was designed to discharge the combined flow directly into Beargrass Creek. The Northeastern Sanitary Trunk Sewer is a 5-7-1/2" x 4'-0" basket-handle sewer with a 0.05 percent slope. The estimated flow capacity is 31.9 MGD. The Northeastern Storm Drain is a rectangular sewer of varying width and height. At the downstream end, the 6'-0" x 4'-9" Storm Drain is on a grade of 0.105 percent and provides an estimated full flow capacity of 78.3 MGD.

The Letterle Pump Station Elimination project eliminated the Letterle Pump Station and re-routing sewers that contributed flow. The storm drain (lower sewer) carried primarily storm flow but contained some sanitary sewage due to improperly connected property service connections. The project included removing all sanitary connections to the lower sewer and allowing it to carry stormwater only to the Beargrass Creek. The Letterle Pump Station was decommissioned and the CSO145 outfall was eliminated and converted into a stormwater outfall.

Sneads Branch Relief Drain

Beginning around 1950, the Sneads Branch Relief Drain was constructed to relieve flooding from the overloaded sewers in the area along Shelby Street near the South Fork of Beargrass Creek. This drain relieves combined sewers using side overflow weirs at 11 locations and receives stormwater discharges from catch basins along its route. The drain discharges directly to the South Fork of Beargrass Creek and carries stormwater and the overflows of the combined sewers it relieves. An inflatable dam was constructed in 2001 at the outlet to store overflow for pumping into the Beargrass Interceptor Sewer. At the outlet end, the 11'-0" semi-elliptical drain line has a slope of 0.125 percent with an estimated full flow capacity of 473 MGD.

2.5.2.2. BEARGRASS CREEK REGION MAJOR PUMP STATIONS

Robert J. Starkey Pumping Plant – Sanitary and Flood

The Buchanan Street Pump Station, renamed the Robert J. Starkey Pumping Plant in 2005, located on the east corner of Buchanan and Franklin Streets, was constructed by the USACE in the 1950s as part of Louisville's flood control system. The Robert J. Starkey Pump Plant functions as a wastewater pump facility during non-flood conditions. The Beargrass Interceptor, Middle Fork Trunk, and the Northeastern Interceptor converge just outside of the pump station. A common 6' x 8' rectangular sewer conveys all flow into the pump station. The pump station was originally equipped with four pumps rated at 31 MGD each for a total of 124 MGD. Recently, the pump plant has been upgraded and is now equipped with four pumps rated at 35 MGD each for a total of 140 MGD. However, a sustainable maximum pumping rate of 108 MGD is assumed within the CSS model. Impeller wear due to heavy grit is a constant issue that degrades the pumps over time. Preventive maintenance of the pumps will keep the station at or above this operating level. Flow in excess of station capacity is discharged via gravity to the Ohio River through two overflow points. When Ohio River stage elevations prevent the discharge of overflow by gravity, the pump station switches to flood pumping and discharges to the river. A schematic of the pump station and influent sewers is shown on Figure 2.5-2.

Figure 2.5-2 Robert J. Starkey Pumping Plant

Figure is located at the end of this chapter.

Nightingale Pump Station - Sanitary

The Nightingale Pump Station, which is located at the end of Nightingale Road on the west side of the South Fork of Beargrass Creek, was designed to convey flow in the Beargrass Interceptor Relief Sewer through the Manning Road-Cardinal Drive Sewer and into the Upper Dry Run Trunk and eventually to the Southwestern Outfall. A schematic of the pump station and influent sewers is shown on Figure 2.5-3. The pump station was built in conjunction with the Beargrass Interceptor Relief sewer to prevent overflows from the Beargrass Interceptor during high flow conditions. The Nightingale Pump Station is designed with three 16" pumps rated at 8,750 gallons per minute (gpm) each for a total capacity of 26,250 gpm or about 37 MGD.

Figure 2.5-3 Nightingale Pump Station

Figure is located at the end of this chapter.

2.5.2.3. BEARGRASS CREEK REGION COMBINED SEWER OVERFLOWS

A detailed description and discussion of each CSO structure and its discharge outfall located within the Beargrass Creek Region is provided in Appendix 2.5.1. A sample Summary Sheet for a CSO is shown in Appendix is ***the same as the 2012 IOAP Modification and is provided on external USB storage drive.***

Figure 2.5-4.

Appendix 2.5.1 CSO Fact Sheets

Appendix is the same as the 2012 IOAP Modification and is provided on external USB storage drive.

Figure 2.5-4 CSO Sample Data Sheets

Figure is located at the end of this chapter.

Sneads Branch (11 CSOs)

As noted earlier, the Sneads Branch Relief Drain was constructed to relieve flooding from an overloaded sewer in the area along Shelby Street near the South Fork Beargrass Creek. The drain relieves combined sewers using overflow weirs at 11 locations and receives stormwater discharges from catch basins along its route. Because the Sneads Branch Relief Drain was constructed specifically to convey the excess flows from each of the noted CSOs, the Drain itself does not function as a consolidation sewer to bring the excess flows to a common point. As a part of RTC Phase I, an inflatable gate was installed at Sneads Branch to capture flows from the 11 CSOs. Pumps send re-captured overflows back into the Beargrass Interceptor for treatment at the Morris Forman WQTC.

The storage capacity of Sneads Branch Inflatable Dam is approximately 2.5 MG and it captures approximately 86 percent of overflow volume from individual CSOs upstream during a typical simulation. During larger wet weather events, in excess of in-line storage capacity, the inflatable dam will modulate to maintain a water level to protect homes from flooding, while maximizing capture of as much CSO as possible.

Middle Fork (Eight CSOs)

CSO206 Manhole Separation and Property Service Reconnection was completed and certified March 31, 2009.

Northeastern Area (Six CSOs)

In January 2001, the public portion of CSO088 was separated. An evaluation of the CSO closure was performed during the year 2005 to determine the effectiveness of the separation and potential influence of a proposed downspout disconnection project. Through this evaluation it was determined that CSO088 operates as a relief point for the Mellwood Interceptor, therefore a downspout disconnection program would have a minimal impact on CSO volume and frequency. CSO088 also has been identified as a CSO with potential backwater impact from the Beargrass Creek during high Ohio River elevation.

2.6. COMPILATION AND ANALYSIS OF EXISTING DATA – OHIO RIVER

This section presents a detailed description of the physical characteristics of the Ohio River Region of the CSS. The narrative summaries described are from the 2009 LTCP. The general descriptions are still relatively accurate. New AAOV information for the current CSOs can be found in Chapter 3. Presented herein is an overview of the collections system mapping, an overview of the pipe network, major interceptors, all pumping stations, and a description of the individual CSOs.

2.6.1. OHIO RIVER REGION OVERVIEW AND MAPPING

The Ohio River Interceptor and Central Relief Drain service areas are designated as the Ohio River North Region since they are downstream of the Robert J. Starkey Pumping Plant and overflow into the Ohio River. See Figure 2.6-1. The collection and conveyance networks in this Region are relatively small with limitations in wet weather capacity. The Ohio River Interceptor conveys flows to the Main Diversion Structure (CSO211) near the Morris Forman WQTC from the Robert J. Starkey Pump Plant, 4th Street and 34th Street Pump Stations, as well as gravity systems generally serving the areas along the south shore of the Ohio River. Forty-nine individual overflow relief structures are widely scattered throughout the two service areas.

Figure 2.6-1 Ohio River North Regional Map

Figure is located at the end of this chapter.

In the Ohio River West Region, the conveyance systems consist of much larger interceptors and trunk sewers that exist in either of the Beargrass Creek or Ohio River North Region. Major sewers and service areas in the Ohio River West Region include the Northwestern Interceptor, Western Interceptor, Western Outfall, Southern Outfall, and the Southwestern Outfall. See Figure 2.6-2. With the exception of the Western Interceptor, the conveyance capacities of these facilities are generally much larger than the capacity required for DWF only, since they must also convey storm flows from small and large events. Taken together, the Northwestern Interceptor, Western Outfall, Southern Outfall, and Southwestern Outfall service areas can nearly contain wet weather flows from storms of 0.10 inch/hour or less in intensity. Considerable overflow can occur for storms having greater intensities. Eight CSO locations exist in this western part of the MSD service area, all of which are located near the downstream ends of the conveyance systems in each area.

Figure 2.6-2 Ohio River West Regional Map

Figure is located at the end of this chapter.

2.6.2. COLLECTION SYSTEM UNDERSTANDING

2.6.2.1. OHIO RIVER NORTH REGION MAJOR INTERCEPTORS/RELIEF SEWER DRAINS

As part of the CSO study, the major interceptors, relief sewer and drains in the Ohio River North Region were designed to route sanitary flow and allotted quantities of diluting stormwater to the Morris Forman WQTC for treatment and final discharge to the Ohio River. A description of the CSS within the Ohio River Region is presented below. The narrative summaries described are from the 2009 LTCP. The general descriptions are still relatively accurate. Some of the flood pump stations have been upgraded and rehabilitated since 2009. The LTCP projects and operational changes to eliminated DWOs have also been completed. New AAOV information for the current CSOs can be found in Chapter 3.

Ohio River Interceptor

In the mid-1950s, the state ordered MSD to provide primary wastewater treatment and eliminate the discharge of raw sewage into the Ohio River. As a result, the Ohio River Interceptor and three major pump stations were constructed to collect flow from eastern, central, and northwestern portions of the system and convey it to the Morris Forman WQTC. Until that time, numerous individual sewers located in the north central section of the city discharged directly into the river. The design and construction of the Ohio River Interceptor enabled these lines to be intercepted and the sewage to flow by gravity to the treatment plant. In addition, the Robert J. Starkey, 4th Street, and 34th Street Pump Stations, which were constructed by the USACE as part of the city's flood control system, were also designed to be utilized as sanitary pumping facilities during non-flood periods. The Ohio River Interceptor, Western Interceptor, and Southern Outfall join south of 45th Street and Winnrose Way at the Main Diversion Structure located on the Whayne Supply Company property.

The Ohio River Interceptor enters the diversion structure as an 8'-0" circular sewer and exits as an 11'-0" semi-elliptical sewer flowing to the Morris Forman WQTC. The Ohio River Interceptor passes under the Southern Outfall in a siphon type arrangement but is open on the top, on each side of the Southern Outfall, within the diversion structure. The Southern Outfall is also open on the top within the structure. The Ohio River Interceptor is routinely backfilled by the Southern Outfall during wet weather. Because the Ohio River Interceptor is lower, water surface elevations equalize in both sewers resulting in some storage being provided before an overflow occurs.

Between the Morris Forman WQTC and the Main Diversion Structure, the Ohio River Interceptor is an 11'-0" semi-elliptical sewer with a slope of 0.03 percent. The estimated full capacity of the line in this reach is about 250 MGD. Upstream of the Main Diversion Structure, the interceptor varies in size, shape, and grade throughout its length. At its outlet end, the 8'-0" circular pipe on a slope of 0.08 percent has an estimated full flow capacity of 155 MGD. Typical daily flow is about 45 MGD.

38th Street Branch Interceptor

The 34th Street Pump Station serves the northwestern portion of the city from about 12th Street westward to the Ohio River. The flow from the station discharges into the 38th Street Branch Interceptor at 35th Street and Northwestern Parkway. The 38th Street Branch Interceptor in turn conveys the flow southward in 38th Street to the Ohio River Interceptor at 38th and Herman Streets. The 38th Street Sewer parallels the branch interceptor along 38th Street but continues one block further south before discharging into the Northwestern Interceptor.

The 38th Street Branch Interceptor is circular in shape and varies in size and grade from a 36-inch sewer with a 0.15 percent slope at its outlet end to a 30-inch sewer with a 0.39 percent slope at its upstream terminus. Estimated full flow capacity range is between 16.6 MGD and 17.2 MGD, respectively.

Central Relief Drain

In the mid to late 1930s, in response to flooding in the central business district from overtaxed combined sewers, the Central Relief Drain was constructed. This drain was designed to only receive flow during wet weather and relieves the combined sewers in the central part of the city at 14 locations. At each location, a side overflow weir was constructed on the sewer being relieved. When flow in the combined sewer reaches the level of the weir, a portion of the flow is relieved into the Central Relief Drain and transported to the Ohio River. The remaining flow continues through the combined sewer to its destination. Around 1950, the Central Relief Drain was extended south, and relief was provided at 13 additional locations. Any flow that enters the Central Relief Drain must be discharged to the Ohio River.

A flood control gate is closed when the upper pool of the Ohio River reaches elevation 439.0 that protects the Central Relief Drain. When this gate is closed, all flow in the Central Relief Drain is diverted to the 5th Street Flood Pump Station and discharged to the Ohio River. Near its outlet end, the 6'-5" x 9'-7-1/2" inverted egg-shaped drain line with a slope of 0.335 percent has an estimated full flow capacity of 305 MGD.

4th Street Relief Sewer

The 4th Street Relief Sewer was designed and constructed to relieve sewers in the central business district that were being surcharged during periods of dry weather. For this reason, at each relief point, all flow in the combined sewers was diverted into the relief sewer. The relief sewer originally discharged flow into the Ohio River at the northern end of 4th Street. The 4th Street Pump Station was built in conjunction with the Ohio River Interceptor when the treatment facilities were built. A dam was constructed across the relief sewer to divert DWF into the pump station. The pump station discharges into the Ohio River Interceptor. Excess flow during wet weather tops the dam and continues through the relief sewer to the river. The majority of the 4th Street Relief Sewer was constructed in a tunnel and is of such depth that the crown of the sewer is below the basement level of most of the adjacent buildings. Just upstream of the pump station, the 7'-6" semi-elliptical relief sewer with a slope of 0.20 percent has an estimated full flow capacity of 215 MGD.

2.6.2.2. OHIO RIVER NORTH REGION MAJOR PUMP STATIONS

The northern region of the Ohio River sewershed contains many larger pump stations, many of which are facilities that are part of the CSS and operate during Ohio River flood and non-flood modes. The pump stations within this region include 4th Street Pump Station, 34th Street Pump Station, 5th Street Pump Station, 10th Street Pump Station, 17th Street Pump Station, and 27th Street Pump Station.

4th Street Pump Station - Sanitary and Flood

The 4th Street Pump Station, located on the southeast corner of 4th and Main Streets, was constructed by the USACE in the 1950s as part of Louisville's flood control system and functions as a wastewater pumping facility. During non-flood conditions, the flow in the 4th Street Relief Sewer is diverted into the pump station and discharged to the Ohio River Interceptor. Per the USACE operational manual, during flood periods the pump station can discharge into the Ohio River Interceptor or the Ohio River, depending on flow.

The 4th Street Relief Sewer was built in the late 1920s to relieve overloaded sewers along 4th Street, Muhammad Ali Boulevard, Chestnut Street and Broadway. The relief sewer was designed to relieve all flows in the overloaded sewers, not just excess flows. Therefore, sanitary flow is present in the relief sewer continuously. A plan view of the pump station, sewers, diversions, and gates is presented in Figure 2.6-3

Figure 2.6-3 Fourth Street Pump Station

Figure is located at the end of this chapter.

The 4th Street Pump Station contains a sanitary wet well, a flood wet well and six pumps (three sanitary pumps and three flood pumps). The sanitary pumps can also be used as flood pumps. There are two 35 horsepower sanitary pumps rated at 4,000 gpm at 25 feet of head and one 60 horsepower sanitary pump rated at 5,900 gpm at 35.7 feet of head. The sanitary pumps discharge into a common header, which leads to either the Ohio River Interceptor or the flood pump discharge chamber. Fourth Street has three 350 horsepower stormwater pumps with a total station capacity of 95,400 gpm.

The 4th Street Pump Station is the ninth flood pump station to be placed into service should flooding occur on the Ohio River. This facility is not placed in flood operation mode until the river elevation exceeds elevation 436.3. This facility is expected to operate as a flood pump facility about once every five years on average.

34th Street Pump Station - Sanitary and Flood

The 34th Street Pump Station, which is located just south of the levee on 34th Street, was constructed by the USACE in the 1950s as part of Louisville's flood control system and functions as a wastewater pump facility. The station conveys flow from the northern portion of Louisville Metro to the Ohio River Interceptor or to the lower pool of the Ohio River, depending on flow and river elevation. A plan of the pump station, sewers, diversions, and gates is presented in Figure 2.6-4.

Figure 2.6-4 34th Street Pump Station

Figure is located at the end of this chapter.

A diversion dam on the sewer flowing north on 34th Street diverts low flows through a 24-inch sewer into the pump station. The pump station discharges to the 38th Street Branch Interceptor that conveys the flow to the Ohio River Interceptor at 38th Street and Herman Street. The diversion dam is designated as CSO 019. Excess flow tops the dam and is discharged through the sewer to the lower pool of the Ohio River. When the river stage exceeds elevation 421.00, the pump station is shut down and backwater and sewage is allowed to pond in the sewer system.

The pump station contains two sanitary pumps rated at 4,250 gpm each at 31.5 feet of head and four storm pumps rated at 15,600 gpm each at 34 feet of head. The sanitary pumps can also be used for flood pumping.

The 34th Street Pump station is the thirteenth station to be placed into service should flooding occurs on the Ohio River. This facility is not placed in flood operation mode until river elevation exceeds 434.6. This facility is expected to operate as a flood pump facility about once every five years on average.

5th Street Pump Station - Flood

The 5th Street Pump station, which is located at 100 Place Montpelier, north of Main Street adjacent to the floodwall, was constructed by the USACE in the 1950s as part of Louisville's flood control system. This facility is equipped with three 50 horsepower pumps and one 25 horsepower pump providing a total capacity of approximately 37,000 gpm at minimum design head. The minimum water level elevation in the wet well is 426.75 based on the smaller pump and 437.00 for the larger pumps. The maximum design pumping elevation is 440.00.

The 5th Street Pump Station is the seventh station to be placed into service should flooding occur on the Ohio River. This facility is not placed in operation until the river elevation exceeds 434.3. Above this level, the facility is used to pump excess combined flows from the sewers in 5th 6th and 7th Streets and storm flows accumulated between Main Street and the floodwall to the river. Normal flows in these sewers, up to the capacities of their appropriate diversion structures, are conveyed to the Ohio River Interceptor. This facility is placed in operation about once every five year on average.

10th Street Pump Station - Flood

The 10th Street Pump Station, which is located on the southwest corner of 10th and Rowan Streets, was constructed by the USACE in the 1950s as part of Louisville's flood control system. This facility utilizes three 200 horsepower pumps and one 25 horsepower unit to achieve a total capacity of approximately 90,000 gpm at minimum design head. The minimum water level elevation in the wet well is 420.50 based on the smaller pump and 427.70 for the larger pumps. The maximum design pumping elevation is 432.10.

The 10th Street Pump Station is the eighth station to go on-line should flooding occur on the Ohio River. This facility is not placed in operation until the river elevation exceeds 434.6. At various stages above this level, the facility is used to pump excess combined flows from the sewer in 8th, 9th, 10th, 11th, 12th, and 13th Streets and storm flows accumulated between Main Street and the floodwall to the river. At upper gauge elevation 439.00, flow in the Central Relief Drain is diverted to the pump station. Normal flows in the numerous tributary sewers in 8th through 13th Streets, up to the capacities of their appropriate diversion structures, are conveyed to the Ohio River Interceptor. This facility is placed in operation about once every five years on average.

17th Street Pump Station - Flood

The USACE constructed the 17th Street Pump Station, which is located at the beginning of 17th Street north of Northwestern Parkway and adjacent to the floodwall, constructed by the USACE in the 1950s as part of Louisville's flood control system. The facility is equipped with three 75 horsepower pumps and one 15 horsepower pump providing a total capacity of approximately 496.0 gpm at minimum design head. The minimum water level elevation in the wet well is 427.25 based on the smaller pump and 433.00 for the larger pumps. The maximum design pumping elevation is 438.20.

The 17th Street Pump Station is the eleventh station to be placed into service should flooding occur on the Ohio River. This facility is not placed in operation until the river elevation exceeds 437.5. Below this level, normal flow in the sewer in 17th Street is conveyed to the 34th Street Pump Station and discharged into the Ohio River Interceptor. High flows top the diversion dam in Northwestern Parkway just upstream of the 17th Street station and are discharged by gravity directly into the river. Above river elevation 437.5 on the upper gauge, combined flows in the sewer in 17th Street are routed to the 17th Street facility and pumped into the river. This facility is placed in operation about once every five to ten years on average.

27th Street Pump Station - Flood

The 27th Street Pump Station, which is located at 27th Street and the floodwall, was constructed by the USACE in the 1950s as part of Louisville's flood control system. The facility utilizes four 350 horsepower pumps and one 60 horsepower unit to achieve a total capacity of approximately 198,150 gpm at minimum design head. The minimum water level elevation in the wet well is 419.25 based on the smaller pump and 428.20 for the larger pumps. The maximum design pumping elevation is 433.20.

The 27th Street Pump Station is the tenth station to be placed into service should flooding occur on the Ohio River. The 27th Street Pump Station is not placed in operation until the river elevation exceeds 436.8. Below Ohio River elevation 427.5, normal flows in the sewer in 22nd and 27th Streets are conveyed around the 27th Street facility to the 34th Street Pump Station and discharged into the Ohio River Interceptor. High flows overflow the diversion dam just upstream of the 34th Street station and are discharged by gravity directly into the river. Between upper gauge elevations 427.5 and 436.8, normal flows are handled in the same manner prescribed above, but a portion of the high flows is diverted by gravity directly into the Portland Canal instead of traveling all the way to 34th Street. Above river elevation 436.8 on the upper gauge, combined flows in the sewers in 22nd and 27th Streets are routed to the 27th Street Pump Station and pumped into the river. This facility is placed in operation about once every five to ten years on average.

2.6.2.3. OHIO RIVER NORTH REGION COMBINED SEWER OVERFLOWS

CSO023 is one of three CSOs within the entire CSS that does not have solids and floatables control. A concerted effort was made in August of 2006 to design and install devices but because of physical limitations of the diversion structure, it was not feasible to install solids and floatables device without extensive engineering or construction. Therefore, solids and floatables will be addressed as part of the Final LTCP at these locations.

2.6.2.4. OHIO RIVER WEST REGION MAJOR INTERCEPTORS/RELIEF SEWER DRAINS

Northwestern Interceptor and Western Interceptor

The Northwestern Interceptor and Western Outfall were constructed around 1911 and 1870, respectively, and both at one time discharged directly into the lower pool of the Ohio River around Shawnee Park. In the early part of the 1900s, park visitors and patrons of a nearby amusement park extensively used this area. The direct discharges from the Western Outfall produced some offensive conditions during periods of low water. Thus, the Western Interceptor was constructed in conjunction with the Northwestern Interceptor. The Western Interceptor was designed to intercept the DWF in both the Northwestern Interceptor and the Western Outfall and convey it to the Southern Outfall, which then were discharged downstream of Shawnee Park and the amusement park.

When the treatment facilities at Morris Forman WQTC were constructed, the Western Interceptor was redirected into the Ohio River Interceptor just upstream of the CSO211. Today, a CSO remains on the Western Interceptor at that point of redirection. Excess flow continues through the Western Interceptor to the Southern Outfall downstream of the CSO211.

Between its outlet end and Broadway, the Western Interceptor is a 5'-0" circular sewer with a slope of .055 percent and provides an estimated full flow capacity of 36.8 MGD. At Broadway, the interceptor becomes a 3'-6" circular sewer on the same grade and remains as such until it terminates at its junction with the Northwestern Interceptor. The estimated full flow capacity of the smaller section is reduced to approximately 14.4 MGD. Peak wet weather flow in the Western Interceptor has been measured at up to 20 MGD.

Western Outfall

The Western Outfall drains the area along Broadway from the Ohio River east to about 12th Street, encompassing about 1,800 acres. DWF from the Western Outfall is directed into the Western Interceptor just south of Shawnee Park in Broadway. Excess flows top an overflow diversion dam and continue through the

Western Outfall to the river. When the lower gauge reaches elevation 435.0, a flood control gate on the Western Outfall is closed and any excess flow is directed into the Shawnee Park Flood Pump Station, which is then pumped to river.

The eastern portion of the Western Outfall service area, notably that area located along Maple Street, has surcharged several times in recent years, flooding vehicles and yards with combined sewage. This low-lying area is especially susceptible to flooding from sewer surcharges. Although the Western Outfall is relatively large in diameter, its flat slope results in insufficient capacity to convey all flows during high intensity storm events. The result is basement backups, sewer surcharging, and/or surface flooding during heavy rains. Surface flooding has occurred all along this sewer since as far back as 1910.

The segment of the Western Outfall in Broadway between Southwestern Parkway and 28th Street is a 10'-6" diameter circular brick sewer that was constructed circa 1873. Just west of the Southwestern Parkway, the sewer becomes 11'-9" in diameter. Based on plans developed during the underground sewer investigations of 1937, the outfall line has an estimated grade of 0.052 percent providing a full flow capacity of approximately 355 MGD upstream of the diversion dam. Peak wet weather flow in the Western Outfall has been measured at over 220 MGD at about two-thirds full. Typical daily flow is 3 or 4 MGD.

Southern Outfall

The Southern Outfall serves a combined sewer area of about 3,500 acres and has an unsurcharged full flow capacity of about 765 MGD at its lower end. The Southern Outfall was constructed around 1912 and discharges to the lower pool of the Ohio River, just upstream of the treatment plant. Continued growth and development in the service area of the Southern Outfall has increased runoff to the extent that basement backups and surface flooding occur during intense storms.

When the diversion structure was built, a dam was constructed across the Southern Outfall to divert DWF through a drop connection into the Ohio River Interceptor to the Morris Forman WQTC. High flows top the dam in the diversion structure and continue through the Southern Outfall to the river. The Western Parkway Flood Pump Station provides flood protection for the Southern Outfall. When the lower gauge of the river exceeds elevation 416.4, the flood control gates are closed, and the pump station begins operation. Overflow from the diversion structure is then pumped to the river.

Southwestern Outfall

The Southwestern Outfall serves the southwestern section of Louisville Metro and through its branches also serves the south-central portion. Flows collected in the south-central area north of the Watterson Expressway are routed via the Manning Road - Cardinal Drive Sewer and Upper Dry Run Trunk Sewer to a junction with the Southwestern Outfall at Taylor Boulevard and Oleanda Avenue. In a similar fashion, flows collected in south central Louisville, south of the Watterson Expressway, are conveyed through the Northern Ditch Trunk Interceptor and Mill Creek Trunk Sewer to the same junction point with the Southwestern Outfall at Taylor and Oleanda.

Flow in the Beargrass Interceptor Relief Sewer is discharged by the Nightingale Pump Station into the upstream end of the Manning Road - Cardinal Drive Sewer and thus enters the Southwestern system. In addition, other sewers, normally a tributary to the Beargrass Interceptor, can be diverted behind the Bashford Manor Mall through the Southeastern Interceptor, Northern Ditch Trunk Interceptor, and Mill Creek Trunk Sewer to the Southwestern Outfall. This diversion can be accomplished manually and is limited by the capacity of the Northern Ditch Pump Station. The Southwestern Outfall is diverted near Bells Lane and

Watterson Expressway to the Southwestern Pump Station where the flow is pumped through the Southwestern Branch Interceptor to the Morris Forman WQTC.

The Southwestern Outfall, constructed in the 1930s, drains a combined sewer area of about 7,700 acres. The expanse of the service area of the Southwestern Outfall dictated its large size, 18'-4" x 27'-6" at one point. This sewer is considered the outstanding accomplishment of the Commissioners of Sewerage. In both length and size, it was one of the largest sewers built in the United States during that era. The Southwestern Outfall is an inverted egg-shaped sewer with varying width, height, and grade throughout its length. At the Southwestern Pump Station, the 18'-4" x 27'-6" line was constructed on a slope of 0.087 percent and provides an estimated capacity of 2,556 MGD flowing full.

DWF in the Southwestern Outfall is diverted by a 6-foot high dam into the Southwestern Pump Station and discharged through the Southwestern Branch Interceptor to Morris Forman WQTC. For a majority of its length, the 6'-0" circular Southwestern Branch Interceptor was laid on a slope of 0.07 percent and provided an estimated full flow capacity of 74 MGD. The 104 MGD capacity of the pump station exceeds the maximum unsurcharged capacity of the Branch Interceptor.

Normal lower pool elevation on the Ohio River is 383.00. Because of the presence of the McAlpine Locks and Dam at Louisville, the lower pool elevations fluctuate much more than the upper pool elevations. Lower pool elevations exceed 400.00 quite regularly. In consideration, the Southwestern Outfall is protected by three large electrically operated sluice gates just below the Southwestern Pump Station.

Southwestern Branch Interceptor

The Southwestern Branch Interceptor conveys flow discharged from the Southwestern Pump Station to the Morris Forman WQTC. For a majority of its length, the 6'-0" circular sewer was laid on a slope of 0.07 percent and provided an estimated full flow capacity of 72 MGD. It should be noted that the 104 MGD capacity of the pump station exceeds the maximum unsurcharged capacity of the Southwestern Branch Sewer.

2.6.2.5. OHIO RIVER WEST REGION MAJOR PUMP STATIONS

Northern Ditch Pump Station - Sanitary

The Northern Ditch Pump Station is located on the Northern Ditch Trunk Interceptor on New Way southeast of Strawberry Lane. The facility differs from other stations discussed herein in that it functions solely as a sanitary lift station (LS). Flow in the 72-inch interceptor is lifted approximately 24 feet and discharged into a 60-inch downstream continuation of the interceptor that ultimately flows to the Mill Creek Trunk Sewer and Southwestern Outfall. See Figure 2.6-5. The Northern Ditch Pump Station utilizes four submersible propeller pumps each rated at 14,400 gpm for a total constructed capacity of 57,600 gpm. Due to limited capacity in the discharge chamber and downstream sewer, only three pumps are operated simultaneously. The fourth pump is used as a stand-by. Therefore, the maximum discharge from the pump station is 43,200 gpm or 62 MGD. The full flow capacity of the Northern Ditch Interceptor, upstream of the pump station is about 52 MGD.

Figure 2.6-5 Northern Ditch Pump Station

Figure is located at the end of this chapter.

Southwestern Pump Station

The Southwestern Pump Station is located just south of Bells Lane on the west side of the Watterson Expressway. The facility was designed to intercept flow in the Southwestern Outfall and convey it via the Southwestern Branch Interceptor to the Morris Forman WQTC. Excessive high flows in the Southwestern Outfall overflow a diversion dam and continue through the outfall line to the Ohio River. See Figure 2.6-6.

Figure 2.6-6 Southwestern Pump Station

Figure is located at the end of this chapter.

The pump station has an east and west wet well, each fed by a 60" sewer. Mechanical screening is provided on both of the wet well inlets. Two 30-inch centrifugal pumps draw from the west wet well and two 20-inch centrifugal pumps draw from the east wet well. The bottom elevation of the wet wells is 382.25. An opening in the dividing wall at elevation 393.34 connects the wet wells. The four pumps are rated at 24,000 gpm each. The fourth pump is used as a standby. Therefore, maximum discharge from the pump station is 104 MGD.

Shawnee Park Pump Station - Flood

The Shawnee Park Pumping Station is located at 612 Southwestern Parkway in the middle of Shawnee Park. The facility has five 800 horsepower pumps and one 75 horsepower pump providing a total capacity of approximately 526,500 gpm at minimum design head. The minimum water level elevation in the wet well is 412.50 based on the smaller pump and 420.00 for the larger pumps. The maximum design pumping elevation is 426.50.

The Shawnee Park Pumping Station is not placed in operation until the river level reaches elevation 435.00 on the lower gauge. Below this level, normal flows in the Northwestern Interceptor and Western Outfall enter the Western Interceptor and are eventually conveyed to the Morris Forman WQTC. Excessive high flows in the Northwestern Interceptor are diverted at its junction with the Western Interceptor to the Ohio River. In a similar fashion, excessive high flows in the Western outfall overflow the diversion dam in Broadway and discharge to the river. Above river elevation 435.00 on the lower gauge, combined flows from both the Northwestern Interceptor and Western outfall are routed to the Shawnee facility and pumped into the river. Shawnee is the fourteenth station to be placed into service should flooding occur on the Ohio River. This pump station operates about once every five to ten years on average.

Western Parkway Pump Station - Flood

The Western Parkway Pumping Station is located on the Southern Outfall west of Southwestern Parkway at 1300 Southwestern Parkway. The facility is equipped with four 1,250 horsepower and three 450 horsepower pumps capable of discharging a total flow of approximately 810,000 gpm at minimum design head. The minimum water level elevation in the wet well is 412.60 based on the smaller pumps and 417.00 for the larger pumps.

The Western Parkway Pumping Station is not placed in operation until the river elevation exceeds 416.4 on the lower gauge. Below this level, normal flows in the Ohio River Interceptor, Southern Outfall, Western Interceptor, and 45th Street-Greenwood Avenue Sewer converge at the CSO211 and continue to the Morris Forman WQTC. Excessive high flows overflow the dam in the main diversion structure and are conveyed by gravity through the Southern Outfall to the Ohio River. Above river elevation 416.4 on the lower gauge, the Western Parkway facility is used to pump the combined flow in the Southern Outfall downstream of the CSO211 into the river. Western Parkway facility is the first station to be placed in service should flooding occur on the Ohio River. This facility can be expected to operate about once or twice a year on average and one of the pumps may run for a short period of time.

Paddy's Run Pump Station - Flood

The Paddy's Run Pumping Station, which is located at 4200 Campground Road, is equipped with four 1,250 horsepower pumps and two 700 horsepower units providing a total capacity of approximately 607,500 gpm at minimum design head. The minimum water level elevation in the wet well is 402.25 based on the smaller pumps and 427.60 for the larger pumps. The maximum design ponding elevation is 434.00.

The Paddy's Run Pumping Station is not placed in operation until the river elevation exceeds 435.3 on the lower gauge. Above this level, the facility is used to pump the surface water in Paddy's Run and excess combined flow in the Southwestern Outfall that overflows the diversion dam at the Southwestern Pump Station to the river. Paddy's Run is the twelfth station to go online should flooding occur on the Ohio River. This facility can be expected to operate about once every five to ten years on average.

2.6.2.6. OHIO RIVER WEST REGION COMBINED SEWER OVERFLOWS

The operating procedures for the outfall gate were revised and implemented at CSO015 to operate as a baffle. CSO015 and CSO211 are two of three CSOs within the entire CSS that do not have solids and floatables control. A concerted effort was made in August of 2006 to design and install devices but because of physical limitations of the diversion structures, it was not feasible to install solids and floatables device without extensive engineering or construction at these locations. Therefore, solids and floatables will be addressed as part of the Final LTCP projects for these CSO locations.

2.7. RECREATIONAL USE SURVEY

The process to evaluate and select CSO control approaches considers several community values identified by the Wet Weather Team (WWT) Stakeholder Group. These values include the protection of the environment, compliance with regulatory requirements, and protection of public health. The performance measures established to quantify protection of public health consider the potential public contact with sewer overflows.

To assist in identifying the locations with the greatest potential for public contact with sewer overflows, MSD conducted a Recreational Use Survey within the Beargrass Creek and Ohio River Watersheds. The result of this survey is summarized in a technical memorandum and was used in the evaluation of overflow control measures, and the prioritization of project implementation schedules. The results may also be useful in the water quality standards review suggested by the CSO Policy and LTCP guidance documents prepared by EPA.

2.7.1. STUDY AREA

The Recreational Use Survey study area consists of the Beargrass Creek and Ohio River watersheds. The Beargrass Creek watershed is further subdivided into three forks (Muddy, Middle, and South) as show below.

- Ohio River Region
- Beargrass Creek Muddy Fork
- Beargrass Creek Middle Fork

- Beargrass Creek South Fork

2.7.2. SURVEY LOCATIONS

Thirteen sites were identified for the Recreational Use Survey, which included four locations within the Ohio River Region watershed, one location within the Beargrass Creek Muddy Fork watershed, six locations within the Beargrass Creek Middle Fork watershed, and two locations within the Beargrass Creek South Fork watershed. During the kickoff meeting on May 14, 2007, two sites (11 – Brown Park and 13 - Louisville Junior Academy) were removed from the survey, because they were located upstream of the CSO area.

Two sites (14 - Eva Bandman Park and 15 - Eva Bandman Park) were added on May 18, 2007, as a follow-up to the kickoff meeting. The Eva Bandman Park was split into two sites because the park is located in both the Ohio River watershed and the Beargrass Creek confluence. On September 1, 2007, two sites (16 - Beargrass Creek at Irish Hill and 17 - Butchertown Trail) were added to the list of survey sites to provide additional data within Beargrass Creek Middle Fork and Beargrass Creek confluence, respectively.

The final list of Recreational Use Survey Sites and associated watersheds are listed in Table 2.7-1.

Figure 2.7-1 indicates the survey site locations, watershed boundaries, and identified CSO locations. Of the 17 survey sites identified in Table 2.7-1, 10 were located downstream of the CSO area in Table 2.7-2.

Figure 2.7-1 Recreation Use Survey Sites Map

Figure is located at the end of this chapter.

Table 2.7-1 List of Recreational Use Survey Sites

SITE NUMBER	SITE NAME	WATERSHED	COMMENTS
1	Riverside, Farnsley Moremen Landing	Ohio River	-
2	Riverview Park	Ohio River	-
3	Waterfront Park	Ohio River	-
4	Cox Park (Public Boat Ramp)	Ohio River	-
5	Louisville Soccer Park	Muddy Fork BGC	-
6	Cherokee Golf Course	Middle Fork BGC	-
7	Cherokee Park	Middle Fork BGC	-
8	Seneca Park (Scenic Loop & Maple)	Middle Fork BGC	-
9	Seneca Park (Big Rock)	Middle Fork BGC	-
10	Seneca Golf Course (1 Mile Stretch)	Middle Fork BGC	-
11	Brown Park		Removed May 14, 2007
12	Joe Creason Park	South Fork BGC	-
13	Louisville Junior Academy		Removed May 14, 2007
14	Eva Bandman Park	Ohio River	Added May 18, 2007
15	Eva Bandman Park	Beargrass Creek Confluence	Added May 18, 2007
16	Beargrass Creek At Irish Hill	Middle Fork BGC	Added September 1, 2007
17	Butchertown Trail	Beargrass Creek Confluence	Added September 1, 2007

Table 2.7-2 Recreational Use Survey Sites Located within/downstream of the CSS

SITE NUMBER	SITE NAME	WATERSHED
1	Riverside, Farnsley Moremen Landing	Ohio River
2	Riverview Park	Ohio River
3	Waterfront Park	Ohio River
6	Cherokee Golf Course	Beargrass Creek Middle Fork
7	Cherokee Park	Beargrass Creek Middle Fork
8	Seneca Park (Scenic Loop & Maple)	Beargrass Creek Middle Fork
14	Eva Bandman Park	Ohio River
15	Eva Bandman Park	Beargrass Creek Confluence
16	Beargrass Creek at Irish Hill	Beargrass Creek Middle Fork
17	Butchertown Trail	Beargrass Creek Confluence

Appendix 2.7.1 Recreational Use Survey Technical Memorandum

Appendix is the same as the 2012 IOAP Modification and is provided on external USB storage drive.

2.7.3. STUDY DESIGN

The Recreational Use Survey was conducted from May 1 through November 29, 2007, to coincide with the Kentucky recreational season. During the months of May through August, the sites were visited twice on the weekends and twice during the week. During September, October, and November, the sites were visited twice on the weekends and once during the week. Table 2.7-3 summarizes the number of site visits conducted at each survey site during the study. Appendix 2.7.1 provides a detailed list of survey site visits conducted throughout the duration of the study.

Table 2.7-3 Survey Site Visits

SITE NUMBER	SITE NAME	# OF SITE VISITS
1	Riverside, Farnsley Moremen Landing	104
2	Riverview Park	104
3	Waterfront Park	104
4	Cox Park (Public Boat Ramp)	104
5	Louisville Soccer Park	104
6	Cherokee Golf Course	104
7	Cherokee Park	104
8	Seneca Park (Scenic Loop & Maple)	104
9	Seneca Park (Big Rock)	104
10	Seneca Golf Course (1-mile stretch)	104
11	Brown Park	8
12	Joe Creason Park	104
13	Louisville Junior Academy	8
14	Eva Bandman Park	94
15	Eva Bandman Park	94
16	Beargrass Creek at Irish Hill	32
17	Butchertown Trail	32

Survey locations 11 and 13 were visited only eight times, because they were removed from the survey on May 14, 2007. Survey locations 14 and 15 were added on May 18, 2007, and survey locations 16 and 17 were added on September 1, 2007, and therefore have a reduced number of site visits.

During the daily site visits, field data at each site was reported on a form entitled Field Data Sheet for Recreational Use Stream Survey. In addition, a minimum of three photos were taken per site (upstream, downstream, and observed recreational activity). Field data reported on the form included:

- Site Information: Name, Location Description, GPS Coordinates
- Photo Log ID Number
- Date & Time
- Personnel
- Current Weather Conditions
- Weather Conditions for Past 7 Days
- Number of People Observed
- Recreational Activities Observed
- Type of Water Contact

SURVEY CATEGORIES

Contact activities:

Boating	Fishing
Wading	Swimming
Jet Ski	Water Ski
Kayak	Study

Non-contact activities:

Dog Walking	Party/Picnic
Playground	Lounging
Walking/Jogging	Sport
Working	Bike Riding
Sunbathing	

Type or magnitude of the contact:

Incidental	Below Ankle
Below Waist	Below Neck
Full	Non-Contact
Non-Recreational	

Recreational activities were split into two subcategories: contact activities and non-contact activities. In addition, the number of people was further subdivided into adults and children, because children are at greater risk of ingestion and present a higher degree of health impact. For purposes of this study, children represented ages 12 and younger.

A summary sheet was created to analyze the field data for all the survey sites. Field data included on the summary sheets include the site description, number of people observed, recreational activities observed and magnitude of water contact. See Appendix 2.7.1 for more details on the survey information.

The survey results are divided into the following categories:

- Adults observed at the site
- Children observed at the site
- Adults observed participating in non-contact activities
- Children observed participating in non-contact activities
- Adults observed participating in contact activities
- Children observed participating in contact activities
- Contact observed

In order to provide assistance in evaluating and selecting overflow control approaches that protect public health, the recreational use survey site locations with the greatest potential contact with overflows need to be identified and prioritized.

The following four parameters were selected to rank and prioritize the survey site locations:

- Average number of people observed per site visit.
- Percent contact observed.
- Potential for water contact; and
- Percent children observed.

An overall summary of the survey results from these seventeen locations throughout the duration of the study are presented in Table 2.7-4. Potential contact is defined as the number of adults and children participating in contact activities but where no contact was observed; therefore, having the potential for water contact.

Table 2.7-4 Overall Summary of the Recreational Use Survey Results, 2007

Table is located at the end of this chapter.

Each survey site was scored on a twenty-point scale (1 = Low and 20 = High) for each parameter with the exception of the percent contact observed parameter, where a weighting factor was applied. A weighting factor (doubling the parameter score) was applied to this parameter, because it represents direct water contact and was therefore considered of greater relative importance. Once the parameters were scored for each survey site, a priority rating was applied to each survey site. The priority rating is based on the sum of the parameter scores following applications of weighting factors.

The priority rating categories range from High (greatest potential for public contact with) to Low (least potential for public contact). The resultant priority scale has a potential maximum of 100 and minimum of zero as shown below:

- High: 51-100
- Medium: 21-50
- Low: 0-20

2.7.4. CONCLUSIONS

Of the seventeen survey sites observed, Seneca Park at Big Rock scored the highest rating equal to 56 and was the only site identified as high priority. Four sites were identified with medium priority and the remaining twelve sites were categorized as low priority. The priority rating scores for all survey sites are listed in Table 2.7-5.

Of the 10 survey sites located within/downstream of the CSS, no sites were identified as high priority. Riverview Park and Cherokee Golf Course ranked the highest of the 10 sites with a rating equal to 26 and 25, respectively. These two sites were the only sites identified as medium priority and the remaining eight sites were categorized as low priority. The priority rating scores for the survey sites within the CSS are listed in Table 2.7-6.

Table 2.7-5 Survey Site Priority Rating Scores, 2007

PARK ID	PARK NAME	WATERSHED	AVERAGE PEOPLE	% CHILD-REN	% POTEN-TIAL	% CON-TACT	TOTAL	RATING
9	Seneca Park - Big Rock	Middle Fork BGC	9	6	6	40	52	High
2	Riverview Park	Ohio River	12	5	12	9	26	Medium
6	Cherokee Golf Course - Lexington Rd	Middle Fork BGC	4	1	20	4	25	Medium
4	Cox Park	Ohio River	20	3	16	5	24	Medium
5	Louisville Soccer Park	Muddy Fork BGC	4	20	1	1	22	Medium
3	Waterfront Park	Ohio River	18	7	8	4	19	Low
12	Joe Creason Park	South Fork BGC	5	10	0	0	10	Low
17	Butchertown Greenway	BGC Confluence	2	1	8	0	9	Low
1	Farnsley Moremen Landing	Ohio River	5	5	1	1	7	Low
7	Cherokee Park - Shelter	Middle Fork BGC	10	6	0	0	6	Low
14	Eva Bandman Park - Ohio River	Ohio River	11	2	3	1	6	Low
15	Eva Bandman Park - Beargrass Creek	BGC Confluence	3	0	6	0	6	Low
16	Beargrass Creek at Irish Hill	Middle Fork BGC	3	4	0	0	4	Low
10	Seneca Golf Course	Middle Fork BGC	8	1	1	1	3	Low
8	Seneca Park - Scenic Loop	Middle Fork BGC	6	1	1	0	2	Low
11	Brown Park	-	8	0	0	0	0	Low
13	Louisville Junior Academy	-	4	0	0	0	0	Low

Table 2.7-6 Survey Sites within/Downstream of the CSS Priority Rating Scores, 2007

PARK ID	PARK NAME	WATERSHED	AVERAGE PEOPLE	% CHILD-REN	% POTEN-TIAL	% CON-TACT	TOTAL	RATING
2	Riverview Park	Ohio River	12	5	12	9	26	Medium
6	Cherokee Golf Course - Lexington Rd	Middle Fork BGC	4	1	20	4	25	Medium
3	Waterfront Park	Ohio River	18	7	8	4	19	Low
17	Butchertown Greenway	BGC Confluence	2	1	8	0	9	Low
1	Farnsley - Moremen Landing	Ohio River	5	5	1	1	7	Low
7	Cherokee Park - Shelter	Middle Fork BGC	10	6	0	0	6	Low
14	Eva Bandman Park - Ohio River	Ohio River	11	2	3	1	6	Low
15	Eva Bandman Park - BGC	BGC Confluence	3	0	6	0	6	Low
16	Beargrass Creek at Irish Hill	Middle Fork BGC	3	4	0	0	4	Low
8	Seneca Park - Scenic Loop	Middle Fork BGC	6	1	1	0	2	Low

2.8. ECOLOGICAL CHARACTERIZATION (SENSITIVE AREA STUDY)

To allow prioritization of CSO discharges, MSD developed a process to rate the ecological condition of each stream reach (defined as length between CSO outfalls). Further assessment was necessary to prioritize implementation of the various CSO controls. Beargrass Creek is an urbanized stream, which has resulted in severe stresses to its aquatic environment. These stresses have been caused by the large extent of paved surfaces (Figure 2.8-1) as well as inputs from both non-point and point sources of pollution. Existing stream conditions range from somewhat natural channels with typical biotic components (Figure 2.8-2) to channelized, concrete-lined channels with little to no natural aquatic habitat (Figure 2.8-3).

Figure 2.8-1 Paved Surfaces Around Beargrass Creek Map

Figure is located at the end of this chapter.

Figure 2.8-2 Typical Good Quality Portion of Beargrass Creek

Figure 2.8-3 Typical Poor Quality Portion of Beargrass Creek

The overall goal of this ecological reach characterization was to construct a framework for prioritizing proposed CSO controls based on the degree of benefit anticipated to be gained by the ecological components of Beargrass Creek from implementation of CSO control measures. Specific study objectives include:

- Provide an ecological component to the decision-making process regarding phasing of CSO controls.
- Provide a measure for distinguishing stream reaches and CSO control projects based on aquatic ecology; and
- Rate and rank stream reaches based on ecologically related parameters, with high scores indicating those reaches that will benefit most from water quality improvements.

The study is presented here in terms of methodology, results, and conclusion.

2.8.1. METHODOLOGY

The ecological characterization study uses an approach that incorporates the biological integrity of existing aquatic communities, as well as the associated physiographic and geomorphologic characteristics of the stream, its riparian corridor, and societal values. The study was undertaken based on identification of discrete stream reaches, selection of appropriate assessment parameters, and the assessment/scoring of each reach under each parameter.

2.8.1.1. REACH IDENTIFICATION

Stream reaches were delineated based on CSO discharge locations, with each reach beginning at a CSO outfall location and continuing downstream to the next CSO outfall location. Some stream reaches may consist of multiple CSOs when the outfalls were located at the same general geographic location and were all considered a component of the same reach. Each stream reach is numbered based on a fork identifier (MU = Muddy Fork; MI = Middle Fork; S = South Fork) and the CSOs that discharges to it. A total of 37 stream reaches were identified: one in Muddy Fork Beargrass Creek; eight in Middle Fork Beargrass Creek; and 28 in South Fork Beargrass Creek.

2.8.1.2. PARAMETER SELECTION

Because the effects of CSO discharges are a concern to a diverse group of constituents (residents, communities, businesses, environmental groups, and MSD), prioritization of CSO control measures must consider numerous factors. These include environmental, economic feasibility, asset protection, public health, and regulatory compliance performance. Parameters for each reach were scored using either in situ field observations or from GIS data obtained from federal, state, and local sources. All of the data used for the rating system were organized and used for analysis, display, and query in a GIS using ArcGIS 9.2 software.

Stream reach rating parameters were chosen for this project to reflect the complex dynamics of ecological conditions of streams and the surrounding land uses. A multi-parameter approach was necessary to accurately characterize existing/potential condition of stream reaches, especially in this highly urbanized environment. The 10 parameters selected for this characterization include:

- **Accessibility** – A measure of the potential for human contact with the creek. Data were obtained through field observations. Reaches where access was encouraged (trails to creek, gradual stream bank angles, lack of fencing, or public ownership) scored high whereas areas where access was discouraged (thick vegetation, fences, steep bank angles, or private ownership) scored low. High scores for this parameter indicate more accessible reaches that would most benefit from water quality improvements.
- **Threatened/Endangered Species** – A defined component of sensitive areas. Protected species occurrence information in the Beargrass Creek Watershed was obtained through a formal data request to the Kentucky State Nature Preserves Commission. Potential threatened/endangered species within the project area include 14 mussels, two crustaceans, one insect, and two fish species. The presence of potential habitat for these species was determined based on qualitative observations of stream substrate and overall aquatic habitat in the field by qualified ecologists. High scores for this parameter indicate a greater potential for the presence of one of these species or their habitats and reaches that would most benefit from water quality improvements.
- **Stream Rapid Bioassessment Protocol** – A method for assessing stream habitat quality and its ability to harbor a healthy ecological community. Data were obtained at each reach using the EPA's Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour et al. 1999). High scores indicate a reach with habitat characteristics that would potentially contain a healthier biological community and would most benefit from water quality improvements.

- **Bank Erosion Hazard Index** – A measure of the potential for streambank erosion. Bank Erosion Hazard Index is a quantitative prediction tool to assess erosion potential using a multi-parameter scoring system based on field measurements of bank heights, angles, materials, layers, rooting depth and density, and amount of bank protection (Rosgen 2001). The Bank Erosion Hazard Index data were obtained from the Stream Assessment Report for the Beargrass Creek Watershed. High scores for this parameter reflect a reach with low erosion potential; an indicator of stable habitat for aquatic communities that would most benefit from water quality improvements. Although stream reaches located within the concrete-lined portion of South Fork Beargrass Creek would rate high because of their stability and limited potential to contribute to downstream sedimentation, these reaches are rated low based on their overall inability to harbor the important biological/organic components of natural streambanks or provide basic aquatic habitat.
- **Index of Biotic Integrity** – An index developed for rating fish community assemblages as an indicator of the degree of impact from pollutants. Data were obtained from MSD's 2005 Long-Term Monitoring Network program. The Index of Biotic Integrity is a multi-metric fish index, which measures stream health using fish community data (Karr et al. 1986). High scores for this parameter indicate a stream reach with favorable ecological integrity that warrants stream protection, and that would most benefit from water quality improvements.
- **CSO AAOV** – Overflow volume for each CSO was obtained from O'Brien & Gere; a typical rainfall year data was applied to CSS model to predict AAOV. High scores for this parameter represent CSO discharge locations with lower discharge and imply less severe impacts to the reach, healthier aquatic communities, a reduced risk to public health, and a reach that would most benefit from water quality improvements.
- **Land Use** – A classification system describing the types of human activities (e.g. parks, residences, industrial, etc.) for a given area. Data were created by Louisville Metro Planning and Design Services in 1992 and were obtained through MSD. For this analysis, land use data were clipped within a 200-foot buffer around each reach and the percentage of each land use type was determined. High scores represent reaches with a high probability of community activity near the creek (e.g. parks and public areas), that would benefit the most from water quality improvements. See Figure 2.8-4.

Figure 2.8-4 Beargrass Creek Land Use

Figure is located at the end of this chapter.

- **Landcover** – Types of vegetative or manmade features covering a landscape. Data were obtained from the USGS National Landcover Database. The National Landcover Database is derived from 2001 satellite (Landsat) imagery and uses the Anderson Level II classification system (Anderson et al. 1976). Landcover raster data were extracted from a 200-foot buffer around each reach using ESRI ArcGIS Spatial Analyst software and the percentage of each type of landcover type was calculated. High scores represent reaches with landcover types that provide shading (tree cover) and reduced stormwater runoff to the creek (pervious surfaces) and would thus benefit most from in-stream water quality improvement.
- **Restoration Potential** – A qualitative assessment of benefits a stream reach may realize considering the level of effort required to restore aquatic/riparian habitat functions. Reaches were scored based on qualitative field observations by qualified ecologists at each reach in terms of the feasibility and need for stream restoration activities. Feasibility is defined in terms of the scale of construction (for example, costs and effort associated with planting trees, bank shaping, and

removal of concrete lining) and accessibility (e.g. equipment access, property ownership, terrain) necessary to perform the work. High scores indicate reaches where lower-cost restoration efforts would provide immediate stream habitat benefits and benefit the most from water quality improvements.

- **Reach Length** – The physical measurement of each reach. Length was measured in the GIS as the length from the CSO discharge point along the centerline of the channel to the beginning of the next reach. High scores correspond to longer stream reaches suggesting that water quality improvements and protection measures would provide more benefit to the overall aquatic system by improving a larger portion of the creek per CSO control measure.

2.8.1.3. SCORING

Parameter scores and subsequent reach priority ratings were graded relative to the distribution of results across all reaches within the CSS. The results provide a means for comparing stream reaches located only within the CSS and do not reflect conditions comparative to reaches outside of the CSS or reference conditions. The rating scale reflects the ecological condition of each stream reach and the degree of ecological benefit to be gained by water quality improvements. “Ecological condition” for these purposes was considered to be the existing, or realistic potential of, stream-related communities in terms of biological integrity, ecological function, and aesthetic/public health value. Based on this approach, reaches with high ratings would realize greater benefit from water quality improvements and, therefore, should be given higher priority during the CSO control and implementation decision process.

Each reach was assessed under each of the 10 parameters and scored on a 10-point scale, with one being the lowest and 10 the highest. The raw scores for each reach were then adjusted based on a weighting factor for individual parameters to obtain an overall priority rating.

The weighting factor involved doubling the score for three parameters:

1. Threatened/endangered species
2. Stream Rapid Bioassessment Protocol
3. Index of Biotic Integrity

These parameters represent direct measures of existing ecological condition and were therefore, considered of greater relative importance in scoring. The final priority rating is based on the sum of the parameter scores following application of the parameter weighting factor. Potential scores could range from 13 (lowest ecological integrity) to 130 (highest ecological integrity). The scores were then broken into five distinct priority categories for data summary purposes: highest priority; high/medium; medium priority; medium/low; and lowest priority. Breaks between priority rating categories were defined based on the distribution of results using only unique values. An attempt was made to evenly distribute reaches across the priority rating categories; however, final break points were chosen at distinct gaps between reach priority scores. Refer to Figure 2.8-5.

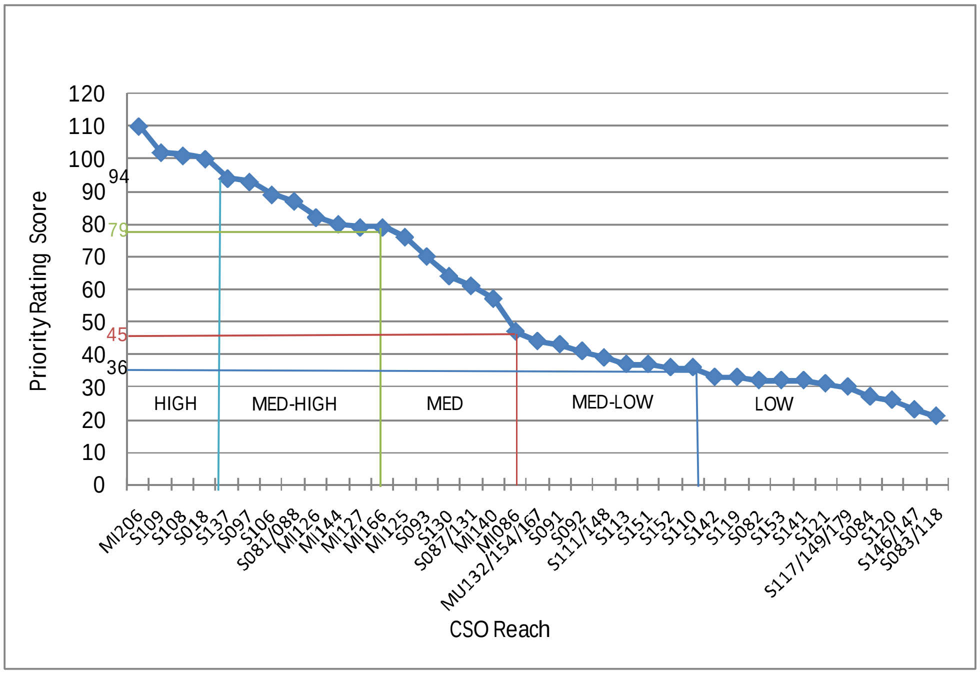


Figure 2.8-5 Beargrass Creek Ecological Reach Characterization

2.8.2. RESULTS

The final scores of all reaches ranged from 21 to 110 and are provided in Table 2.8-1 and Table 2.8-2. The distribution of priority rating scores across the five priority categories is depicted in Figure 2.8-6.

Figure 2.8-6 Distribution of Stream Priority Rating

Figure is located at the end of this chapter.

Overall, existing ecological condition tends to decrease as the creek moves downstream through the watershed. This suggests that water quality improvements within the upper portions of the watershed may produce greater beneficial effects to the aquatic system as a whole than similar water quality improvements to downstream reaches.

Examples of characterization results are outlined in

Table 2.8-2 for high, medium, and low priority reaches.

Table 2.8-1 Distribution of Priority Rating Scores

SCORE	PRIORITY CATEGORY	NUMBER OF REACHES
95-130	Highest Priority	4
80-94	High/Medium	6
46-79	Medium Priority	8
37-45	Medium/Low	6
13-36	Lowest Priority	13

Table 2.8-2 Reach Score Distribution

PRIORITY SCORE	REACH NUMBER	PRIORITY SCORE	REACH NUMBER
110	MI-206	44	MU-132/154/167
102	S-109	43	S-091
101	S-108	41	S-092
100	S-018	39	S-111/148
94	S-137	37	S-113
93	S-097	37	S-151
89	S-106	36	S-110
89	S-081/088	36	S-152
84	MI-126	33	S-119
80	MI-144	33	S-142
79	MI-127	32	S-082
79	MI-166	32	S-141
76	MI-125	32	S-153
70	S-093	31	S-121
64	S-130	30	S-117/149/179
61	S-087/131	27	S-084
57	MI-140	26	S-120
47	MI-086	23	S-146/147
		21	S-083/118

PRIORITY SCORES
95-130 Highest Priority
80-94 High/Medium
46-79 Medium
37-45 Medium/Low
13-36 Lowest Priority

2.8.2.1. HIGH PRIORITY

The upper portions of Middle and South Forks of Beargrass Creek rated higher. These reaches are characterized by wooded riparian corridors and have received fewer human-made disturbances. The highest priority stream reach score is the most upstream reach in Middle Fork at Cherokee Park, Reach MI-206. See Figure 2.8-7. This reach rated as high priority due to its higher quality of aquatic habitat, potential for threatened/endangered species and Index of Biotic Integrity scores. It also exhibits moderately stable banks, is located within a more vegetated watershed, has a relatively low AAOV, good restoration potential, and high accessibility. It scored 110.

Figure 2.8-7 High Priority Reach (Middle Fork Beargrass Creek CSO206)

2.8.2.2. MEDIUM PRIORITY

An example of a medium-rated priority reach is Reach MI-086 (Figure 2.8-8). It has poor accessibility, low quality habitat, and low potential for threatened/endangered species. It also exhibits high discharge volumes (low AAOV score), is located within a developed watershed, and is a relatively short reach. It scored 47.

Figure 2.8-8 Medium Priority Reach (Middle Fork Beargrass Creek CSO086)

2.8.2.3. LOW PRIORITY

The concrete-lined portion of South Fork Beargrass Creek rated lowest of all reaches and would benefit least from water quality improvements. Reach S-081/118 (Figure 2.8-9) scored low for most parameters. It has poor accessibility and little to no viable aquatic habitat, although it did exhibit a moderate fish population (Index of Biotic Integrity). It also has a large AAOV, urban/developed land use and landcover, little restoration potential, and short reach length. It scored 21.

Figure 2.8-9 Low Priority Reach (South Fork Beargrass Creek CSO081 and CSO118)

2.8.2.4. CONCLUSION

In order to provide cost-effective CSO control implementation, it is important that a phased approach be used that will target the most problematic areas while protecting existing sensitive features. Because CSOs impact a diverse set of constituents, numerous factors must be considered when prioritizing and evaluating CSO control alternatives.

The Beargrass Creek Ecological Reach Characterization Report (Appendix 2.8.1) presents one component of a multifaceted decision process framework that is being used in development of a LTCP for the Louisville Metro CSS. This tool was developed to provide a means for comparing individual stream reaches within the CSS in terms of ecological condition. High scores/ratings indicate more favorable ecological conditions that would most benefit from water quality improvements. The results do not imply that stream reaches with high priority ratings should be the sole target for CSO control activities. The parameters used for this rating system were chosen in an attempt to reflect the complex and dynamic interaction between ecological condition of streams, diverse constituencies, and varied land use practices in urban environments. Results of this prioritization process and ecological reach ranking are one of numerous components integrated into the Final LTCP selection process and implementation schedule, to be established by the community Stakeholder Group in compliance with the value-based risk management process.

Appendix 2.8.1 Beargrass Creek Ecological Reach Characterization Report

Appendix is the same as the 2012 IOAP Modification and is provided on external USB storage drive.

2.9. RECEIVING WATER CHARACTERIZATION

2021 Update: This chapter was developed for the 2009 IOAP. The statistical data and receiving water characterization show results from the 2007 analysis. Some narrative updates have been incorporated with respect to current Kentucky standards and applicability for the Presumption Approach.

System characterization, monitoring, and modeling are one of the nine elements of a long-term CSO control plan. Receiving water characterization, monitoring, and modeling "establishes the existing baseline conditions and provides the basis for determining receiving water goals and priorities and identifying specific CSO controls in the LTCP" (EPA, 1995). MSD has conducted receiving water monitoring and reviewed water quality data for Beargrass Creek and the Ohio River near Louisville (river mile 594 to 620) since the start of the CSO program in 1991 (MSD, 2006a; MSD, 2006b). The most recent assessments are documented in *Water Quality Status Report: Beargrass Creek and Ohio River at Louisville* (LimnoTech, 2007).

This section presents the water quality standards and summarizes the findings of the 2007 assessment and provides a review of data obtained after the status report was completed.

The review of the available receiving water quality data show that the following:

- All three tributary branches of Beargrass Creek and the Ohio River (river mile 593 to 621) are listed as being impaired by pathogens. E. Coli and fecal coliform bacteria concentrations are significantly higher during wet weather conditions.
- The lower portions of Beargrass Creek, Middle Fork, and Muddy Fork are listed as being impaired by organic enrichment (causing low dissolved oxygen levels). pH violations may also be indicative of organic impairment.
- Biological conditions are generally poor to fair at most of the monitored locations, which is not uncommon for urbanized watersheds.

The receiving water data were used to calibrate and confirm the receiving water quality models. The models were then applied to establish current (baseline) conditions, establish how CSOs and other sources are impacting water quality, and to assess the effectiveness of controls in attaining water quality standards.

Most importantly, and as stated in the CSO Policy regarding the Presumption Approach:

A program that meets any of the criteria listed below would be presumed to provide an adequate level of control to meet the water quality-based requirements of the CWA. provided the permitting authority determines that such presumption is reasonable in light of the data and analysis conducted in the characterization, monitoring. and modeling of the system.

The water quality sampling and modeling conducted by MSD, provides the regulatory agencies the necessary justification for approving an LTCP based on an 85 percent capture Presumption approach.

2.9.1. WATER QUALITY STANDARDS

Water quality standards are established for MSD's receiving waters by the Kentucky Energy and Environment Cabinet and the Ohio River Valley Water Sanitation Commission (ORSANCO) has developed Pollution Control Standards for the Ohio River which have been developed for use or consideration by signatory States. Kentucky's Water Quality Regulations establish surface water use classifications for all waters of the Commonwealth. Kentucky has designated stream uses for the Ohio River near Louisville and the Beargrass Creek Basin. These uses are summarized in Table 2.9-1.

ORSANCO has designated the Ohio River as "public and industrial water supplies after reasonable treatment, suitable for recreational usage, capable of maintaining fish and other aquatic life."

Table 2.9-1 Stream Use Designation

STREAM	USE DESIGNATION
Ohio River - Main Stem	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation, Domestic Water Supply
South Fork Beargrass Creek and Tributaries	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation
Middle Fork Beargrass Creek and Tributaries	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation
Muddy Fork Beargrass Creek and Tributaries	Warm Water Aquatic Habitat, Primary Contact Recreation, Secondary Contact Recreation

To protect warm water aquatic life uses, Kentucky's standards require that:

- Dissolved oxygen is to be maintained at a minimum concentration of 5.0 mg/l daily average; the instantaneous minimum shall not be less than 4.0 mg/l.
- Total dissolved solids and TSS are not to be changed to the extent that the indigenous aquatic community is adversely affected.
- pH to be no greater than nine, and no less than six at any time.
- The addition of settleable solids that may alter the stream bottom to affect productive aquatic communities adversely is prohibited.
- The concentration of un-ionized ammonia shall not be greater than 0.05 mg/l at any time in-stream after mixing.

ORSANCO's standards also suggest that the dissolved oxygen in the main stem of the Ohio River not be less than 5.1 mg/l during the August 15th to June 15th spawning season. Kentucky and ORSANCO have bacteria criteria for protection of primary contact recreational uses (for example, swimming), as shown in Table 2.9-2. These criteria apply during the recreation season of May 1st to October 31st. Kentucky's standards apply during any 30-day period whereas ORSANCO's standards are applied on a monthly basis.

401 KAR 10:031 states:

Section 7. Recreational Waters. (1) Primary contact recreation water. The following criteria shall apply to waters designated as primary contact recreation use during the primary contact recreation season of May 1 through October 31: (a) Escherichia coli content shall not exceed 130 colonies per 100 ml as a geometric mean based on not less than five (5) samples taken during a thirty (30) day period. Content also shall not exceed 240 colonies per 100 ml in twenty (20) percent or more of all samples taken during a thirty (30) day period for Escherichia coli. Fecal coliform criteria listed in subsection (2)(a) of this section shall apply during the remainder of the year.

For the non-recreational period from November 1st to April 30th, Kentucky's fecal coliform criteria are the same as the criteria for secondary contact recreation (that is, "waters that are suitable for partial body contact recreation, with minimal threat to public health due to water quality"). Kentucky's standards state:

"Fecal coliform content shall not exceed 1,000 colonies per 100 ml as a thirty (30) day geometric mean based on not less than five (5) samples; nor exceed 2,000 colonies per 100 ml in twenty (20) percent or more of all samples taken during a thirty (30) day period."

ORSANCO's 2019 Pollution Control Standards states that:

Maximum allowable level of E. coli bacteria for contact recreation -- for the months of April through October, measurements of E. coli bacteria shall not exceed 130/100 mL as a 90-day geometric mean, based on not less than five samples per month, nor exceed 240/100 mL in more than 25 percent of samples.

ORSANCO has also established criteria for the Ohio River main stem for protection of public water supply uses at all times as follows:

"Fecal coliform bacteria content shall not exceed 2,000/100 ml as a monthly geometric mean based on not less than five samples per month."

Table 2.9-2 Indicator Bacteria Criteria for Protection of Primary Contact Recreation, 2021

INDICATOR BACTERIA	STANDARD	GEOMETRIC MEAN[1] (PER 100 ML)	INSTANTANEOUS MAXIMUM[2] (PER 100ML)	PERIOD FOR MEASURING COMPLIANCE
E. Coli bacteria	Kentucky	130	240	Any 30-day period
	ORSANCO	130	240	90-day

[1] The geometric mean for both Kentucky and ORSANCO are to be calculated using no less than 5 samples per month.

[2] Kentucky water quality criteria allow this value to be exceeded in up to 20% of the samples collected during a 30-day period to exceed the instantaneous maximum criterion. ORSANCO's standards specify that E. Coli shall not exceed 240 per 100 ml in any sample.

A key principle of the 1994 CSO Control Policy is "[r]eview and revision, as appropriate, of water quality standards and their implementation procedures when developing CSO control plans to reflect site-specific wet weather impacts of CSOs" (59 FR 18688). Review and revision of standards is accomplished through a Use Attainability Analysis (UAA). A UAA is a structured scientific assessment of the factors affecting the attainment of uses specified in Section 101(a)(2) of the CWA. In response to directives from Congress, EPA developed guidance in 2001 for coordinating water quality standards reviews for water bodies where long-term CSO control plans will be implemented because "implementation of this principle has not progressed as quickly as expected" (US EPA, 2001). Several states such as Maine (MDEP, 2003), Massachusetts (MassDEP, 2007), and Indiana (IDEM, 2008) have adopted provisions in their water quality standards to recognize the challenges associated with attaining recreational uses even after CSO controls have been fully implemented. ORSANCO has provisions in its water quality standards for the Ohio River allowing for development and application of alternative criteria if CSO communities have submitted a long-term CSO control plan and a UAA.

In the most recent triennial review of Kentucky's Water Quality Standards, provisions were added to the regulations regarding the suspension or redesignation of primary contact recreation uses in CSO impacted waters.

"PCR criteria may be suspended in CSO receiving waters during CSO events for a duration determined by the cabinet-approved Long-Term Control Plan as established in 401 KAR 5:005 and the facility KPDES permit; if: a. An exception to criteria is approved: (i) In accordance with Section 10 or 11 of this administrative regulation; and (ii) Consistent with 40 C.F.R. 131.14; or b. A redesignation pursuant to a use

attainability analysis has been approved: (i) In accordance with 401 KAR 10:026, Sections 2 through 4; and (ii) Consistent with 40 C.F.R. 131.10(g).”

2.9.2. RECEIVING WATER QUALITY MONITORING ANALYSIS – OHIO RIVER

Receiving water quality data are available for the Ohio River from ORSANCO for 2000 to 2007. ORSANCO’s monitoring stations (and Ohio River miles) are shown on Figure 2.9-1. A total of 596 fecal coliform measurements and 596 E. Coli measurements were taken as part of ORSANCO’s routine monitoring on the Ohio River in the Louisville Metro area during the period 2000-2007. E. Coli data (1,008 measurements) were obtained from ORSANCO’s five-week longitudinal, “snapshot” and tributary only surveys of the Ohio River for the period October 2003 to October 2007. Both data sets were analyzed in terms of average concentrations during wet and dry weather periods as well as percentage of individual samples exceeding specific target levels. Samples were characterized as “wet” using hourly rainfall from the Louisville International Airport (Standiford Field) and the following criteria:

- Precipitation greater than or equal to 0.1 inch within 24 hours of sample collection.
- Precipitation greater than or equal to 0.25 inch within 25-48 hours of sample collection; and
- Precipitation greater than or equal to 0.5 inch within 49-72 hours of sample collection.

A separate analysis was conducted on the bacteria data collected by ORSANCO as part of their Wet Weather Demonstration Project during 2001. Water quality data for other parameters from ORSANCO’s routine sampling of the Ohio River main stem are summarized as well.

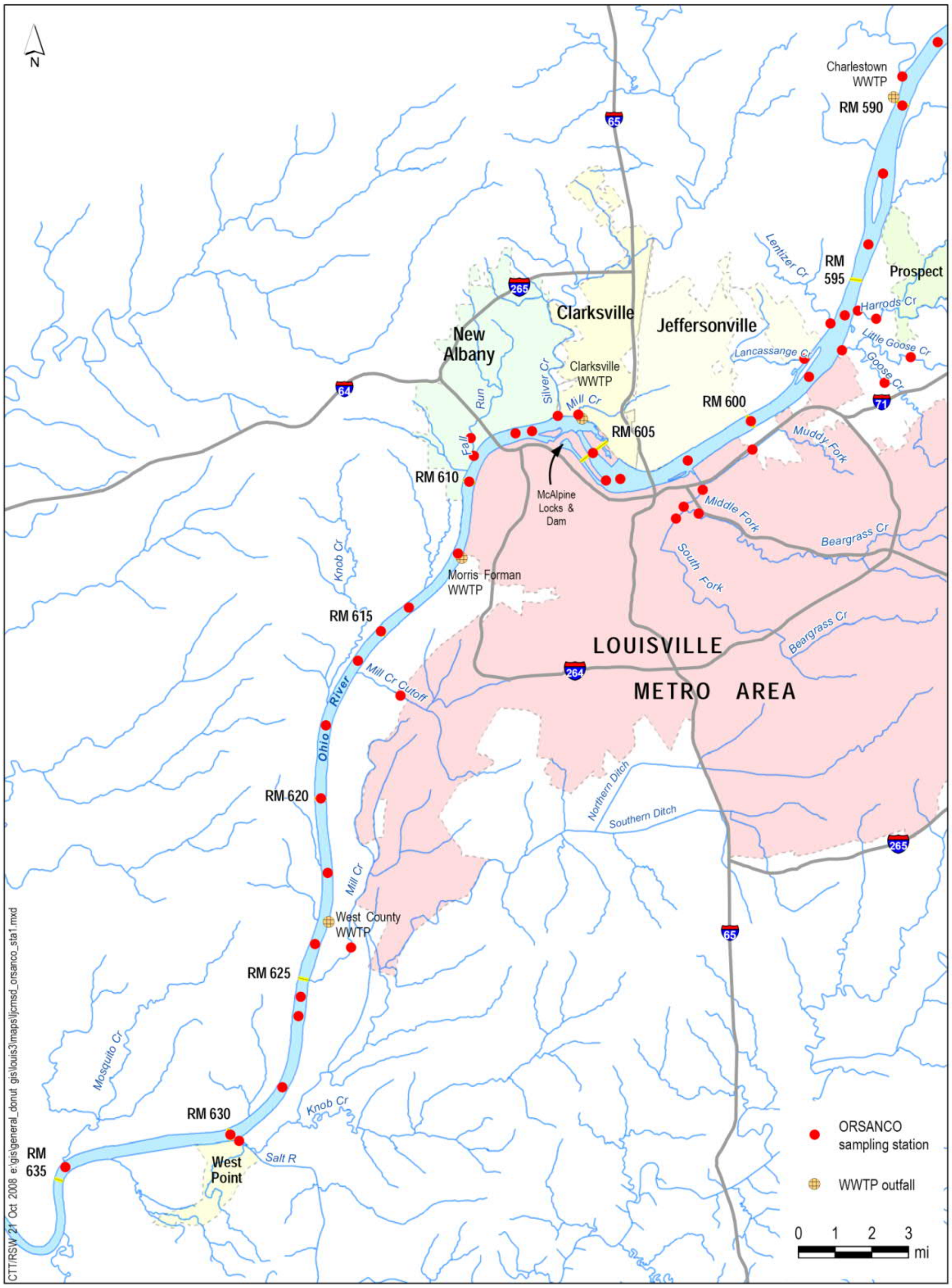


Figure 2.9-1 ORSANCO Ohio River Monitoring Stations, 2007

2.9.2.1. AVERAGE BACTERIAL CONCENTRATIONS FROM ROUTINE MONITORING

Figure 2.9-2 shows a summary display of average fecal coliform concentrations for each of the routine ORSANCO monitoring stations, stratified by climatic condition. Concentrations at River Mile 594.0 (upstream of the CSOs) are similar to concentrations at River Mile 608.7 (downtown, downstream of the CSOs). The highest concentrations are observed at River Mile 619.3, which is downstream of the Mill Creek Cutoff. Concentrations at this location are also noticeably higher during wet weather periods. Results are displayed in similar format in Figure 2.9-3 for E. Coli, with similar results.

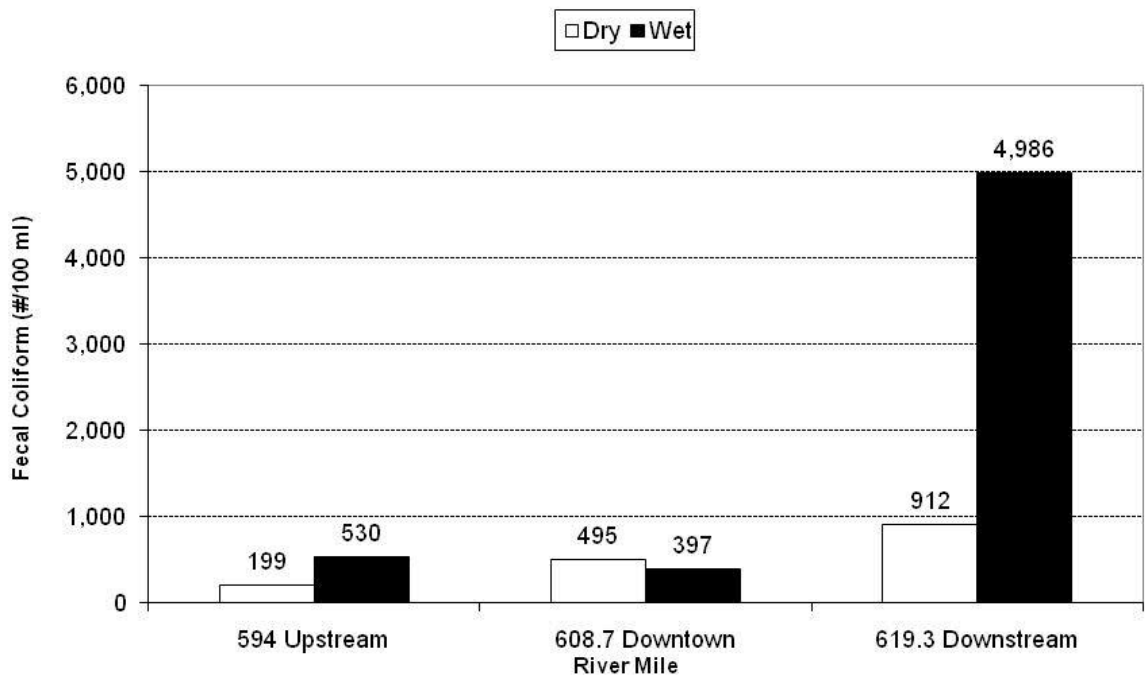


Figure 2.9-2 Average Fecal Coliform Levels During Wet and Dry Periods at Three Stations on the Ohio River near Louisville, KY Using Data from 2000 to 2007

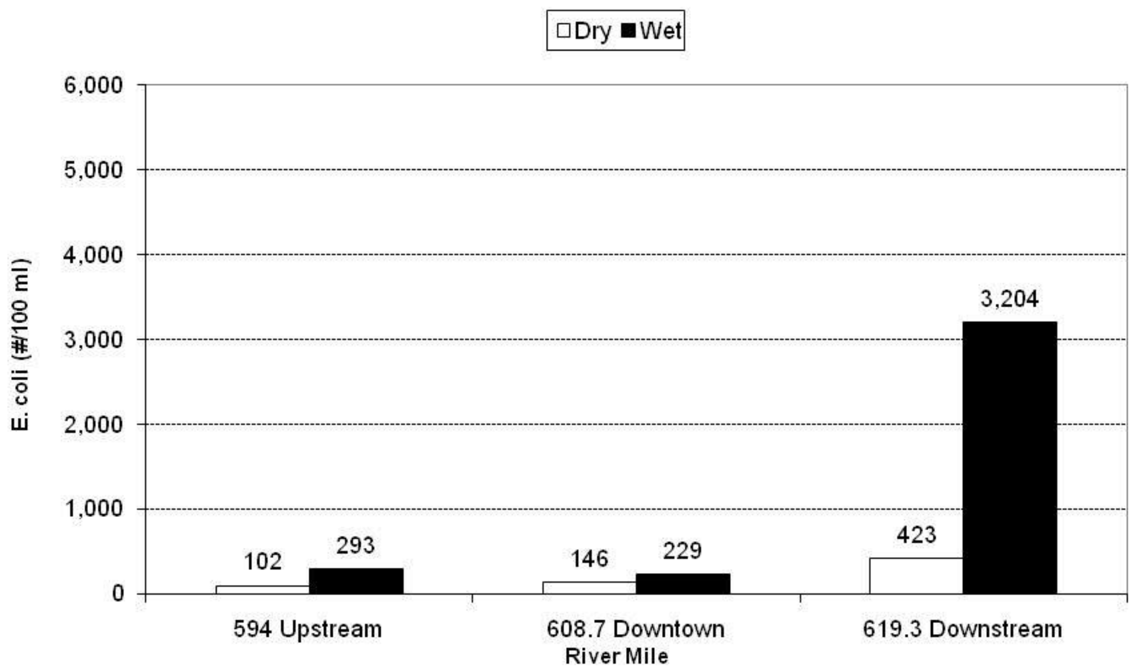


Figure 2.9-3 Average E. coli Levels during Wet and Dry Periods at Three Stations on the Ohio River near Louisville, KY Using Data from 2000 to 2007

Figure 2.9-4 and Figure 2.9-5 show temporal variability in average (geometric mean) dry and wet weather concentrations at the location upstream of the CSOs (River Mile 594) for fecal coliform and E. Coli, respectively. Figure 2.9-6 and Figure 2.9-7 provide similar results for River Mile 608.7 (downtown, downstream of the CSOs), while Figure 2.9-8 and Figure 2.9-9 represent 619.3 (downstream of the Mill Creek Cutoff). No long-term trend is consistently observed across all three stations.

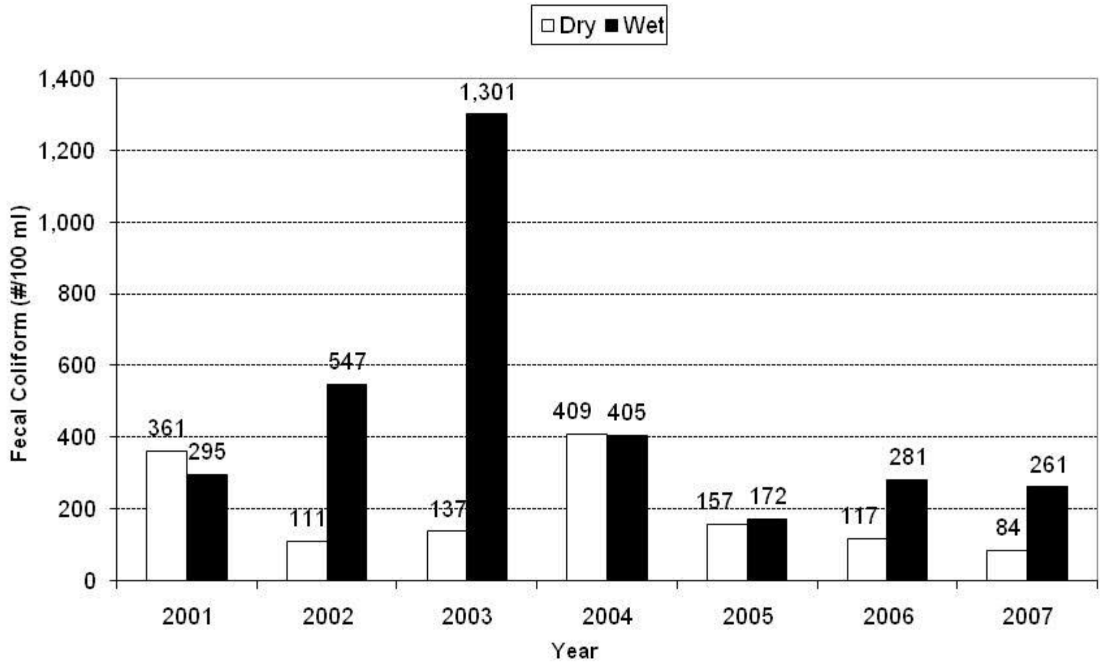


Figure 2.9-4 Average Fecal Coliform Levels during Wet and Dry Periods at River Mile 594 on the Ohio River

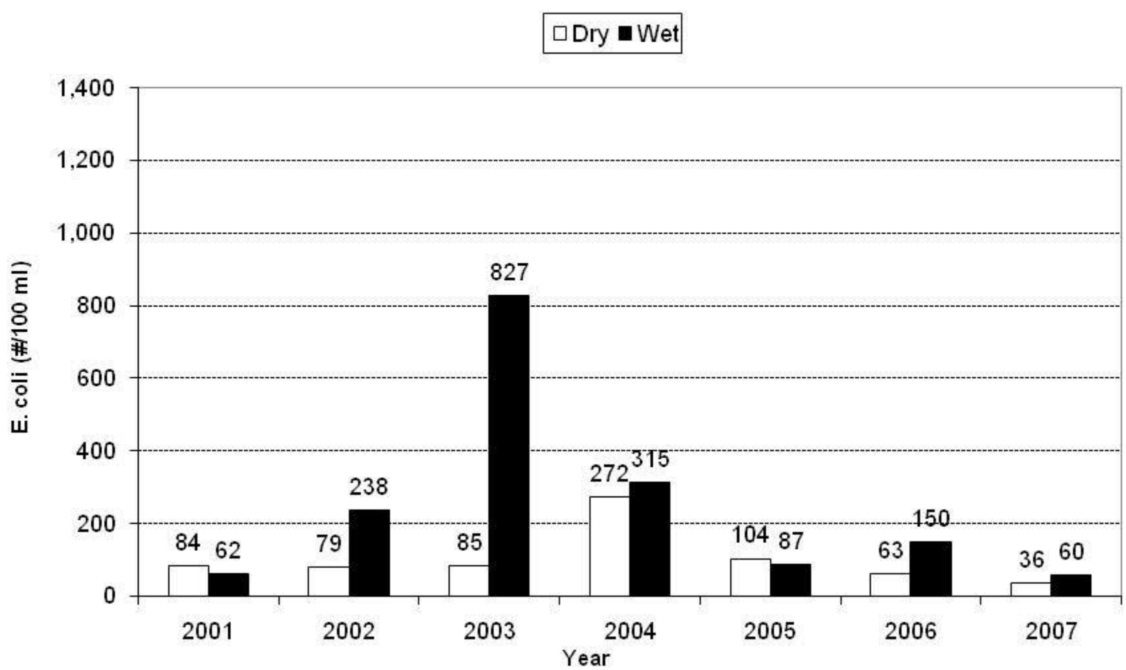


Figure 2.9-5 Average E. coli Levels during Wet and Dry Periods at River Mile 594 on the Ohio River

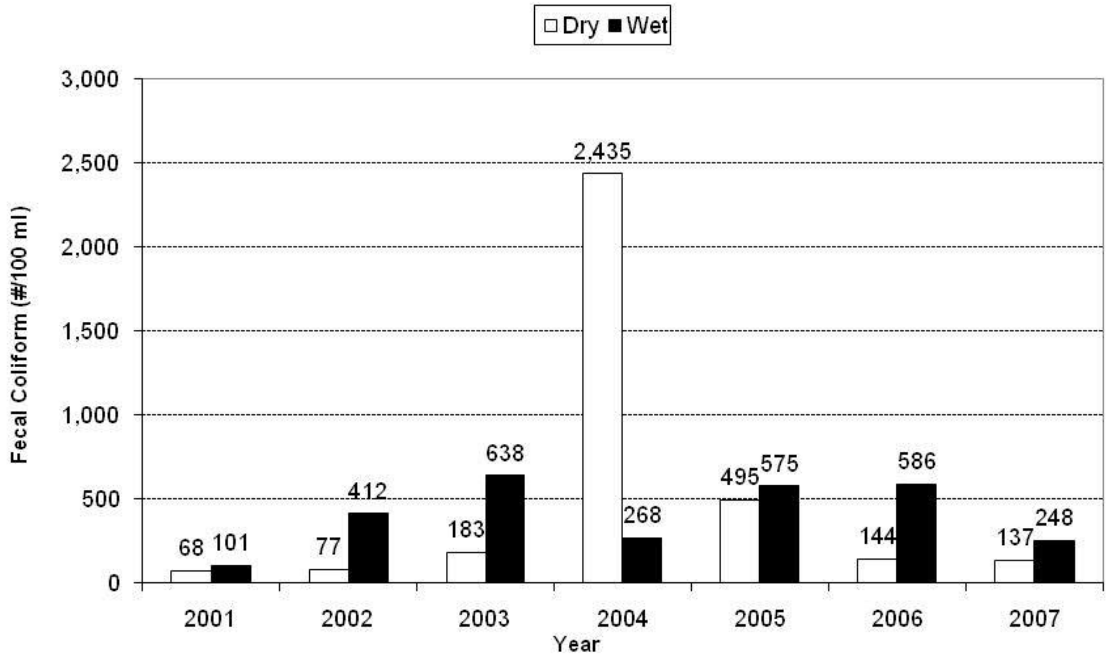


Figure 2.9-6 Average Fecal Coliform Levels during Wet and Dry Periods at River Mile 608.7 on the Ohio River

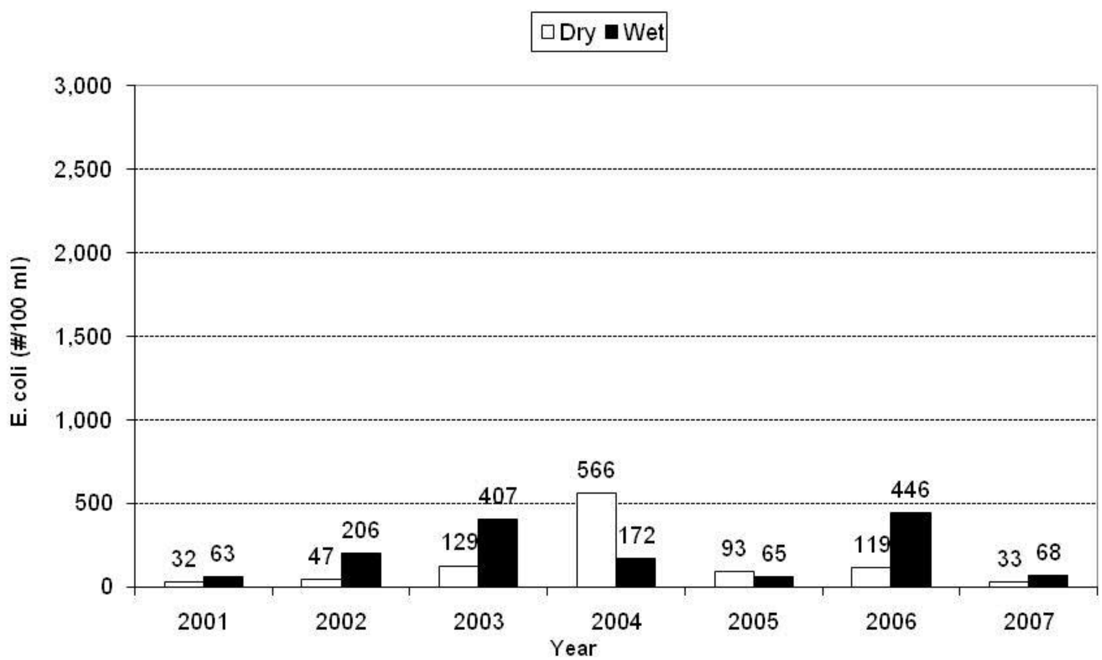


Figure 2.9-7 Average E. coli Levels During Wet and Dry Periods at River Mile 608.7 on the Ohio River

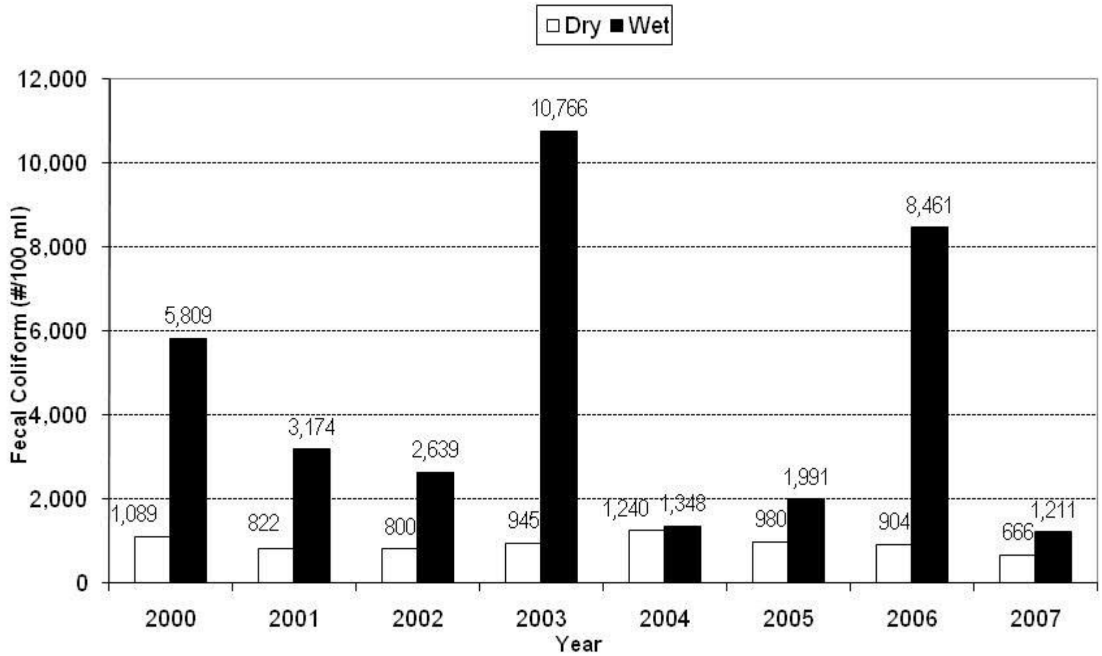


Figure 2.9-8 Average Fecal Coliform Levels during Wet and Dry Periods at River Mile 619.3 on the Ohio River

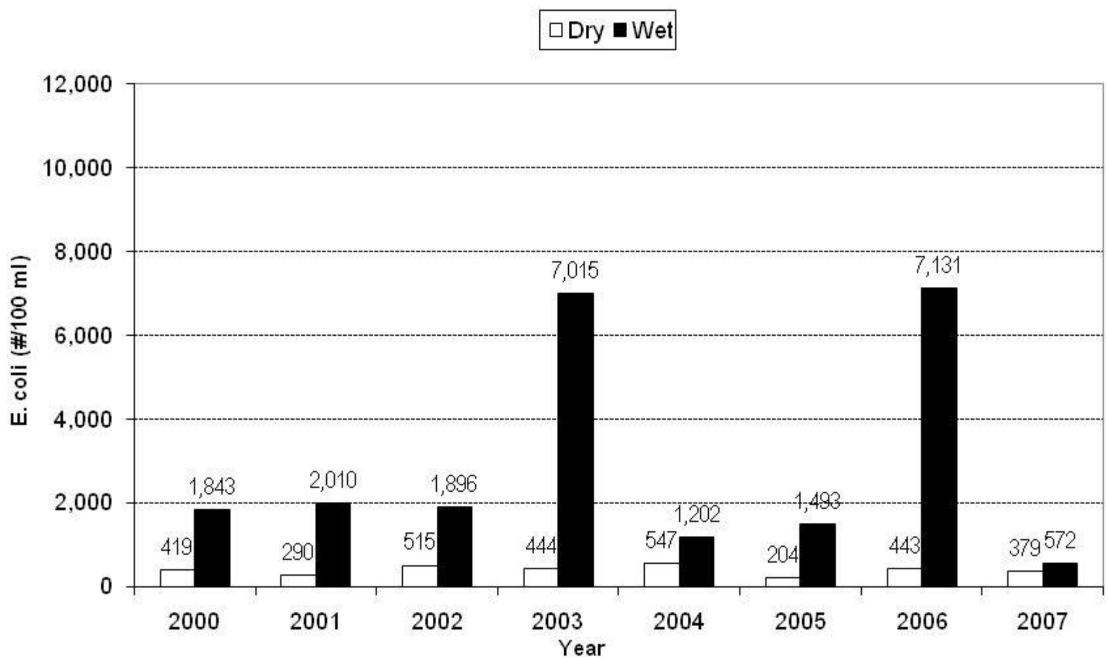


Figure 2.9-9 Average E. coli Levels during Wet and Dry Periods at River Mile 619.3 on the Ohio River

2.9.2.2. FREQUENCY OF EXCEEDANCE OF BACTERIAL TARGETS FROM ROUTINE MONITORING

This section examines the frequency of exceedances of the monthly geometric mean criterion and the instantaneous maximum in the Ohio River exceeded the fecal coliform and E. Coli criteria. It should be noted that this analysis does not represent a direct comparison to water quality standards criteria, as individual measurements are being compared to regulatory targets that are based on representing a geometric mean or an 80th percentile value. Therefore, the use of the term exceedances, particularly when referred to as instantaneous maximums, must be viewed in the context of a relative value versus a regulatory exceedance. Additionally, data were not necessarily collected of sufficient frequency to allow for a direct comparison to the water quality criteria.

Available routine monitoring data from each station was used to calculate the number of exceedances of the geometric mean criterion for each monthly period. Available data was used to calculate the percent of samples that were greater than the instantaneous maximum for dry and wet weather samples. Note that this is not a direct comparison to water quality standards for fecal coliform, since the criteria allow for 20 percent of the samples to exceed the criterion during a month. A comparison to the instantaneous maximum criterion for fecal coliform was conducted based on the percentage of samples exceeding the criterion each month.

The comparison of the geometric mean criterion for E. Coli is shown in Table 2.9-3. In most instances, there were five samples collected during each month (a few of the months had only four samples). Exceedances are relatively infrequent (17-50 percent) at the upstream and downtown stations but are prevalent (67-100 percent) at the downstream station.

Table 2.9-3 Number of Exceedances of the E. coli 30-day Geometric Mean of 130 per 100 ml, 2007

YEAR	RM 594.0 (UPSTREAM)			RM 608.7 (DOWNTOWN)			RM 619.3 (DOWNSTREAM)		
	NO. MONTHS GM > 130	TOTAL NO. MONTHS	% MONTHS GM > 130	NO. MONTHS GM > 130	TOTAL NO. MONTHS	% MONTHS GM > 130	NO. MONTHS GM > 130	TOTAL NO. MONTHS	% MONTHS GM > 130
2000							5	6	83%
2001	0	6	0%	0	6	0%	6	6	100%
2002	2	6	33%	1	6	17%	4	6	67%
2003	3	6	50%	3	6	50%	6	6	100%
2004	3	6	50%	2	6	33%	6	6	100%
2005	0	2	0%	0	2	0%	2	2	100%
2006	0	6	0%	1	6	17%	6	6	100%
2007	0	6	0%	0	6	0%	1	6	17%

Table 2.9-4 shows that exceedances of the fecal coliform geometric mean criterion are similar to those of the E. Coli criterion. Exceedances are relatively infrequent (17-67 percent) at the upstream and downtown stations but are prevalent (50-100 percent) at the downstream station.

Table 2.9-4 Number of Exceedances of the Fecal Coliform 30-day Geometric Mean of 200 per 100 ml, 2007

YEAR	RM 594.0 (UPSTREAM)			RM 608.7 (DOWNTOWN)			RM 619.3 (DOWNSTREAM)		
	NO. MONTHS GM > 200	TOTAL NO. MONTHS	% MONTHS GM > 200	NO. MONTHS GM > 200	TOTAL NO. MONTHS	% MONTHS GM > 200	NO. MONTHS GM > 200	TOTAL NO. MONTHS	% MONTHS GM > 200
2000							6	6	100%
2001	1	6	17%	0	6	0%	6	6	100%
2002	2	6	33%	1	6	17%	6	6	100%
2003	3	6	50%	4	6	67%	6	6	100%
2004	2	6	33%	2	6	33%	5	6	83%
2005	0	2	0%	1	2	50%	2	2	100%
2006	0	6	0%	1	6	17%	6	6	100%
2007	0	6	0%	1	6	17%	3	6	50%

Table 2.9-5 shows the percent of samples where the E. Coli concentrations were greater than the instantaneous maximum criterion of 240 per 100 ml.

Table 2.9-6 shows a similar comparison for fecal coliform. Again, the percentage of samples that were greater than the criteria levels was similar at the location upstream of the CSOs (River Mile 594) and downstream of the CSOs (River Mile 608.7). The percentage of samples with concentrations that were greater than the instantaneous maximum criterion was higher downstream of the Mill Creek Cutoff (River Mile 619.3).

Table 2.9-5 Number of E. coli Samples that were Greater than the Instantaneous Maximum of 240 per 100 ml, 2007

RIVER MILE (RM)	NO. OF DRY WEATHER SAMPLES		% DRY	NO. OF WET WEATHER SAMPLES		%WET	%ALL SAMPLES
	GREATER THAN	TOTAL		GREATER THAN	TOTAL		
RM 594.0	11	104	11%	19	85	22%	16%
RM 608.7	11	103	11%	20	86	23%	16%
RM 619.3	38	116	33%	66	102	65%	48%

Table 2.9-6 Number of Fecal Coliform Samples that were Greater than the Instantaneous Maximum of 400 per 100 ml, 2007

RIVER MILE	NO. OF DRY WEATHER SAMPLES		% DRY	NO. OF WET WEATHER SAMPLES		%WET	%ALL SAMPLES
	GREATER THAN	TOTAL		GREATER THAN	TOTAL		
RM 594.0	8	104	8%	21	85	25%	15%
RM 608.7	10	103	10%	23	86	27%	17%
RM 619.3	51	116	44%	75	102	74%	58%

2.9.2.3. LONGITUDINAL AND "SNAPSHOT" DATA FOR THE OHIO RIVER

E. Coli data (1,008 measurements) were obtained from ORSANCO's five-week longitudinal, "snapshot" and tributary surveys of the Ohio River and tributary mouths for the period October 2003 to October 2007. For the Ohio River main stem, data were collected on the Kentucky side (left-descending bank), the middle of the river, and the Indiana side (right-descending bank). Louisville Metro CSO study area. Results for these surveys are presented in Figure 2.9-10 through Figure 2.9-14.

Surveys were generally conducted on a weekly basis during the longitudinal surveys. Some of the data therefore reflect dry weather conditions, and some of the data reflect wet weather conditions. Table 2.9-7 provides a summary of the number of surveys that were reflective of dry and wet weather conditions and the total amount of rain falling during that period or preceding the survey. The May 25 to June 22, 2006, survey (Figure 2.9-10) is reflective of more wet weather conditions whereas the October 4 – 8, 2007, (Figure 2.9-11) is reflective of dry weather conditions. Under wet weather conditions, E. Coli concentrations increase in the CSO-impacted area but are highest well downstream of the CSO-impacted area.

Table 2.9-7 Number of Dry and Wet Weather Survey Days for the ORSANCO Longitudinal and Tributary Surveys

SURVEY PERIOD	NO. OF SURVEY DAYS		TOTAL RAIN (IN)
	DRY	WET	
October 2 - 30, 2003	3	2	2.15
May 12 - June 7, 2005	4	1	5.53
May 25 to June 22, 2006	4	1	6.24
July 24 to August 21, 2006	3	2	4.63
July 30 - 31, 2007	1	1	0.58
September 4 - 5, 2007	2	0	0
October 4 - 8, 2007	2	0	0

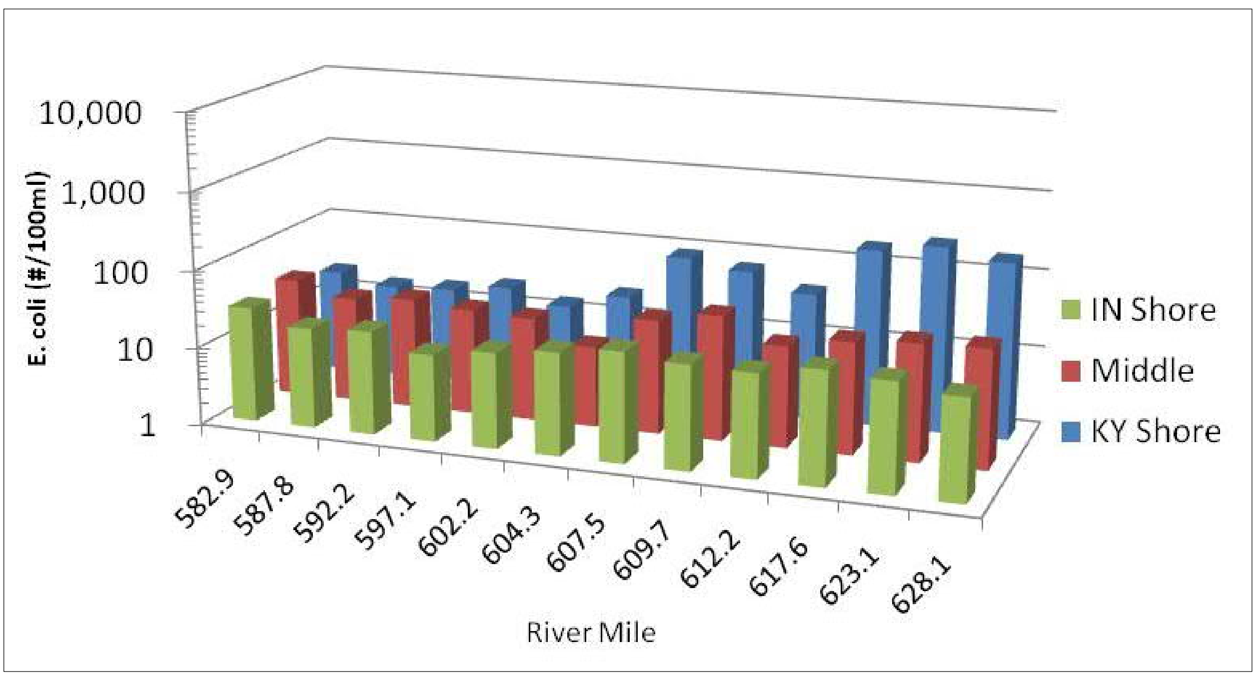


Figure 2.9-10 E. coli Concentrations for the October 2-30, 2002 Longitudinal Survey of the Ohio River

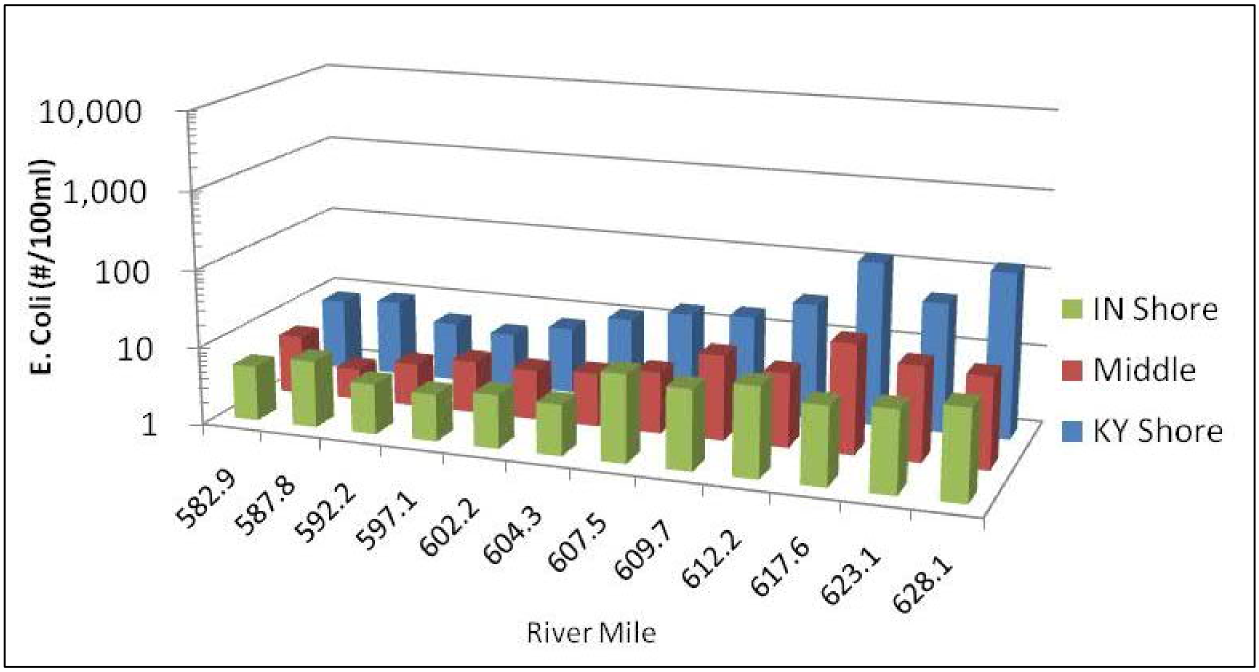


Figure 2.9-11 E. coli Concentrations for the May 12 to June 9, 2005 Longitudinal Survey of the Ohio River

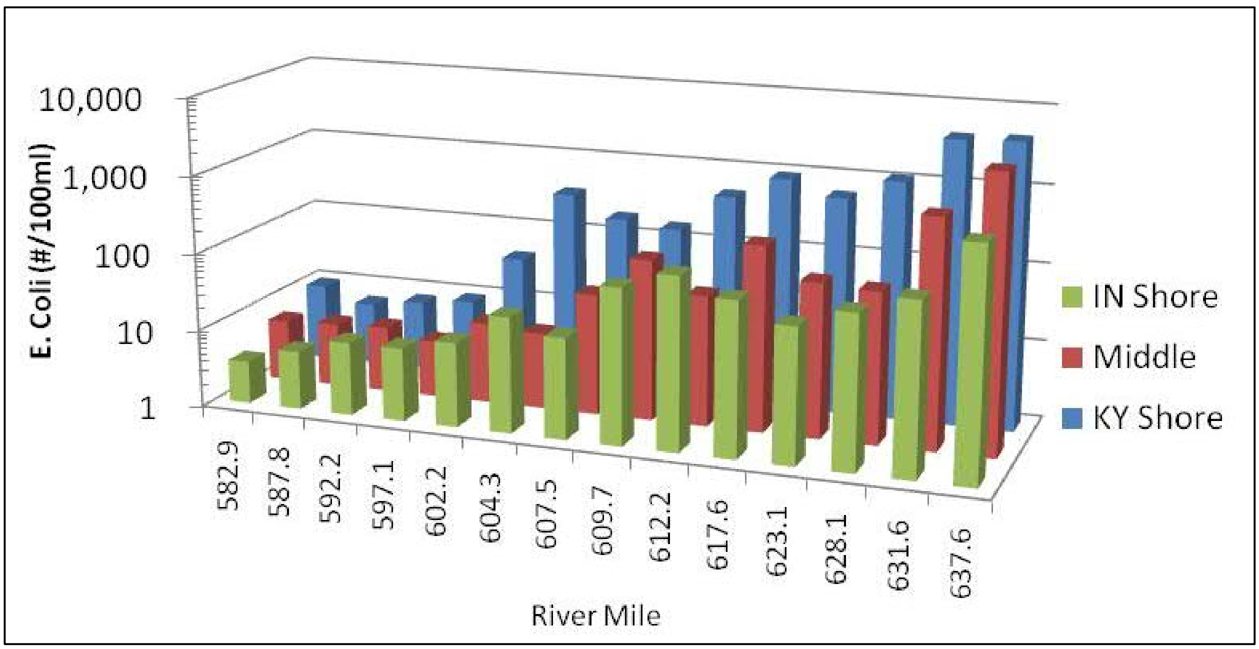


Figure 2.9-12 E. coli Concentrations for the May 25 to June 22, 2006 Longitudinal Survey of the Ohio River

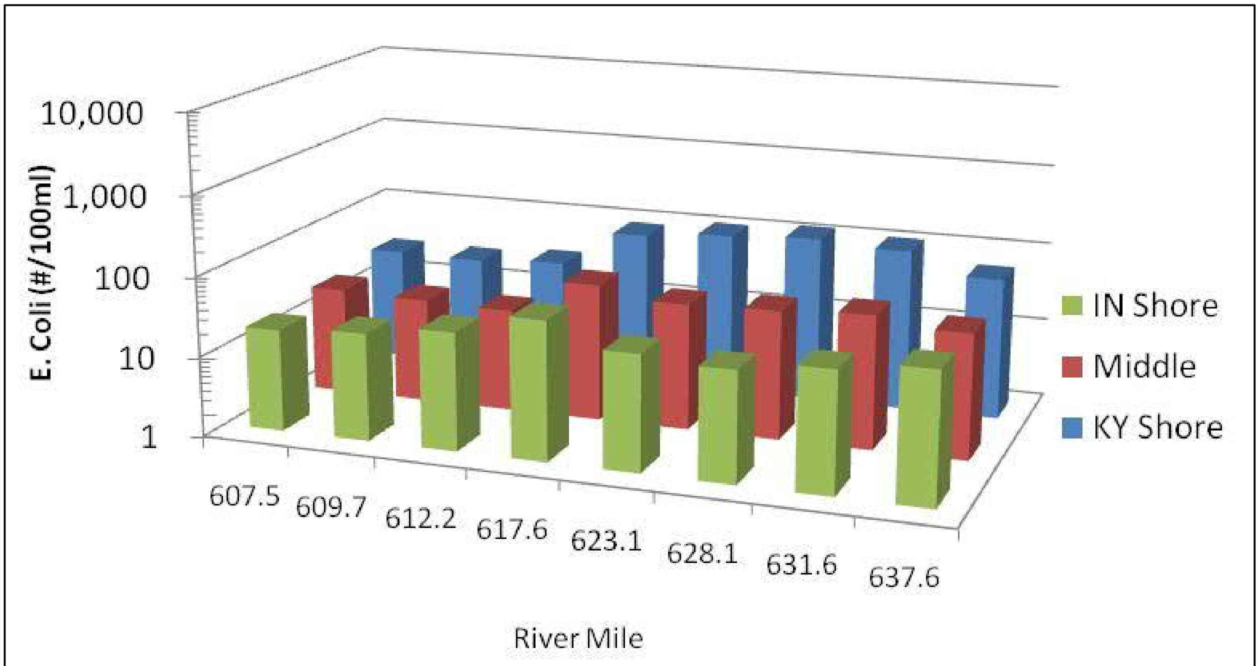


Figure 2.9-13 E. coli Concentrations for the July 24 to August 21, 2006 Longitudinal Survey of the Ohio River

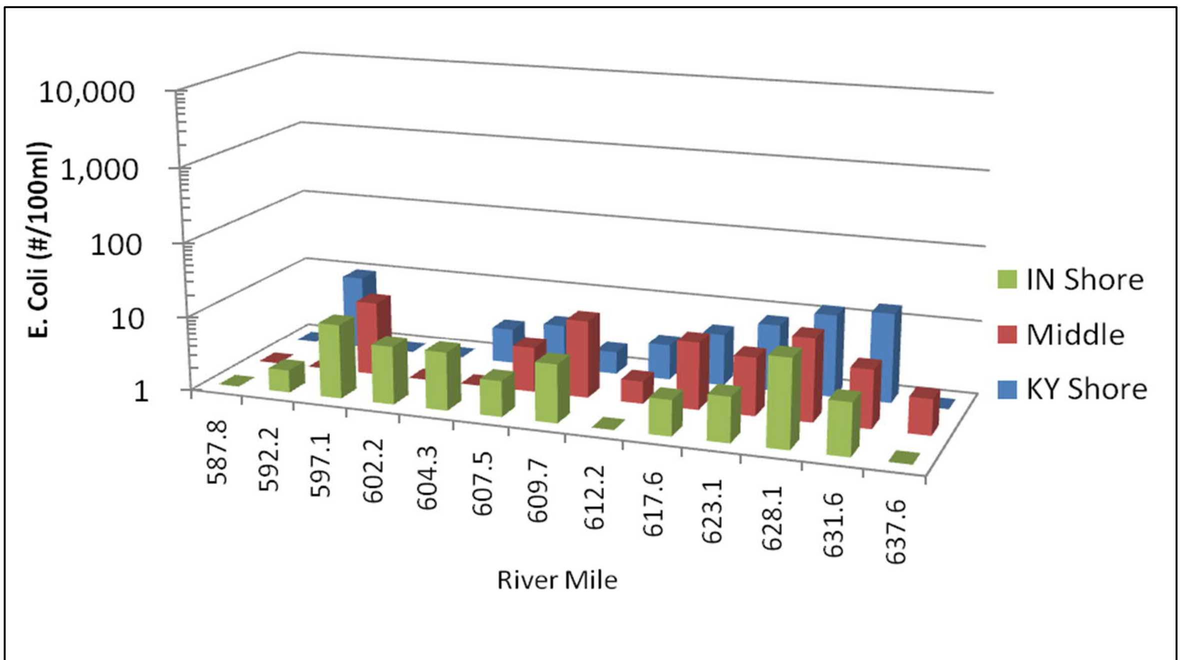


Figure 2.9-14 E. coli Concentrations for the October 4 -8, 2007 Longitudinal Survey of the Ohio River

Table 2.9-8 presents a summary of the total number of E. Coli longitudinal survey samples available from 2003 to 2007 for the Ohio River main stem along the Kentucky shore that exceeded the 240 per 100 ml value. Although there is an increase (6 to 19 percent) within the CSO-impacted area, the largest increase is downstream of the Mill Creek Cutoff.

The tributary sampling data are presented in

for periods when data were collected on Beargrass Creek. In general, concentrations in Beargrass Creek are significantly higher than the other tributaries. E. Coli concentrations at some of the other tributaries exceed the instantaneous maximum criterion of 240 per 100 ml. The percent of samples at the tributary mouths that exceeded the instantaneous maximum (shown in Table 2.9-8) was greater than 10 percent for all tributaries and was highest for Beargrass Creek (100 percent).

Table 2.9-8 Percent of Longitudinal E. Coli Samples on the Ohio River that Exceeded the Instantaneous Maximum of 240 per 100ml (2003-2007)

STATION	NO. >240	TOTAL NO.	PERCENT > 240
RM_582.9	0	15	0%
RM_587.8	0	16	0%
RM_592.2	0	16	0%
RM_597.1	0	16	0%
RM_602.2	1	16	6%
RM_604.3	3	16	19%
RM_607.5	4	21	19%
RM_609.7	4	21	19%
RM_612.2	3	21	14%
RM_617.6	8	21	38%
RM_623.1	8	21	38%
RM_628.1	8	21	38%
RM_630	5	10	50%
RM_631.6	11	20	55%
RM_637.6	9	20	45%
Total	64	271	24%

RM = River Mile

Table 2.9-9 E. Coli Concentrations for the Mouths of the Ohio River Tributaries, 2005 and 2007

TRIBUTARY STATION	MAY 25 TO JUNE 9, 2005 (#/100 ML)	JULY 30 TO 31, 2007 (#/100 ML)	SEPTEMBER 4 TO 5, 2007 (#/100 ML)	OCTOBER 4 TO 8, 2007 (#/100 ML)
RM_595.9-Harrods_Ck	268	990	629	327
RM_597-Goose_Ck	759	113	8	71
RM_602.1-a_Muddy_Fk_BGC	5,438	353	216	399
RM_602.1-b_Middle_Fk_BGC	12,597	10,200	12,700	14,100
RM_602.1-c_South_Fk_BGC	7,278	680	194	634
RM_605.2-Cane_Run	3,400	1,210	5,400	361
RM_606.2-Mill_Ck (IN)	2,370	133	130	228
RM_606.5-Silver_Ck	3,670	290	25	435
RM_609.3-Falling_Run	4,214	469	55	1,150

Table 2.9-9 E. Coli Concentrations for the Mouths of the Ohio River Tributaries, 2005 and 2007

TRIBUTARY STATION	MAY 25 TO JUNE 9, 2005 (#/100 ML)	JULY 30 TO 31, 2007 (#/100 ML)	SEPTEMBER 4 TO 5, 2007 (#/100 ML)	OCTOBER 4 TO 8, 2007 (#/100 ML)
RM_616.4-Mill_Ck_Cutoff	1,566	104	10	5
RM_625-Mill_Ck (KY)	976	47	11	57
RM_629.9-b_Salt_Ck	132			7

RM = River Mile

Table 2.9-10 Percent of E. Coli Samples on the Ohio River Tributary Mouths that Exceeded the Instantaneous Maximum of 240 per 100 ml (2003-2007)

STATION	NO. > 240	TOTAL NO.	PERCENT > 240
RM_595.9-Harrods_Ck	6	8	75%
RM_597-Goose_Ck	4	8	50%
RM_602.1-a_Muddy_Fk_BGC	7	8	88%
RM_602.1-b_Middle_Fk_BGC	8	8	100%
RM_602.1-c_South_Fk_BGC	7	8	88%
RM_605.2-Cane_Run	13	13	100%
RM_606.2-Mill_Ck (IN)	6	13	46%
RM_606.5-Silver_Ck	9	13	69%
RM_609.3-Falling_Run	9	13	69%
RM_616.4-Mill_Ck_Cutoff	4	13	31%
RM_625-Mill_Ck (KY)	2	13	15%
RM_629.9-b_Salt_Ck	3	21	14%
Total	78	139	56%

RM = River Mile

2.9.2.4. ORSANCO WET WEATHER DEMONSTRATION PROJECT

The data collected during the ORSANCO Wet Weather Demonstration Project in 2000-2002 provide much more spatial resolution on bacterial concentrations. Results for the only wet weather event that was monitored after the year 2000 near Louisville are shown in Figure 2.9-15, which shows longitudinal and lateral variation in concentrations. Concentrations are observed to increase as the river moves downstream through the Louisville metropolitan area. Concentrations are also observed to be consistently higher along the Kentucky shoreline than they are in the middle of the river channel.

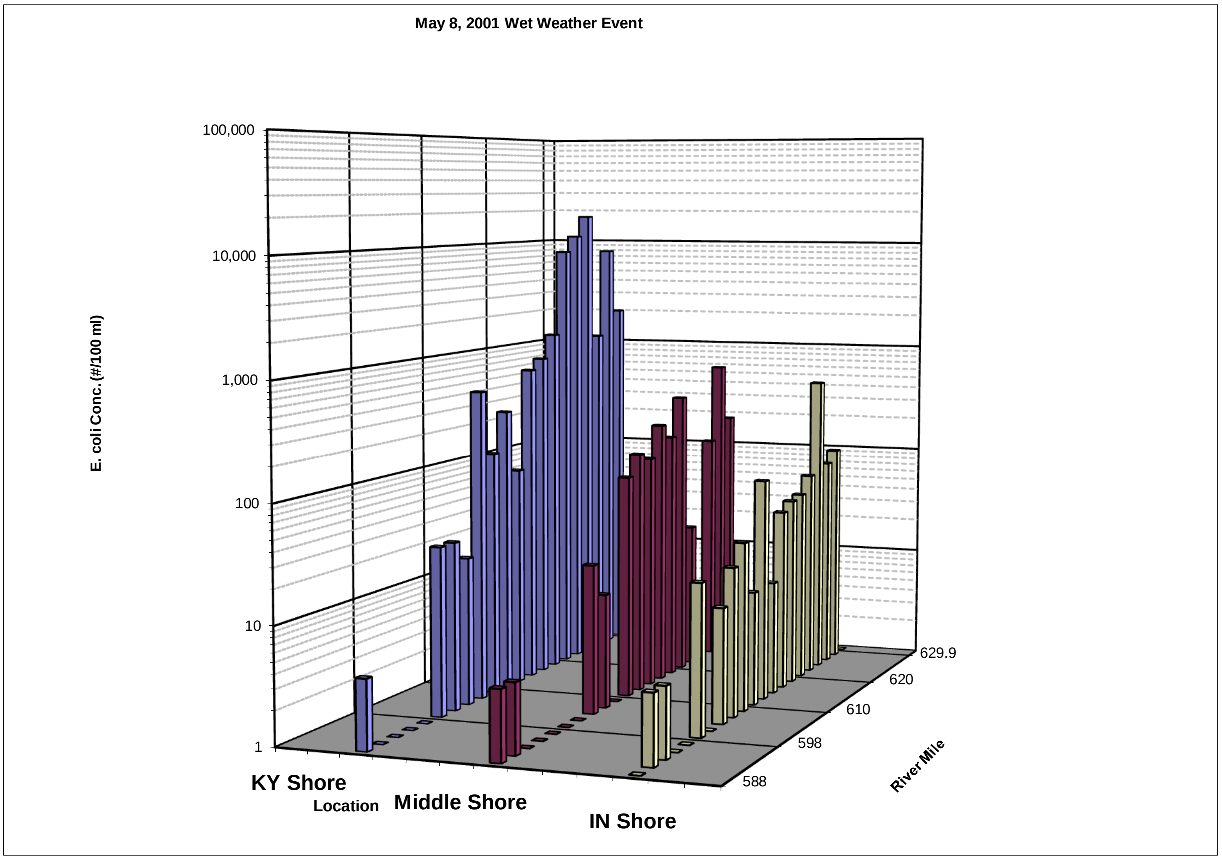


Figure 2.9-15 E. coli Concentrations Observed during May, 2001 ORSANCO Wet Weather Event

2.9.2.5. OTHER PARAMETERS

ORSANCO collects other parameters beyond bacteria as part of its routine monitoring. Results for these parameters are shown in **Error! Reference source not found.**. As discussed previously, the known impairments associated with the CSOs are limited to bacteria.

Table 2.9-11 Summary of ORSANCO Routine Monitoring Data from 2000-2007 for Other Parameters

PARAMETER	NUMBER OF SAMPLES	AVERAGE	MINIMUM	MAXIMUM
Ammonia as Nitrogen (MG/l)	147	0.06	0.03	0.27
Nitrate-Nitrite as N (MG/l)	155	1.17	0.06	2.41
Total Kjeldahl Nitrogen (MG/l)	152	0.62	0.10	2.95
Total Phosphorus (MG/l)	152	0.16	0.01	1.94
Chlorophyll (ug/l)	196	6.6	0	36.67
Turbidity (ntu)	196	46.46	0	347
pH	196	7.9	7.4	8.5
Copper (ug/l)	34	3.2	0.9	9.3
Hardness (MG/l)	34	143.6	111.5	205.7
Nickel (ug/l)	34	3.9	1.1	13.1

Table 2.9-11 Summary of ORSANCO Routine Monitoring Data from 2000-2007 for Other Parameters

PARAMETER	NUMBER OF SAMPLES	AVERAGE	MINIMUM	MAXIMUM
Lead (ug/l)	34	1.8	0.3	9.3
Zinc (ug/l)	34	10	1.8	46.2

2.9.3. RECEIVING WATER QUALITY MONITORING ANALYSIS – BEARGRASS CREEK

Data available for Beargrass Creek included fecal coliform and continuous monitoring data from MSD's long-term monitoring network (LTMN); other parameters from the LTMN; biological data from the LTMN; and other studies that were conducted to support development of the Beargrass Creek Water Quality Tool (Tetra Tech, 2008). Figure 2.9-16 shows the three forks of Beargrass Creek and the location of the LTMN network and rainfall gages.

For the fecal coliform and other parameters from the LTMN ambient stations, rainfall data were used to assign each sample as a "wet" or "dry" sample with the criteria discussed in Section 2.9.3. For data preceding May 2003, hourly rainfall from the Louisville International Airport was used. In May 2003, MSD installed a high frequency (5 minute) rain gage network. MSD selected the nearest rainfall gages to each Beargrass Creek ambient station to make the assignment of "wet" or "dry" samples for the data collected after April 2003.

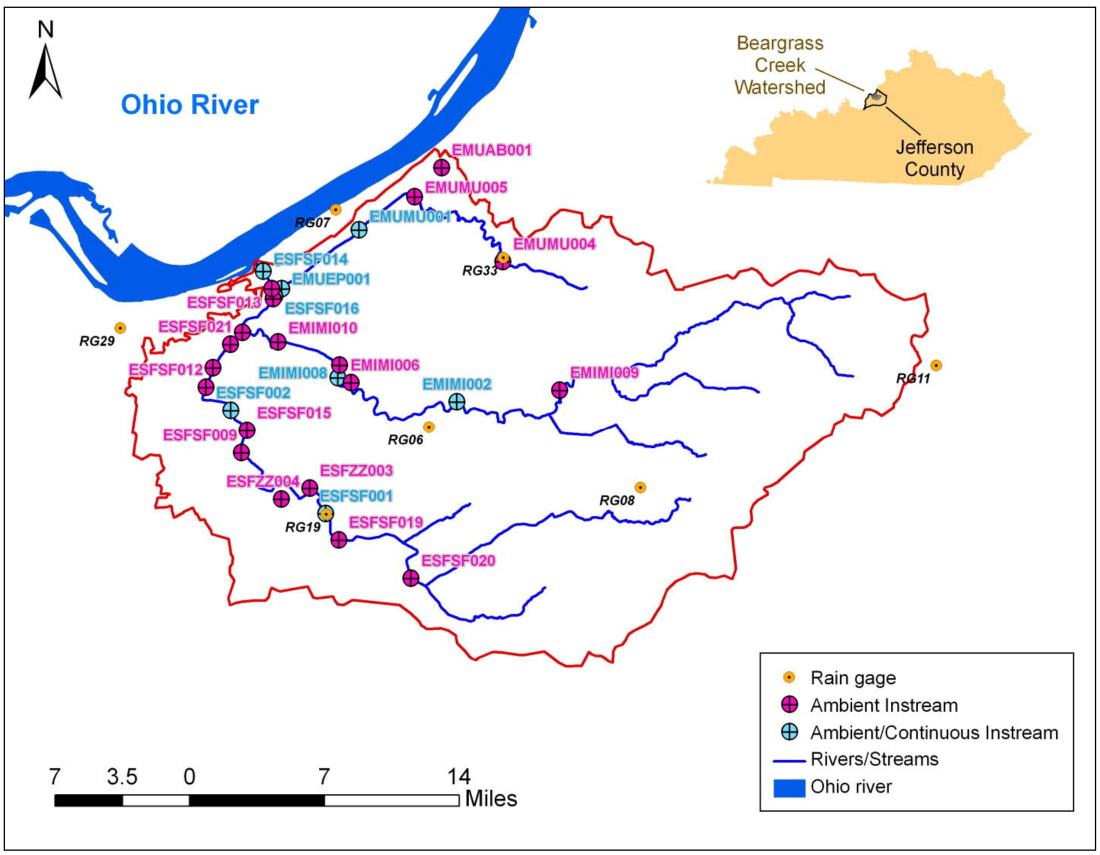


Figure 2.9-16 Location of MSDs Beargrass Creek Monitoring Stations

2.9.3.1. AVERAGE FECAL COLIFORM CONCENTRATIONS

A total of 1,840 fecal coliform measurements were collected by MSD throughout the Beargrass Creek watershed during the period 2000-2007. These data were analyzed in both terms of average concentrations during wet and dry weather periods as well as percentage of individual samples exceeding specific target levels associated with the water quality standards.

A summary display of average concentrations is provided in Figure 2.9-17, which stratifies results by tributary branch and climatic condition. Average concentrations are higher in the Middle and South Forks than in Muddy Fork during both dry and wet weather. Concentrations in all three tributaries are also noticeably higher during wet weather periods.

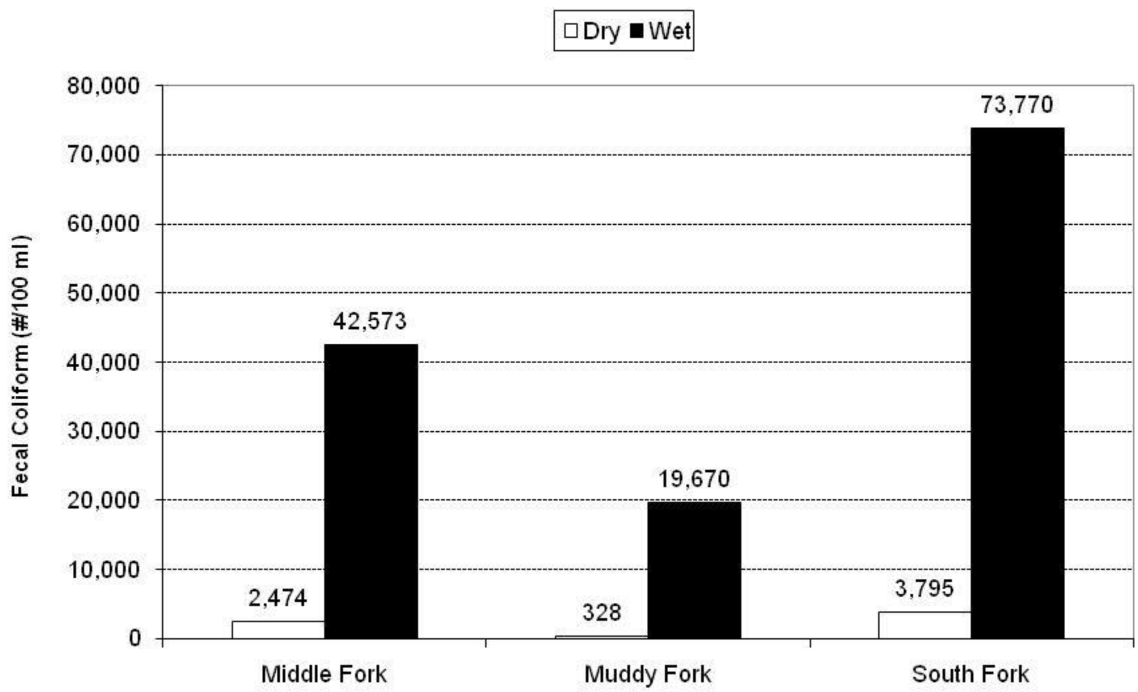


Figure 2.9-17 Average Fecal Coliform in Beargrass Creek 2000-2007

Figure 2.9-18 through Figure 2.9-21 show annual variation in fecal coliform concentrations in the Middle, Muddy, and South Forks, respectively. Concentrations are higher in the years 2000, 2001, and 2007 for all three forks. Concentrations are higher in years when additional sampling was performed for special wet weather monitoring studies.

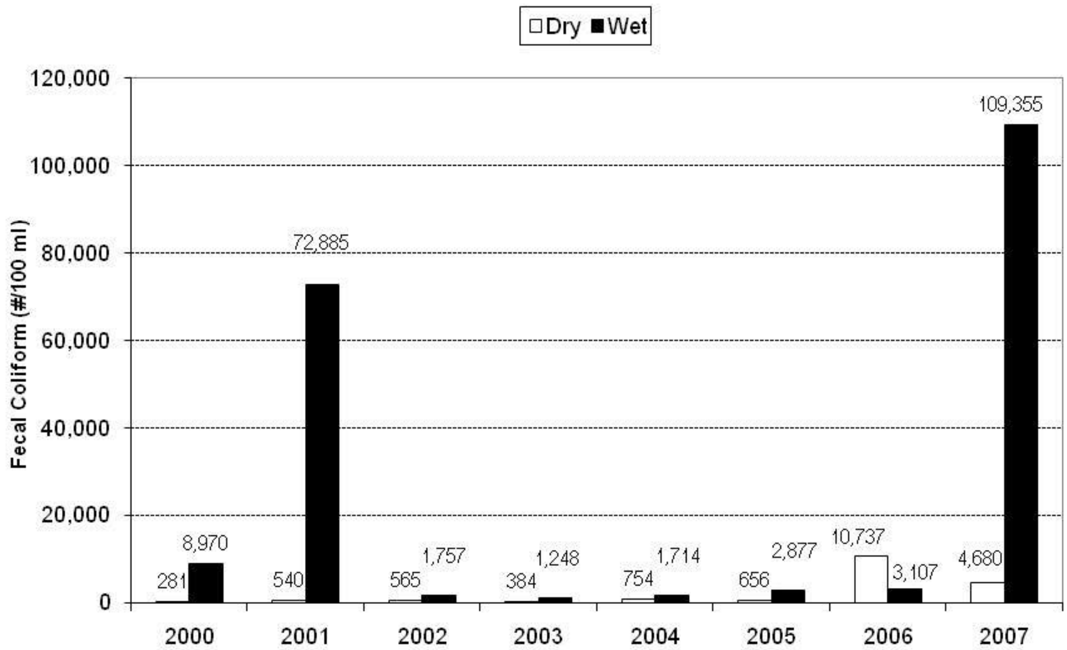


Figure 2.9-18 Average Fecal Coliform on The Middle Fork of Beargrass Creek

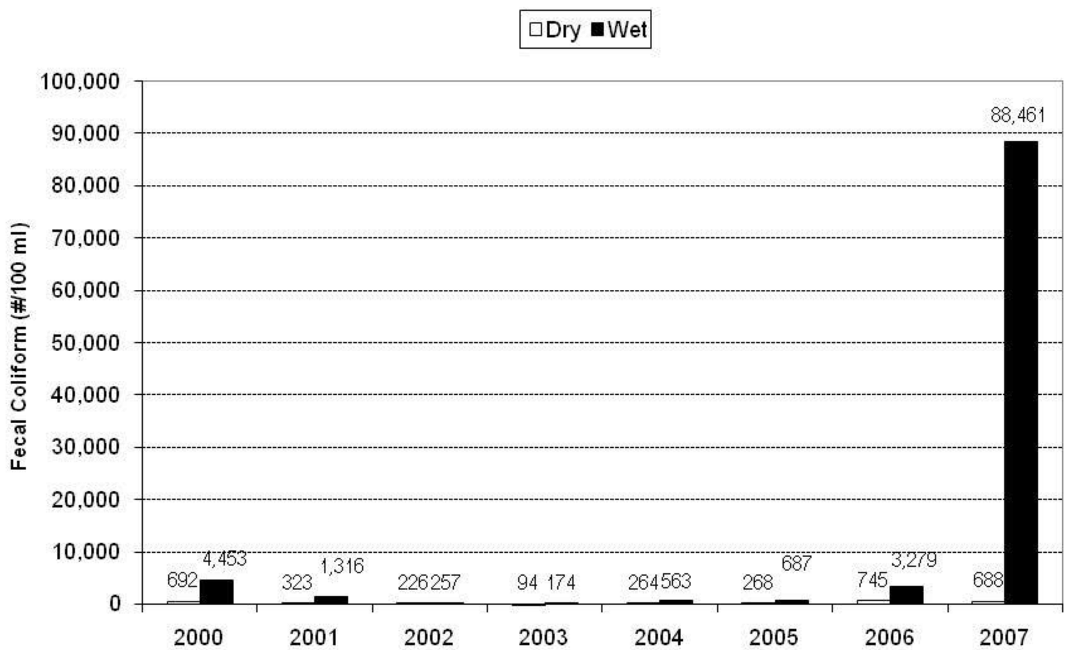


Figure 2.9-19 Average Fecal Coliform on the Muddy Fork of Beargrass Creek

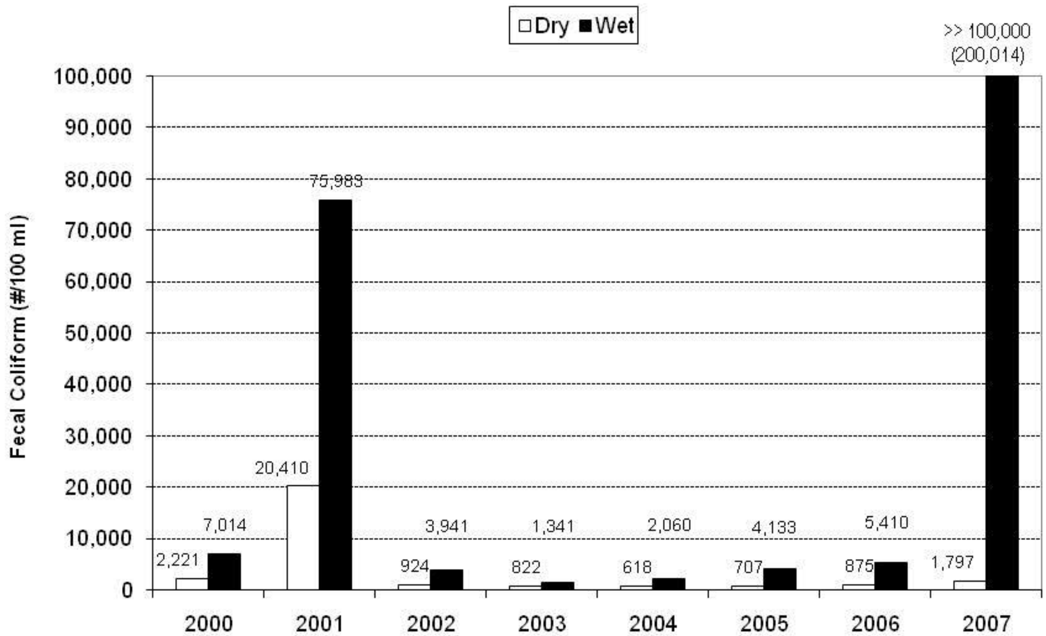


Figure 2.9-20 Average Fecal Coliform on the South Fork of Beargrass Creek

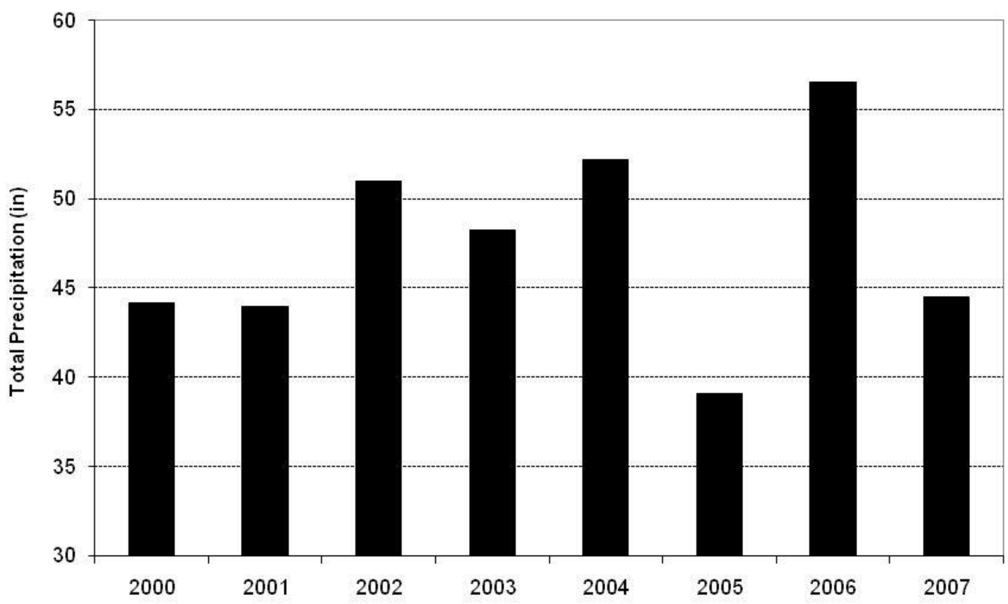


Figure 2.9-21 Annual Rainfall Total as Measured at the Louisville Standiford Field

2.9.3.2. FREQUENCY OF EXCEEDING TARGET LEVELS

As discussed in Section 2.9.2, water quality standards for indicator bacteria in waters designated for primary contact recreation consist of two parts. When this analysis was originally performed, fecal coliform bacterial was the indictor organism used to determine attainment of the contact recreation use. At that time, the water quality standards stated that the fecal coliform concentrations during the contact recreation season

(May - October) shall not exceed 200 per 100 ml as a geometric mean based on not less than five samples taken during a 30-day period. Further, the fecal coliform concentration shall not exceed 400 colonies 100 ml in 20 percent or more of all samples taken during a 30-day period.

This section examines the frequency of time that these target values are exceeded. It should be noted that this analysis does not represent a direct comparison to water quality criteria, as individual measurements are being compared to regulatory targets that are based on a geometric mean or an 80th percentile value. Therefore, the use of the term exceedances must be viewed in the context of a relative value versus a regulatory exceedance. Additionally, data were not necessarily collected of sufficient frequency to allow for a direct comparison to the water quality criteria.

Available data from each branch were used to calculate the number of exceedances of the geometric mean criterion (Table 2.9-12). Exceedances are prevalent for all six years on all three branches, with the average exceedance percentage across the three branches ranging from 69-79 percent.

Table 2.9-12 Exceedances of the 30-day Geometric Mean (200 per 100 ml) Fecal Coliform Target in each Branch of Beargrass Creek from May – October

YEAR	MIDDLE FORK			MUDDY FORK			SOUTH FORK		
	EXCEED	TOTAL	PERCENT	EXCEED	TOTAL	PERCENT	EXCEED	TOTAL	PERCENT
2000	5	6	83%	5	6	83%	4	6	67%
2001	4	6	67%	5	6	83%	3	6	50%
2002	3	6	50%	2	6	33%	4	6	67%
2003	3	6	50%	1	6	17%	3	6	50%
2004	5	6	83%	3	6	50%	5	6	83%
2005	6	6	100%	5	6	83%	6	6	100%
2006	6	6	100%	6	6	100%	6	6	100%
2007	6	6	100%	6	6	100%	6	6	100%
Total	38	48	79%	33	48	69%	37	48	77%

Table 2.9-13 presents a similar exceedance analysis, using the 80th percentile fecal coliform standard (400 per 100 ml). The percent of time that the target is exceeded is less than for the geometric mean criteria, which is expected because the target value is higher. Nonetheless, these percentages indicate that water quality standards are likely not being met over large periods of time. The nature of the target is that no more than 20 percent of the samples should exceed it, and the observed percentage exceedance ranges from 42-61 percent.

Table 2.9-13 Number of Exceedances of the 80th Percentile Fecal Coliform Standard (400 per 100 ml) in each Branch of Beargrass Creek from May-October, 2000-2007

	MIDDLE	MUDDY	SOUTH
Exceed	385	151	455
Total	634	358	805
%	61%	42%	57%

2.9.3.3. CONTINUOUS MONITORING DATA

As shown in Figure 2.9-22, MSD has operated seven continuous water quality monitors in the Beargrass Creek watershed. Data from these monitors are summarized in the report entitled *Water Quality in Jefferson*

County, Kentucky: A watershed synthesis report, 2000-2005 (Jin, 2007). Figure 2.9-22 to Figure 2.9-27 present a summary of the percent of days where the daily average dissolved oxygen criterion of 5.0 mg/l was exceeded. Stations are presented in upstream to downstream order for each of the three forks. Both the raw and the USGS corrected data is presented because the sondes (continuous monitors) were subject to fouling and many of the raw data were considered unreliable. MSD has since replaced these sondes with sensors that are less prone to fouling. Corrected data were not provided for 2005. In general, there are less violations at the locations upstream of the sanitary sewer overflows (SSOs) and the CSOs.

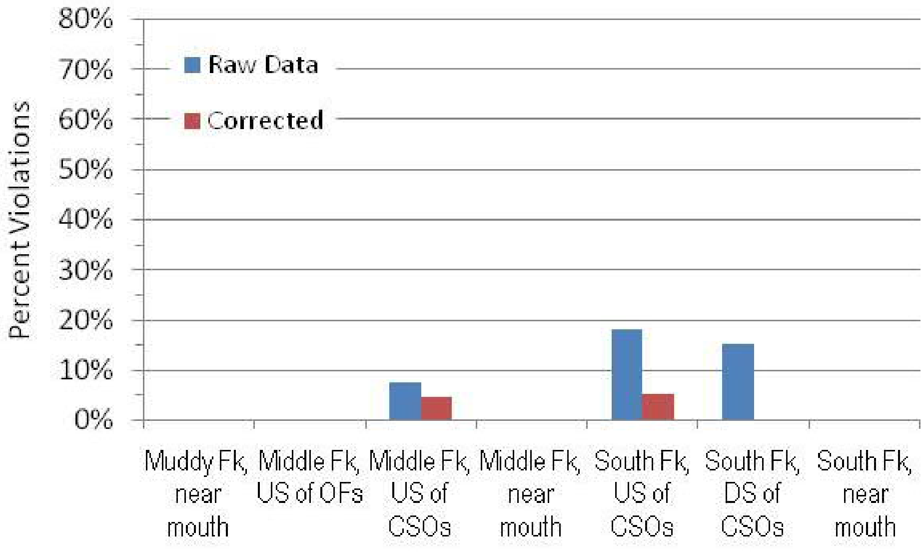


Figure 2.9-22 Percent Daily Average Dissolved Oxygen Violations in Beargrass Creek, 2000

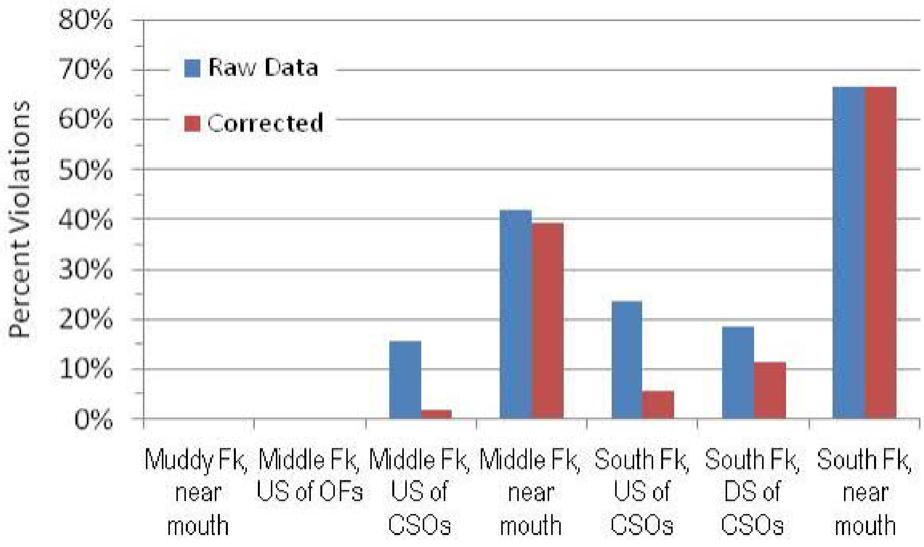


Figure 2.9-23 Percent Daily Average Dissolved Oxygen Violations in Beargrass Creek, 2001

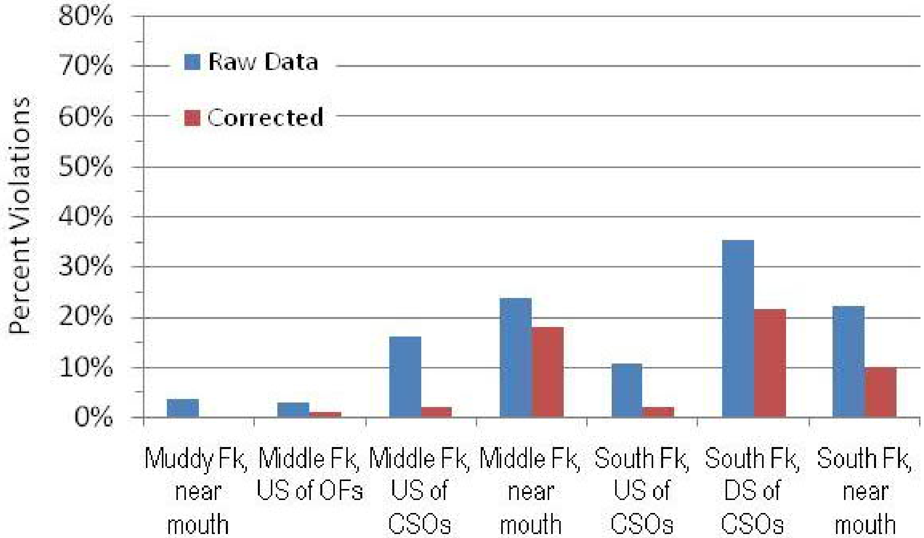


Figure 2.9-24 Percent Daily Average Dissolved Oxygen Violations in Beargrass Creek, 2002

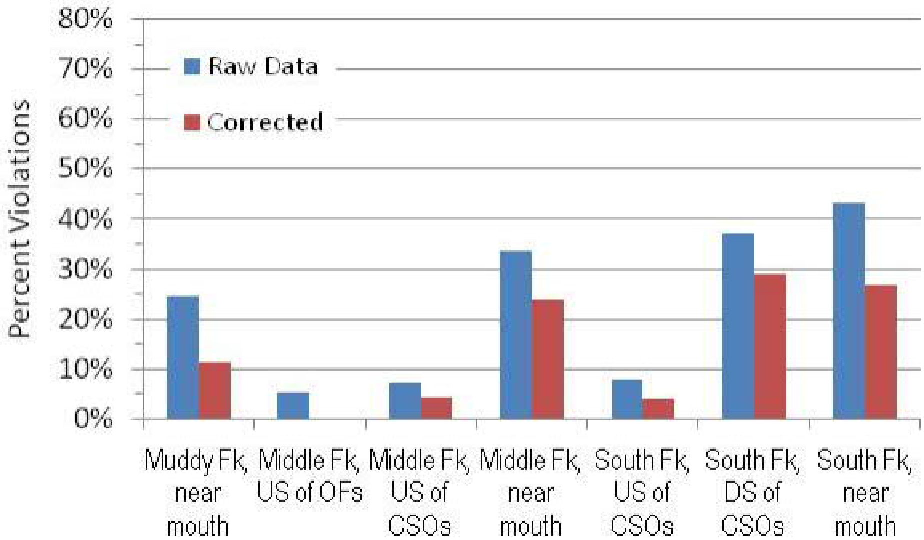


Figure 2.9-25 Percent Daily Average Dissolved Oxygen Violations in Beargrass Creek, 2003

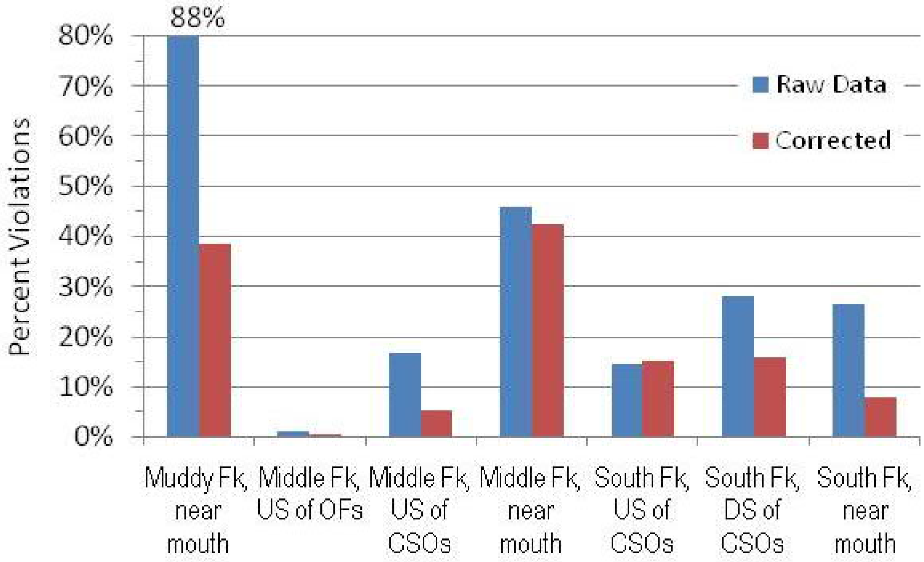


Figure 2.9-26 Percent Daily Average Dissolved Oxygen Violations In Beargrass Creek, 2004

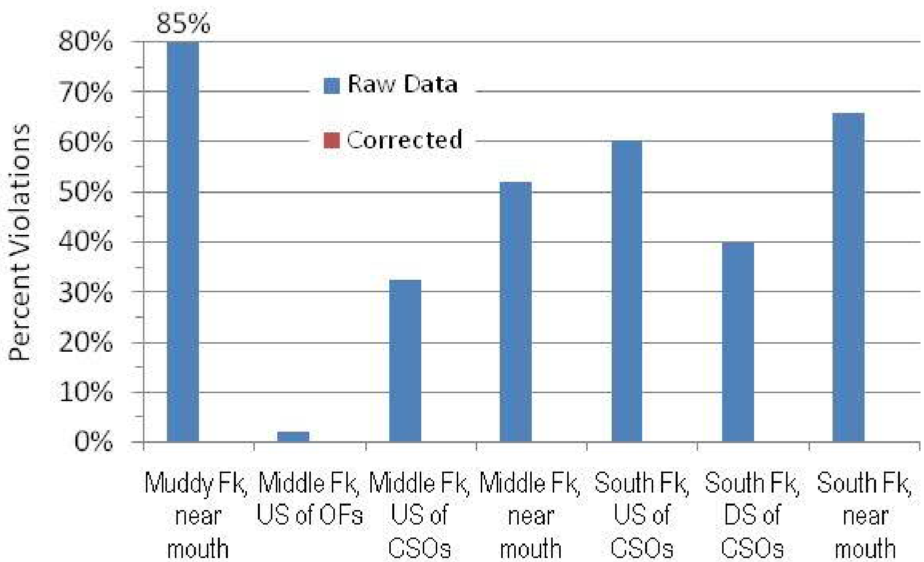


Figure 2.9-27 Percent Daily Average Dissolved Oxygen Violations in Beargrass Creek, 2005

The evaluation of the daily average pH reported in the Synthesis Report indicated that there were occasional violations of the minimum and maximum pH criteria. This occurred at all locations with the exception of EMIMI002 on the Middle Fork, upstream of the CSOs.

2.9.3.4. BIOLOGICAL DATA

MSD conducts biological (fish and macroinvertebrate), habitat and bioassessment data at the long-term monitoring network stations. Data are summarized in the Synthesis Report for 2000 to 2005 (Jin, 2007). Macroinvertebrate biotic integrity scores ranged from vary poor to fair at all locations, depending on the year. The fish index of biotic integrity, which is often highly variable particularly for urbanized streams, ranged from poor to excellent. The diatom bioassessment index ranged from fair to excellent.

2.9.3.5. OTHER PARAMETERS

MSD collects other parameters beyond bacteria as part of its routine monitoring. Results for these parameters for 2000-2006 are shown in Table 2.9-14 through Table 2.9-16.

Table 2.9-14 Summary of Water Quality Data for Middle Fork (2000-2007)

PARAMETER	NUMBER OF SAMPLES	AVERAGE	MINIMUM	MAXIMUM
Ammonia as Nitrogen (MG/l)*	141	0.32	0.05	10.00
Nitrate (MG/l)	9	0.74	0.05	1.10
Nitrite (MG/l)	9	0.02	0.01	0.04
Total Kjeldahl Nitrogen (MG/l)	155	16.2	0.2	832.0
Total Phosphorus (MG/l)	153	0.23	0.02	2.28
TSS (MG/l)**	508	71	0	5,916
pH	30	6.68	4.21	8.76
Copper (ug/l)	120	0.092	0.002	2.62
Hardness (MG/l)	82	203	7	337
Nickel (ug/l)	106	0.071	0.001	1.960
Lead (ug/l)	148	0.011	0.0005	0.239
Zinc (ug/l)	116	0.341	0.008	9.150

*Does not include suspect ammonia data from 9/13/01 and 10/30/01, which were > 50 MG/l. These data are undergoing further investigation.

**TSS data are from 2000-2006.

Table 2.9-15 Summary of Water Quality Data for Muddy Fork (2000-2007)

PARAMETER	NUMBER OF SAMPLES	AVERAGE	MINIMUM	MAXIMUM
Ammonia as Nitrogen (MG/l)	394	0.15	0.05	1.46
Nitrate (MG/l)	3	1.04	0.67	1.23
Nitrite (MG/l)	3	0.02	0.01	0.03
Total Kjeldahl Nitrogen (MG/l)	205	0.7	0.04	2.6
Total Phosphorus (MG/l)	361	0.112	0.006	7.17
TSS(MG/l)*	396	14	1	246
pH	375	7.27	5.05	10.43
Copper (ug/l)	214	0.010	0.002	0.028
Hardness (MG/l)	253	285	3	469
Nickel (ug/l)	200	0.003	0.001	0.124
Lead (ug/l)	284	0.002	0.001	0.040
Zinc (ug/l)	204	0.021	0.003	0.430

*TSS data are from 2000-2006.

Table 2.9-16 Summary of Water Quality Data for South Fork (2000-2007)

PARAMETER	NUMBER OF SAMPLES	AVERAGE	MINIMUM	MAXIMUM
Ammonia as Nitrogen (MG/l)	192	0.68	0.05	34.0
Nitrate (MG/l)	9	0.74	0.48	0.90
Nitrite (MG/l)	9	0.04	0.01	0.08
Total Kjeldahl Nitrogen (MG/l)	241	9.45	0.40	801
Total Phosphorus (MG/l)	210	0.454	0.013	14.700
TSS (MG/l)*	565	96	0	1,470
pH	52	6.95	5.13	8.00
Copper (ug/l)	162	0.148	0.003	6.290
Hardness (MG/l)	107	198.1	7.0	379.0
Nickel (ug/l)	170	0.067	0.001	2.050
Lead (ug/l)	204	0.040	0.001	2.100
Zinc (ug/l)	177	0.482	0.008	23.000

*Does not include suspect ammonia data from 9/13/01, 10/30/01, 11/8/01, and 11/14/01, which were > 50 MG/l. These data are undergoing further investigation.

**TSS data are from 2000-2006.

2.9.4. RECEIVING WATER QUALITY MODELING OVERVIEW

A water quality model is a series of mathematical equations describing real world processes. The mathematical equations contained in the model are based upon scientific principles describing known relationships that affect water quality. As a depicted in Figure 2.9-28, water quality models are designed to convert inputs on environmental conditions and human activities into outputs of water quality.

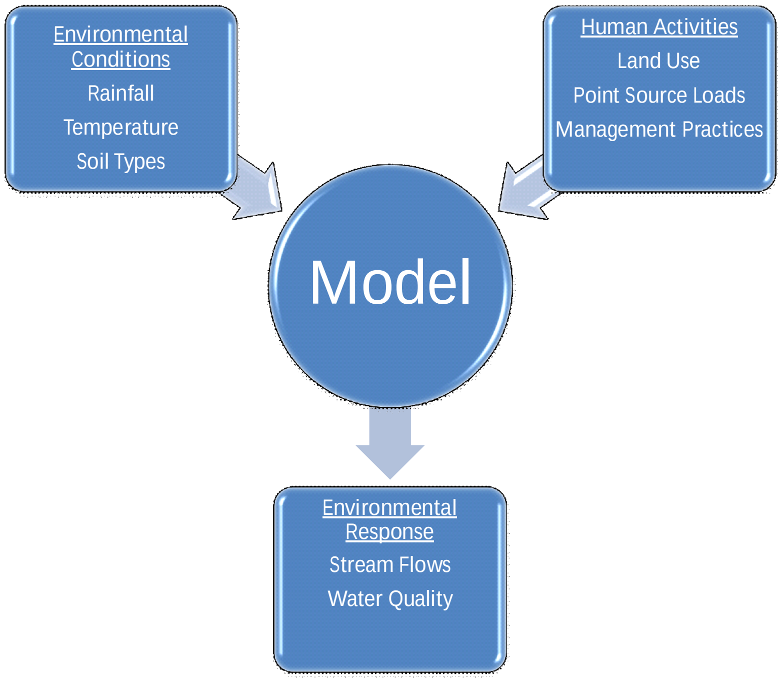


Figure 2.9-28 SIMPLE Depiction of a Water Quality Model

Mathematical models, such as water quality models, are commonly used to predict the consequences of future actions for complicated analyses when it is unfeasible to gain the necessary information via trial and error. In the context of the LTCP, water quality model answers will be used to define the water quality benefit to be obtained by various levels of CSO control, allowing MSD to define optimal controls prior to spending millions of dollars on implementation.

The water quality models developed for the Final LTCP describe water quality throughout MSD's service area. The Beargrass Creek WQT predicts water quality throughout all branches of Beargrass Creek, while the Ohio River Water Quality Model predicts water quality in the Ohio River. Both models predict how concentrations change over distance in a downstream direction, and the Ohio River Water Quality Model also considers lateral variation in water quality, i.e. the difference in concentration between the Kentucky shoreline, mid-channel areas, and the Indiana shoreline. Both models also consider how concentrations change over time, on an hour-by-hour basis over the course of a year.

2.9.5. BEARGRASS CREEK WATER QUALITY MODEL

The CWA has the goal of making our nation's waters suitable for the uses of drinking water, aquatic habitat, and recreation through the establishment of water quality standards. When a stream is polluted to the level that the water quality standards are not met, it is designated by the state or federal government as impaired. This triggers the next step in the CWA requirements - a study of the reasons for the impairment and a measurement of the amount of pollution that needs to be reduced, known as the Total Maximum Daily Load

(TMDL) study. Watershed managers need to know the sources and amounts of pollutants so that they can develop and implement plans to make the needed improvements.

Water quality in streams and rivers is a result of the interactions between the water flow, pollutants, living systems, weather, and chemical changes. Water resource engineers have developed computer programs that simplify these systems so that they can be better understood. These computer programs, or models, can also be modified to predict the effects of changes in pollution levels and other systems in "what if" scenarios.

2.9.5.1. BEARGRASS CREEK RECEIVING WATER MODELING OBJECTIVES

Beargrass Creek has a 61 square-mile watershed with a variety of land uses, ranging from farmland, suburban residential areas, historic parks, and urban areas. Discharges to the stream include stormwater runoff from the Municipal Separate Storm Sewer System (MS4), nonpoint source discharges, CSOs, and SSOs.

KDEP has determined that portions of Beargrass Creek do not support the Designated-Use Criteria for Primary Contact Recreation and Aquatic Life due to pathogens, organic enrichment/low dissolved oxygen, and habitat alteration. These segments are in the Middle Fork (25-mi^2 drainage area), Muddy Fork (9-mi^2 drainage area), and South Fork (27-mi^2 drainage area) sub-basins of Beargrass Creek. See Figure 2.9-29.

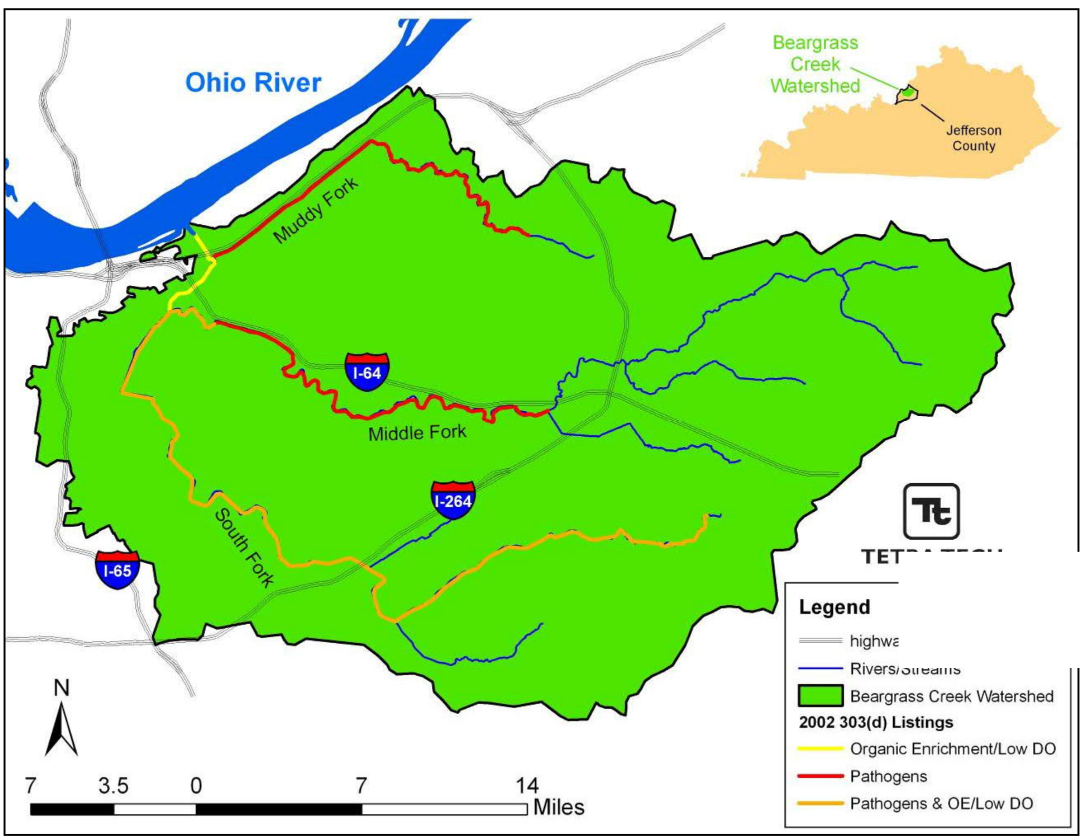


Figure 2.9-29 Segments of Beargrass Creek Listed as Impaired by Pathogens and/Ohio River Organic Enrichment/Low Dissolved Oxygen (2002)

The Beargrass Creek watershed is drained by an extensive system of natural stream segments, open concrete channels, storm sewers, sanitary sewers, and combined sewers. This watershed also has karst geology in some areas. The complex hydrology and combination of point and nonpoint sources pose significant technical obstacles for the prediction of water quality.

In the 1990s, MSD and the KDEP discussed the need for water quality improvements in Beargrass Creek, beginning with the preparation of TMDL studies to determine the pollutant loading reductions that would be needed to attain the stream's designated uses. MSD offered to partner with the KDEP to develop watershed and stream water quality models that would be used to develop the TMDLs. MSD wanted to use the models for use in planning sewer overflow controls and to ensure that the TMDLs include all sources of pollutant loading to the stream, not just CSOs.

The initial plan for a modeling system was to link two existing models: the watershed model Hydrologic Simulation Program – FORTRAN that had been developed by the USGS for part of the watershed, and the existing SWMM model used by MSD to simulate CSOs. These linked models would generate a continuous simulation of the runoff, sewer overflows, stream flows, and water quality to provide a more complete assessment of the water quality effects of overflows and runoff. The linked models were named the Beargrass Creek WQT.

Overflow Abatement Modeling Objectives

MSD's objectives for the modeling system were to quantify the effects of sewer overflows on water quality and to provide a tool that could be used to predict the future effects of various overflow abatement projects. The ability to predict water quality impacts of projects would allow MSD to prioritize efforts to get the best results.

When the WQT was being planned, MSD used the AAOV of each CSO as a measure of its relative importance and need for abatement, but recognized that this method may oversimplify the relationship and could cause inefficient use of capital funds by focusing on the larger, more expensive abatement projects. CSOs affect receiving stream water quality by the amount of overflow, but factors such as frequency, location, receiving stream flow rate and water quality should also be taken into account.

Overflow abatement costs are also not always directly associated with the AAOV. There are many types of abatement, each with its application and costs that vary widely depending on the specific location and amount of control desired.

Water Quality Modeling Objectives

Because the water quality impairments in Beargrass Creek include both pathogens and organic enrichment, the models had to have the ability to simulate the movement of pollutants in the stream and the dissolved oxygen concentrations that result directly from the pollutants and indirectly from algae in the stream.

Accurate prediction of fecal coliform concentrations must take into account the transport and mixing of the bacteria, including association with solids and storage in stream sediments. In addition, there is a loss of bacteria over time due to die-off, which varies with temperature and exposure to sunlight.

Dissolved oxygen in a stream is affected by many variables, including direct consumption of oxygen from bacteria that break down organic compounds, respiration of aquatic life (both plants and animals), increased oxygen from aeration, temperature effects, sunlight/shade, etc.

MSD recognized that the connection of a complex stream water quality system with a complex CSS would make for complex relationships between the two and that a computer modeling system would be needed to guide overflow abatement.

Environmental Data Variance

Environmental data variance is discussed extensively in Appendix 2.9.1. The fecal coliform and dissolved oxygen data sets, in particular, show a great deal of variability, which caused some areas within the water quality model calibration to fall short of the targets within the Quality Assurance Project Plan (QAPP). The best available data sets were used for calibrating the Beargrass Creek water quality model, although additional data is being continuously collected by MSD.

Appendix 2.9.1 Beargrass Creek Water Quality Tool Model Calibration and Validation Report
Appendix is the same as the 2012 IOAP Modification and is provided on external USB storage drive.

In order to address variability and QAPP calibration targets, a review of the QAPP targets may be needed as well as additional stream monitoring and sampling using more stringent data collection, equipment calibration, and data quality control procedures. These activities are being discussed for Beargrass Creek among the parties involved in the development of the draft Beargrass Creek TMDLs and associated water quality model.

However, for the purpose of assessing CSO impacts under existing system conditions and simulating anticipated conditions after implementing MSD's proposed Final Long Term Control Plan, the water quality model for the Beargrass Creek is sufficiently accurate and the best available assessment tool to support the analysis of water quality impacts for the CSO control Presumption Approach developed by MSD. The modeling approach undertaken for the system was supported by a relatively large amount of reliable environmental data and subjected to much third-party scrutiny and quality control, in comparison with typical efforts.

2.9.5.2. BEARGRASS CREEK WATER QUALITY MODEL SELECTION

As discussed above, the initial plan for the WQT was to use the Hydrologic Simulation Program – FORTRAN and SWMM models that were already available and in use separately, combining them to operate as a single system. Initially, the plan was to modify these models to run as an integrated system and then to calibrate and validate the resulting system's simulation results using monitoring data. This type of combination of Hydrologic Simulation Program – FORTRAN and SWMM was unprecedented. The models required substantial modification to merge them into an integrated system. For example, the Hydrologic Simulation Program – FORTRAN model had been developed for the Middle and South Forks of Beargrass Creek, but not the Muddy Fork. The SWMM model was set up to simulate specific rain events, rather than continuous simulation. Both models had specific data file requirements for input and output that were not directly compatible, requiring development of data transfer programs that could manage large and complex files.

As the WQT was developed and calibration was planned, the models were re-evaluated several times. The following models were considered as replacement models for all or part of the receiving stream simulation originally performed with Hydrologic Simulation Program – FORTRAN:

- CE-QUAL-W2 (version 3.1)
- CE-QUAL-RIV1 (version EPD-RIV1)
- CE-QUAL-ICM

- EFDC-WASP (WASP6)
- BRANCH-BLTM

MSD and its consultants also considered replacing some Hydrologic Simulation Program – FORTRAN functions with the SWMM model and other hydraulic models.

2.9.5.3. BEARGRASS CREEK WATER QUALITY MODEL DESCRIPTION

Although other models were considered, the Hydrologic Simulation Program – FORTRAN and SWMM models have remained a part of the WQT. Some additional models were added, however, to address specific needs. The following overview describes the functions of the WQT.

- **Hydrologic Simulation Program** – FORTRAN **-** the watershed model that uses actual precipitation data from a specific time period, land use, and topography data to generate runoff and subsurface water flow that is routed to Beargrass Creek directly or indirectly through the storm sewer system, the CSS, or tributaries and ditches.
- **XP-SWMM** - the combined sewer model that receives runoff flow from the watershed model (see Figure 2.9-30), combines the stormwater flow with sanitary sewer flow that varies in amount throughout the day, and produces a CSO output.
- **Simulated SSO flow** from a separate simulation program that relates SSO volume to precipitation based on hydraulic model results.
- **Hydrologic Simulation Program** – FORTRAN, RIV1H, and WASP – the receiving stream models that simulate the flow rate and water quality of Beargrass Creek as a series of stream segments or reaches, getting inputs of flows and pollutants on a continuous basis from the above models; RIV1H and WASP are used in the lower Beargrass Creek area where more complex stream hydraulic conditions required the use of these models for both hydrology and water quality.

Data transfer programs known as bridge routines are needed to convert the large amounts of flow and water quality data at each location and time interval from one model's data format to another.

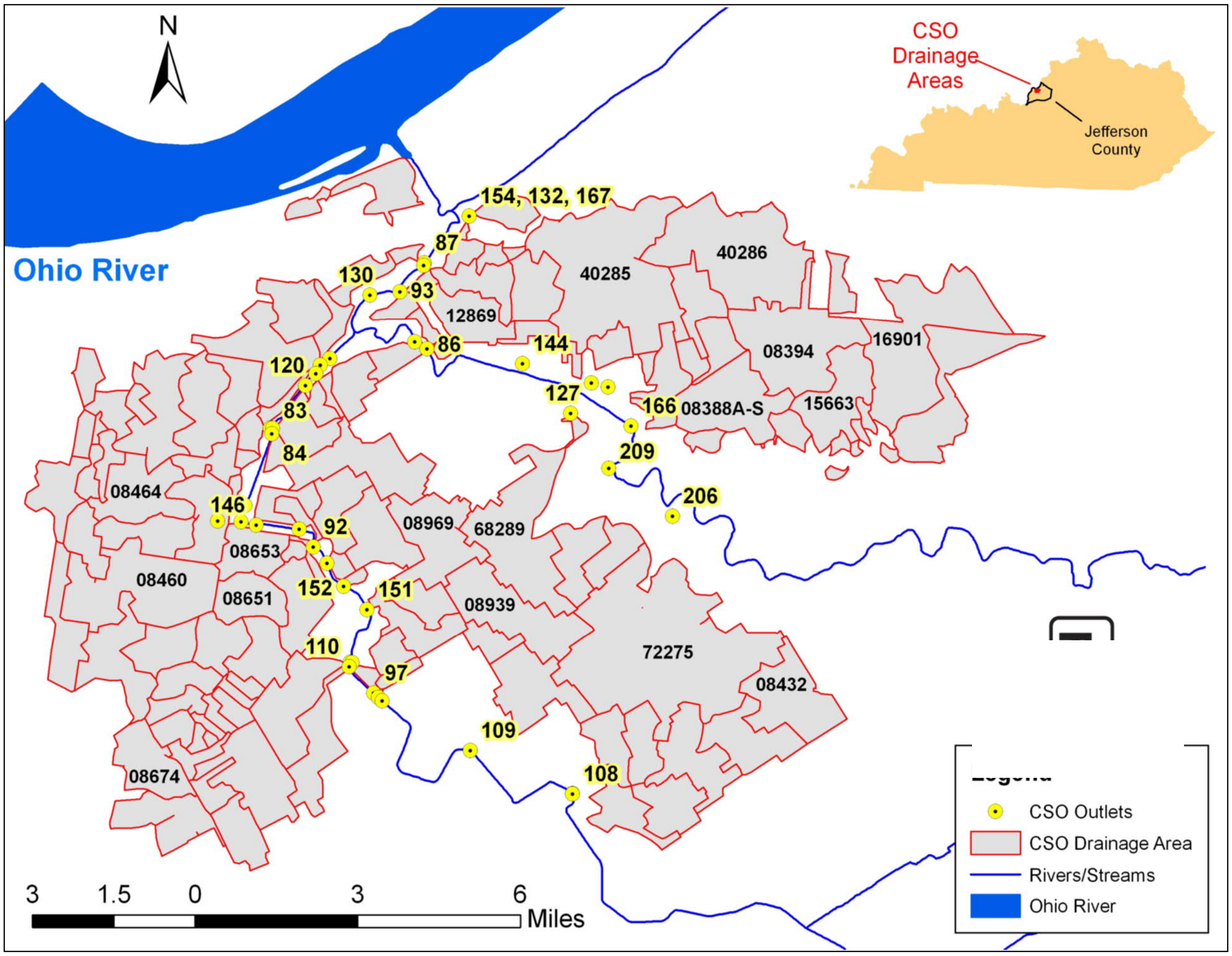


Figure 2.9-30 CSO Drainage Areas

The original models needed additional modifications to meet the project objectives. The Hydrologic Simulation Program – FORTRAN model's receiving water simulation was refined to smaller stream reaches, the CSO drainage areas were refined in the Hydrologic Simulation Program – FORTRAN watershed (Figure 2.9-30), precipitation information was processed to specific watershed areas, the SWMM model was converted from the EPA version to the XP Software version, and many other adjustments were made.

Figure 2.9-31 illustrates the inter-relationships between these models within the WQT.

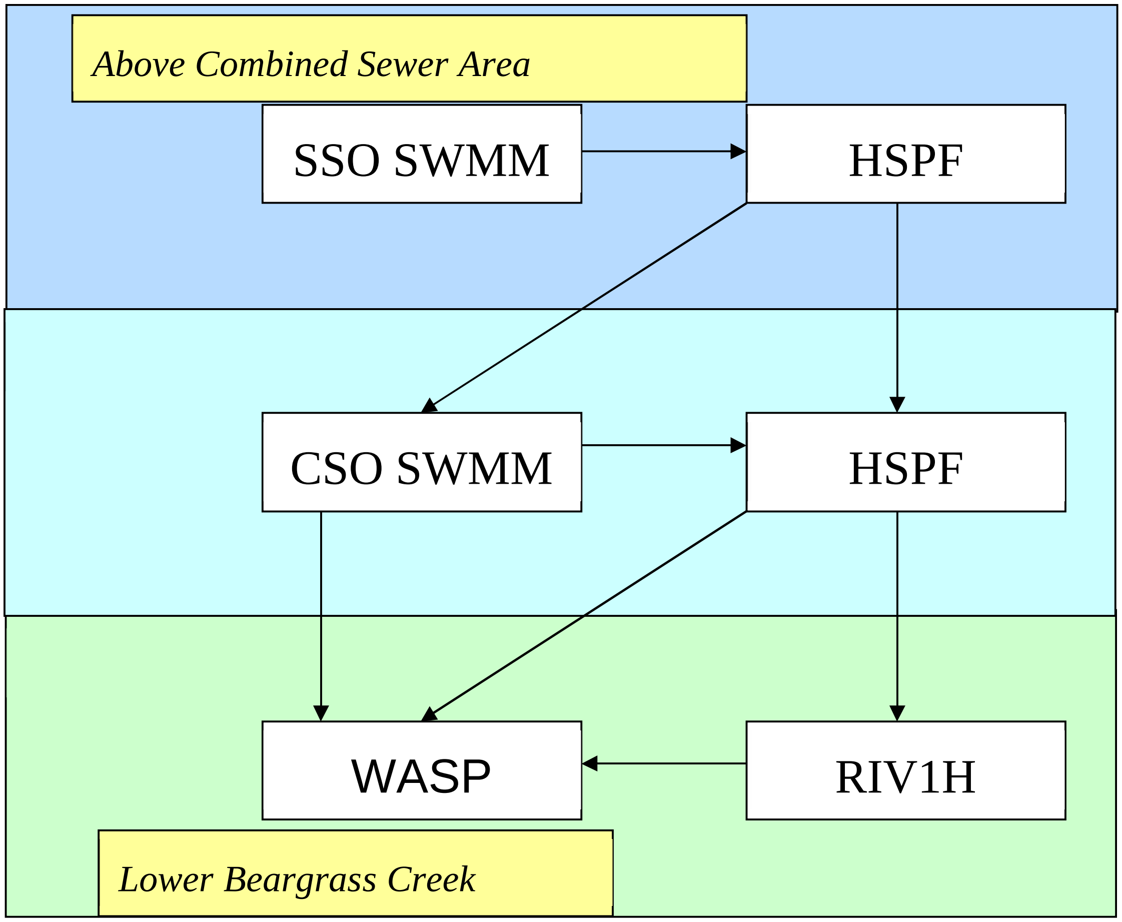


Figure 2.9-31 Relationships between the Models of the Beargrass Creek Water Quality Tool

2.9.5.4. BEARGRASS CREEK WATER QUALITY MODEL DEVELOPMENT

Model development and calibration were performed in accordance with a QAPP and regular consultation with Dr. Lindell Ormsbee of the Kentucky Water Resources Research Institute. Peer reviewers Tony Donigian and Wayne Huber evaluated the model development process and final system, providing valuable input that improved the end result. The WQT calibration and validation have been completed and documented in the Tetra Tech report to MSD “Beargrass Creek Water Quality Tool Model Calibration and Validation Report,” May 2008 (see Appendix 2.9.1).

The WQT performs a continuous simulation of rainfall, runoff, sewer overflows, stream flow, and water quality in surface water and groundwater over the five-year period from January 1, 2000, through December 31, 2004. The actual conditions for this period are the baseline condition against which TMDL allocations and overflow abatement scenarios are assessed. In some analyses, the year 2001 was used as a representative year for the comparisons.

2.9.5.5. OVERVIEW OF BEARGRASS CREEK WATER QUALITY MODEL RESULTS

In June 2008, the WQT was used to generate the pollutant load allocations used by Kentucky Water Resources Research Institute to develop both fecal coliform and organic enrichment/low dissolved oxygen TMDLs for the KDEP. Currently, the WQT is being used to quantify pollutant loads and their effects on

Beargrass Creek water quality for various scenarios considered for overflow abatement planning. The following summarizes the results of these efforts.

2.9.5.5.1. TMDLS

The TMDL reports have been completed by Kentucky Water Resources Research Institute and submitted to the KDEP for review. The fecal coliform TMDL was presented for public comment on September 11, 2008. The TMDLs were developed on a sub-basin basis, with each of the major basins (Muddy, Middle, and South) subdivided into three or four sub watersheds. Loads were allocated on an annual basis and then expressed in terms of a daily load. The TMDL is the maximum load that, with a margin of safety, could be applied to Beargrass Creek without causing water quality standards violations above a minimal level. Two scenarios were used to develop load allocations for the TMDL. Both scenarios included elimination of SSOs and modification of minor sources.

- Scenario I - CSO reduction (95 percent reduction in volume, 50 percent concentration reduction).
- Scenario II - Sewer separation (100 percent).

In the Organic Enrichment TMDL, the pollutant loading is expressed as biochemical oxygen demand. Sources are SSOs, CSOs, stormwater, and groundwater. Of these sources, the stormwater source is the largest (65 percent) and CSOs are the next-largest source (28 percent). The total biochemical oxygen demand waste load reductions in the TMDL range from 49 to 71 percent for Scenario I (CSO reduction through storage) and 49 to 65 percent for Scenario II (sewer separation).

The fecal coliform TMDL was prepared using similar methods in terms of the load allocation scenarios and sub-basins. Stormwater is the largest source of fecal coliform (61 percent) and CSOs are the next-largest source (38 percent). The total fecal coliform waste load reductions in the TMDL range from 95 to 96 percent for both scenarios.

2.9.5.5.2. OVERFLOW ABATEMENT SCENARIOS

Various scenarios have been evaluated with the WQT to predict the water quality effects of planned abatement approaches. Results are evaluated in terms of attainment of the fecal coliform water quality standard. (See Figure 2.9-32 and Figure 2.9-33) There are also different levels for these criteria in the summer or recreational season and the winter season. Scenarios are compared to the baseline or actual condition for the five-year period 2000 - 2004 or for the representative year 2001.

Scenarios are developed by MSD and its overflow abatement consultants as the planning work proceeds. Several scenarios have been completed and more are expected to be performed in the future. The following summarizes the findings to date.

No CSOs/SSOs

The WQT simulated the effects of eliminating SSOs and CSOs completely. The results were used in development of the TMDLs. This scenario reduced, but did not eliminate, violations of the primary recreation and aquatic life water quality standards (fecal coliform and dissolved oxygen criteria, respectively).

CSO-Only

The WQT was set up to make CSOs the only source of fecal coliform bacteria, eliminating the pathogens from all other sources. This scenario is designed to distinguish the effect that CSOs have on water quality alone. The predicted water quality standard compliance for this case was much higher than baseline confirms with background loads, virtually eliminating excursions in the upper reaches of all three forks. However, there remained violations of the geomean standard at the mouths of South (41 percent of the year), Middle (<one percent), and Muddy Forks (four percent). At the confluence with the Ohio River, the predicted nonattainment rates were 48 and 17 percent for the geomean and maximum standards, respectively. The simulation also predicted that the maximum standard would be exceeded four to seven percent of the time from the mouth of South Fork to the Beargrass Creek Flood Pumping Station.

CSO-Only with Reductions

An additional set of simulations was added to the above scenario that reduced the fecal coliform concentrations in the CSOs by 50 and 90 percent. All other parameters remained the same. The reductions further reduced but did not eliminated violations. For example, at the Beargrass Creek Flood Pump Station the scenarios predicted geomean water quality standard violations would drop from 72 percent for the baseline to 41 percent for CSOs-only to about 11 percent for the 90 percent reduction case. The effects of the CSO-only simulations were greater on the 30-day geometric mean standard attainment, especially the winter standard.

Simulated zero, two, four, and eight overflows per year scenarios were evaluated in August 2008. This analysis varied from previous WQT simulations in that the CSS hydraulic model had changed from XP-SWMM to the new InfoWorks model. These simulations showed that reductions in CSOs did have an effect, but the differences between the levels of control were small. The results are shown on Figure 2.9-32 and Figure 2.9-33. Figure 2.9-32 incorporates the 20 percent allowance for exceedance of the 400 CFU/100 ml value.

After the IOAP projects were defined, the WQT was used to predict the water quality effects of the planned controls on SSO and CSO discharges to Beargrass Creek. These simulations, discussed in detail in Chapter 4, Section 4.4.2, predict that, when these levels of control were combined with the CSO-Only assumption, both geometric mean and instantaneous maximum water quality standards would be met in the stream for the entire Typical Year.

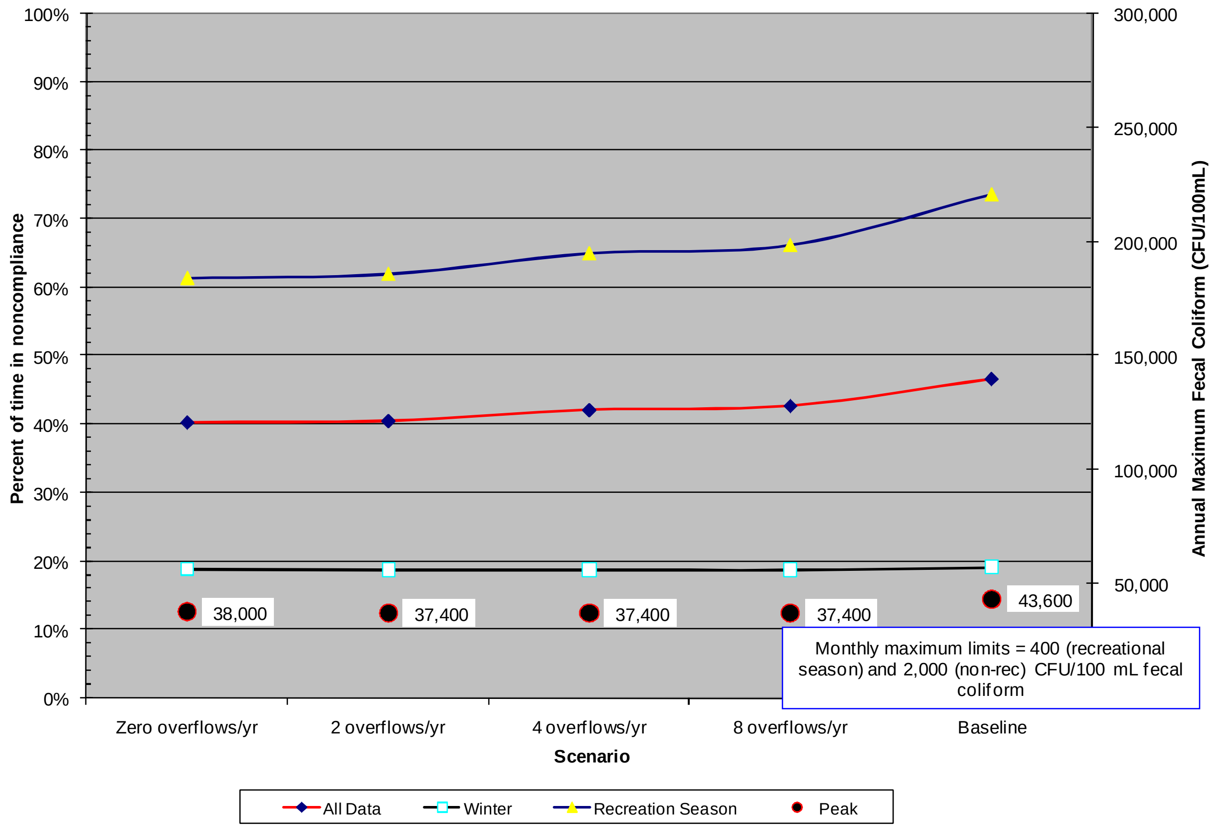


Figure 2.9-32 Recreational Water Quality Standard Analysis (Maximum Criteria) for Various Overflow Scenarios as Compared to Current Conditions (Baseline) at the Mouth Of Beargrass Creek at the Ohio River

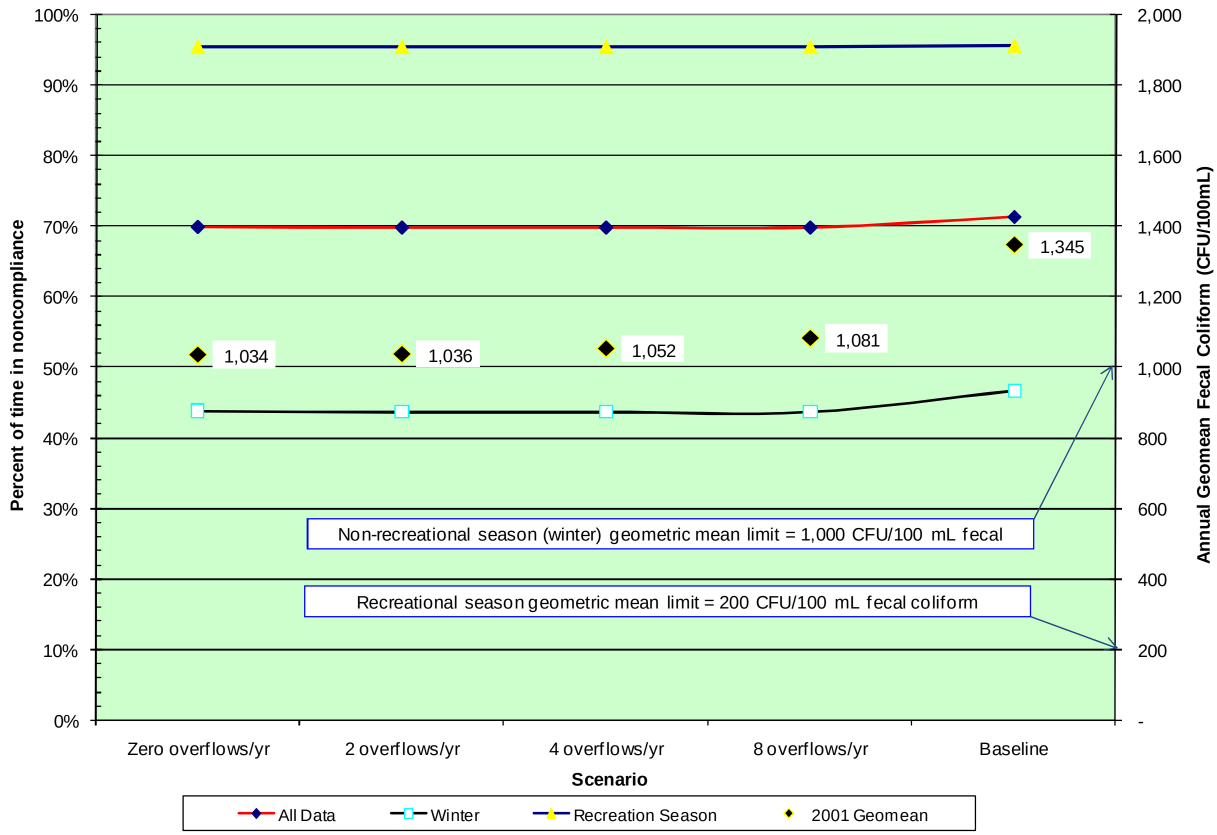


Figure 2.9-33 Recreational Water Quality Standard Analysis (Geomean Criteria) for Various Overflow Scenarios as Compared to Current Conditions (Baseline) at the Mouth of Beargrass Creek at the Ohio River

2.9.6. OHIO RIVER WATER QUALITY MODEL

The Ohio River water quality model was initially developed in 2005 as part of a demonstration project along the Ohio River conducted by the Ohio River by ORSANCO. This section provides an overview of the development and application of the Ohio River water quality model applied for development of the Final LTCP.

2.9.6.1. OHIO RIVER WATER QUALITY MODELING OBJECTIVES

The specific objective of the water quality models developed for the LTCP is to predict the water quality expected to result from the various CSO control alternatives that are being considered. Water quality predictions will be characterized in several ways, including:

- Percent of time in compliance with the geometric mean water quality standard for fecal coliform bacteria.
- Percent of time in compliance with the single sample maximum water quality standard for fecal coliform bacteria; and
- Maximum fecal coliform concentration.

Results will be provided for multiple locations throughout Beargrass Creek and the Ohio River, as well as for both the recreational season and the non-recreational season. These results will be used to support a cost-benefit analysis that defines the relationship between the cost of the pollution control alternatives and the resulting water quality benefit. This information will allow MSD (and its stakeholders) and the regulatory agencies to select a LTCP that best balances improvements in water quality with the cost of implementation.

2.9.6.2. OHIO RIVER WATER QUALITY MODEL SELECTION

The water quality model selected for the Ohio River portion of this study was originally developed as part of a wet weather demonstration project conducted on the Ohio River by ORSANCO (2005). This section presents the model selection process originally applied for the ORSANCO project and demonstrates the relevance of the water quality model selection to the current LTCP process. The factors considered in selecting a water quality model include the following categories:

- Management objectives
- Project constraints
- Site-specific characteristics

Specifics on how these factors are incorporated into the model selection process are detailed elsewhere (ORSANCO, 1999). However, primary emphasis in model selection was given to the study's modeling objectives, which included:

- Define the parameters that violate water quality standards during wet weather in the Ohio River under present conditions. Parameters considered include fecal coliform, E. Coli and, potentially, dissolved oxygen.
- Estimate the duration of criteria exceedance for all parameters.
- Provide a description of the spatial extent (that is, area) of exceedance.

These original ORSANCO objectives are consistent with the objectives of the water quality model for the LTCP process.

Based upon these objectives, project constraints, and site-specific characteristics of the Ohio River, the "Water Quality Analysis Simulation Program, Version 5 (WASP5) was selected to be used as the water quality model for the Ohio River. This model is supported by the EPA and has been widely used. It has the capability to simulate all of the parameters of concern in the study, to provide time-variable simulations capable of defining the duration of criteria exceedances, and to simulate lateral and longitudinal concentration gradients important in large rivers. The WASP5 model was successfully applied to the section of the Ohio River near Cincinnati in a similar wet weather demonstration study (ORSANCO, 2002, A Study of Impacts and Control of Wet Weather Sources of Pollution on Large Rivers).

Application of the WASP5 model to the Ohio River required interaction with other models. Because lateral variation in flow and quality are important in the Ohio River, the USACE hydrodynamic model, Resource Management Associates-2V, was applied by the USGS for the original ORSANCO study to describe the routing of the water flowing through the river. Resource Management Associates-2V simulates lateral and longitudinal variability in river hydraulics. CSO discharging directly to the Ohio River were defined using the CSS model developed by O'Brien and Gere. CSO and stormwater loads from Beargrass Creek were simulated with the Beargrass Creek Water Quality Tool. A flowchart depicting how the Ohio River Water Quality Model interacts with these other models is shown in Figure 2.9-34.

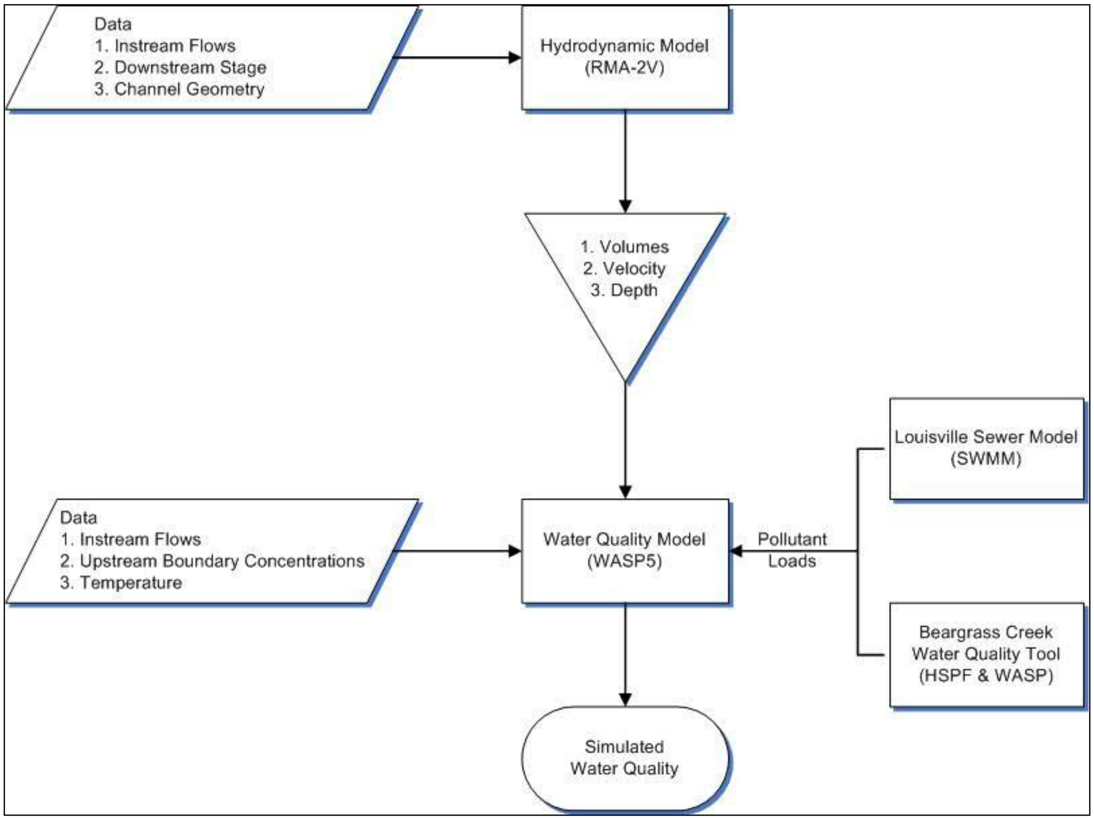


Figure 2.9-34 Ohio River Water Quality Modeling Flow Chart

2.9.6.3. OHIO RIVER WATER QUALITY MODEL DESCRIPTION

This section describes the basic formulations used in the WASP5 water quality model. WASP5 is a three-dimensional finite difference model that computes constituent concentration in a compartmentalized representation of the physical study area using the principle of conservation of mass. WASP5 can simulate the dynamic response of aquatic systems to pollutant loadings, including CSO discharges and tributary inflows.

The model balances water volume and constituent mass in each model segment over space and time using a governing equation that includes the following water quality processes: 1) transport processes, such as advection, diffusion, dispersion and boundary exchanges; 2) external loadings such CSO; and 3) transformation such as decay. A more rigorous description of the governing equation and water quality processes used in the model is available in the user's manual (Ambrose et al., 1993).

For this study, WASP5 was applied in a two-dimensional mode to address lateral and longitudinal variations in concentration. Model simulated concentrations represent a vertically averaged (or depth-averaged) concentration. EUTRO5 is a sub-component of the WASP5 model used to simulate conventional pollution such as dissolved oxygen, biochemical oxygen demand, nutrients and eutrophication, while TOXI5 is the sub-model used to simulate toxic pollution resulting from constituents such as metals, organic chemicals and bacteria.

In the ORSANCO (2002) study of the Ohio River near Cincinnati, the EUTRO5 model code was modified so that bacteria and dissolved oxygen constituents could be simulated simultaneously in a single model run. This version of the model was used for calibration and validation, although bacteria were the only constituent simulated in this study.

The WASP5 model was constructed in two sections to correspond to the Resource Management Associates-2V model formulations of the study area. The first section covered the portion of the study area upstream of McAlpine Locks and Dam, or approximately from river mile 590 to river mile 607. The second section of the model covered the portion of the study area downstream of McAlpine Locks and Dam, approximately from river mile 607 to river mile 635. These sections were later combined into a single model.

The water quality model covers (see Figure 2.9-35) the portion of the Ohio River from upstream of the Louisville Metro area (river mile 590) extending downstream to just below the confluence with the Salt River at river mile 635. McAlpine Locks and Dam are located in the center of the model domain at river mile 607. The hydrodynamic model domain was split into two sections with McAlpine Locks and Dam as the boundary between the sections. McAlpine Locks and Dam system includes upper and lower sets of tainter gates and a hydropower plant whose operations vary depending on flow through the system. The increased flow complexity around the McAlpine Locks and Dam necessitated the split in the hydrodynamic modeling. The water quality model was originally set up in the two sections that corresponded to the hydrodynamic model sections and was then combined into a single model prior to calibration and validation.

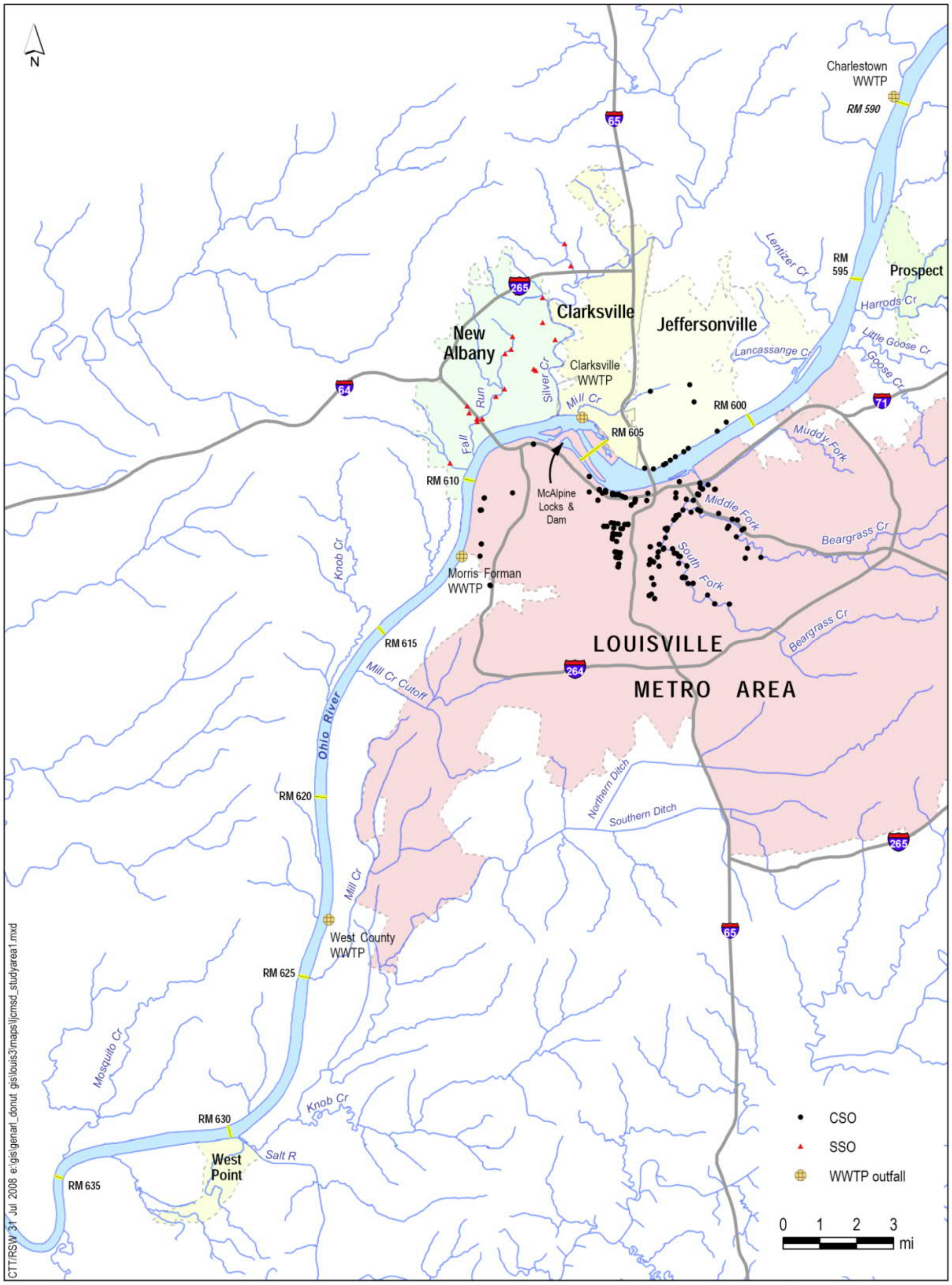


Figure 2.9-35 Ohio River Study Area

Model Segmentation

The water quality model is two-dimensional, describing concentration variations both laterally and longitudinally. Water quality model results are vertically averaged. The modeled area includes all of the CSOs from both Louisville MSD and Jeffersonville, Indiana discharging directly into the Ohio River as well as tributaries that receive CSO loads from these sewerage districts and SSO loads from New Albany, Indiana.

- Kentucky tributaries considered in the model consist of Harrod's Creek, Little Huckleberry Creek, Goose Creek, Beargrass Creek, Mill Creek Cutoff, and Mill Creek.
- Indiana tributaries considered in the model are 14-Mile Creek, Lancassange Creek, Lentizer Creek, Silver Creek, Fall Run, Vincennes Run, French Creek, and 4-Mile Creek. Discharges from WQTCs with outfalls to the Ohio River are also included in the model domain.

Consequently, the portion of the Ohio River simulated with the water quality model is the area where the biggest impacts from CSOs are expected and where near shore effects would be most pronounced.

The scale required by the Resource Management Associates-2V model for hydrodynamic stability was too refined to adapt directly for use in the water quality model. As a result, the WASP5 water quality model segmentation was defined as a "subset" of the hydrodynamic grid, where a WASP5 segment contained, on average, twenty-four hydrodynamic model elements. The model's spatial resolution was based upon the approach used in the Cincinnati project (ORSANCO 2002), where it was determined that the model would consist of five lateral segments, approximately divided as follows:

- Bankside channels (one on each shore) = ~10 percent of each cross-sectional area
- Intermediate channels (one on each side of the centerline) = ~20 percent of each cross-sectional area
- Center segment = ~40 percent of each cross-sectional area

The average segment lengths were defined by the length of the hydrodynamic elements and were approximately 0.30 miles in length. The model segmentation immediately upstream of McAlpine Locks and Dam was much larger than the rest of the model domain so that the flow through the Locks and Dam under varying conditions could be reasonably simulated using some simplifying assumptions. The area immediately downstream of the Locks and Dam does not maintain the five-segment lateral geometry because of the complexity in river bathymetry and flow patterns through the Locks and Dam area. The WASP5 segmentation is shown in Figure 2.9-36.

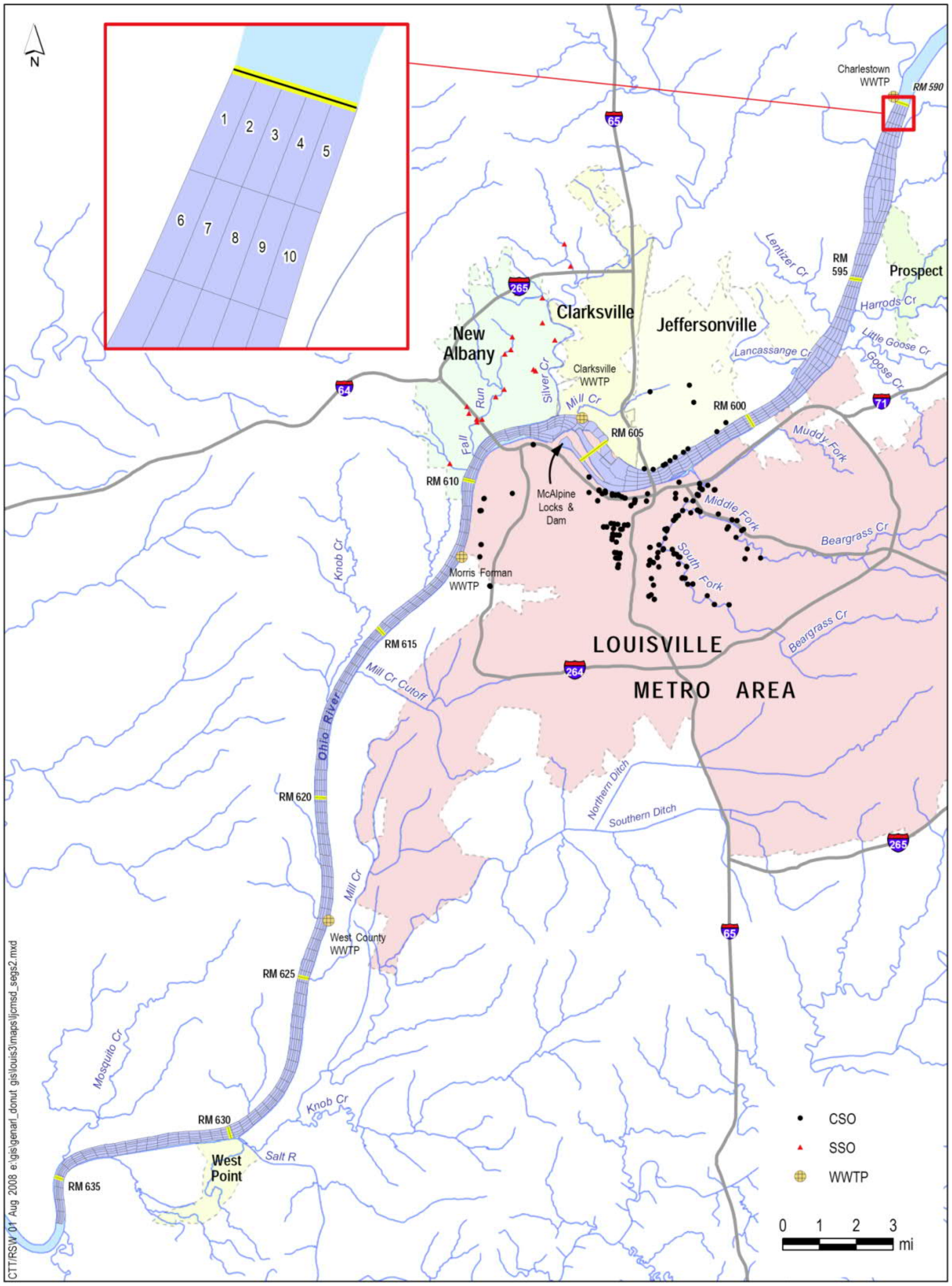


Figure 2.9-36 WASP5 Model Segmentation

The water quality model contains 738 segments in the Ohio River. Of these, 228 segments span the reach upstream of McAlpine Locks and Dam and 510 segments span the reach downstream of McAlpine Locks and Dam.

Linkage to Hydrodynamic Model

The hydrodynamic model results are used to drive the transport in the water quality model. However, direct use of the Resource Management Associates-2V model results in the WASP5 model is not possible for several reasons. First, the Resource Management Associates-2V model is spatially defined by a set of nodes whereas the WASP5 model is spatially defined by a series of segments. The Resource Management Associates-2V model produces a velocity field defined at the nodes, while WASP5 requires a set of balanced and routed steady state flows defined for segment interfaces. Thus, the Resource Management Associates-2V results have to be translated into WASP5 segment space. The second reason is that Resource Management Associates-2V conserves momentum but does not inherently conserve water mass, which is required by the WASP5 model under the steady state flow conditions for which the Resource Management Associates-2V simulations were conducted.

A computer program was created and used to convert finite element nodal information from the hydrodynamic model into water quality model segment volumes, dispersion areas and mixing lengths. A series of three programs were created to transform the Resource Management Associates-2V model results into inputs for the WASP5 model. These programs performed the following operations:

- Converted strings of Resource Management Associates-2V nodes into WASP5 segment interfaces.
- Smoothed (balanced) the inter-segment flows calculated by Resource Management Associates-2V for the WASP5 segment interfaces.
- Converted the individual smoothed segment flows into flow routings through the WASP5 model so that water volume was balanced in each water quality model segment.
- As expected for a large river system, the linkage between the Resource Management Associates-2V model and the WASP5 model routes the majority of the flow downstream from one segment to a segment immediately downstream of it rather than laterally to an adjacent segment.

Flow around McAlpine Locks and Dam

The hydrodynamic-water quality model linkage was complicated by the need to incorporate a representation of the McAlpine Locks and Dam and its operating rules into the routings. The area of the river immediately upstream and downstream of McAlpine Locks and Dam (approximately 1.5 miles in either direction) is complex and varies depending on the upstream flow and hydropower needs. Routings through the McAlpine Locks and Dam area were balanced by hand as described below.

McAlpine Locks and Dam consist of structures on the Ohio River extending from river mile 604.4 to river mile 607.4. There are three discharge points, which are illustrated in Figure 2.9-37:

- The lower gates consist of four gates and a number of hydropower units for producing electricity
- The upper gates consist of five gates
- The locks discharge a relatively small portion of the flow

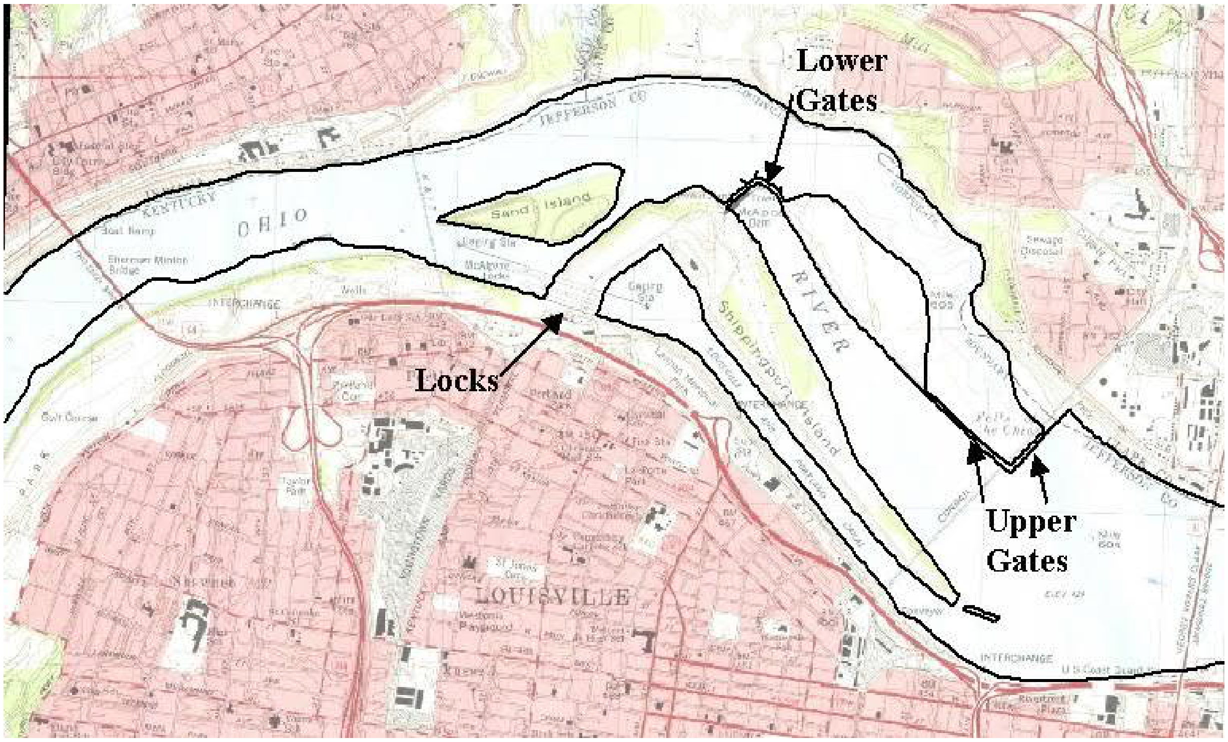


Figure 2.9-37 McAlpine Lock and Dam

Each hydropower unit discharges at a rate of several thousand cubic feet per second (cfs) when operating. The remaining flow, other than the Locks, is split between the lower gates and the upper gates depending on the ratio of feet of gate opening for each (that is, one gate open one foot gives one foot of gate opening). Configurations vary based on the time of year, number of hydropower units in operation, etc. Thus, it may not be possible to predict the specific operation of the dam at a given time. However, Table 2.9-17 presents information prepared by the USGS showing typical modes of operating procedure.

Table 2.9-17 Operating Procedures Observed at McAlpine Dam

DISCHARGE, CFS	LOWER GATE OPENING, FT	UPPER GATE OPENING, FT	HYDRO UNITS IN OPERATION
200,000	32	65	5
100,000	4	39	6
43,000	7	1	7
36,000	9	0	5
23,000	11	0	1
23,000	2	0	4
16,000	1	0	3
6,500	1	0	1

cfs - cubic feet per second

A set of empirical equations was developed by regression analysis, based on the data in Table 2.9-17 Operating Procedures Observed at McAlpine Dam to predict a reasonably likely operating procedure for a given flow. Equation 1 ($r^2 = 0.999$) relates flow to hydropower units in operation and feet of gate opening. This equation predicts a discharge of 3,882 cfs from each operating hydropower unit (slightly less than the USGS estimate of 4,000 to 4,400 cfs per unit), a discharge of 1,835 cfs for each foot of total gate opening, plus a constant 951 cfs, which is assigned to the locks discharge.

$$Flow,(cfs) = [3{,}882 * (\# HydroUnits)] + [1{,}835 * (GateOpening,\ ft)] + 951 \qquad \text{(Eq'n 1)}$$

Equation 2 ($r^2 = 0.502$) relates the number of hydro units in operation (when the result is rounded to the nearest integer) to the flow.

$$\text{Units} = -10.61 + 1.407 \times (\ln(\text{Flow,cfs} - 951)) \qquad \text{(Eq'n 2)}$$

From equations 1 and 2, the flow through the locks, the hydro units, and the total gate flow is predicted. The remaining variable is the split in gate flow between the lower and upper gates. Equation 3 ($r^2 = 0.887$) relates the ratio of flow through the lower gates to total gate flow, to the total flow. As in Table 1, no flow is predicted through the upper gates if total flow is less than 36,000 cfs.

$$\frac{\text{Lower Gate}}{\text{Gate Total}} = 1.0 \quad if\ (\text{discharge} \leq 36{,}000\ \text{cfs}) \qquad \text{(Eq'n 3b)}$$

$$\frac{\text{Lower Gate}}{\text{Gate Total}} = \min\left(1.0,\ 0.1667 + \frac{1.083e9}{(\text{Flow, cfs - 951})^2}\right) \qquad \text{(Eq'n 3b)}$$

A spreadsheet was developed which uses the Resource Management Associates-2V to WASP5 flow routing just above the dam, the above equations, and simple hand-developed flow routing relationships to route flow through the dam and downstream to the start of the downstream Resource Management Associates section. The routings generally transport flow to the segment immediately downstream of the segment being routed.

An analysis of routings around the McAlpine Locks and Dam indicates that the fraction of flow through each model segment can be described using routings corresponding to three flow regimes. The low flow routings simulate conditions when the upper gates are closed and are based on the spreadsheet results for a flow of 22,900 cfs, which corresponds to the 25th percentile flow at the USGS Gauge (gauge number 03294500) below McAlpine Locks and Dam. The average flow routings simulate conditions between 36,000 cfs and 70,000 cfs when the upper gates are open but less so than the lower gate openings (see Table 2.9-17). The average flow routings for this flow regime were developed from the spreadsheet results for a flow of 42,150 cfs, the median summer flow based on records at the USGS gauge. High flow routings simulate conditions above 70,000 cfs when the flow is split largely between the hydropower units and the upper gates with only a small fraction of flow going through the lower gates. The high flow routings for this flow regime were developed from the spreadsheet results for a flow of 96,625 cfs, which corresponds to the 75th percentile flow at the USGS gauge below McAlpine Locks and Dam. The choice of representative routing used in the model is dependent on the upstream flow at the boundary of the model domain and can be changed daily.

2.9.6.4. OHIO RIVER WATER QUALITY MODEL CALIBRATION AND VALIDATION

Water quality model calibration consists of performing model simulations for some period of historical conditions for which observed water quality data are available. Model predictions are compared to the observed data to ensure that the model matches observed conditions and, as necessary, certain model parameters are adjusted to allow model predictions to best match observed data. The Ohio River water quality model calibration consisted of two parts, 1) calibration of lateral mixing coefficients to dye survey data, and 2) calibration to observed wet weather Ohio River bacteria concentrations.

ORSANCO conducted two dye surveys in the Ohio River during the Fall of 1999 and Spring of 2000 to determine the magnitude of this mixing under a range of flow conditions. The results from these surveys were used to calibrate dispersion coefficients in the WASP5 water quality model as described below.

The Ohio River Water Quality Model was calibrated to data collected by ORSANCO for four wet weather water quality surveys between 1998 and 2001. The model was originally calibrated for the ORSANCO study, and then improved upon for the LTCP. The landside loadings used in the original version of the Ohio River Water Quality Model were taken from an HSPF-based model named the Louisville/Southern Indiana Water Quality Model (ORSANCO, 24). The Louisville/Southern Indiana Water Quality Model did not explicitly model CSOs and used regression equations to predict CSO volume as a function of precipitation. Complete documentation of the ORSANCO study is contained in Appendix 2.9.2. Significant efforts have been made in improving the landside loading inputs to the Ohio River Water Quality Model as part of this LTCP effort. The Beargrass Creek Water Quality Tool (described earlier in this report) was used to calculate all landside loading to Beargrass Creek, as well as their transfer to the Ohio River. The InfoWorks CS (also described earlier in this report) model was used to calculate all direct CSO discharges to the Ohio River.

In the current recalibration phase, the improved landside loads have been applied to the existing model and the model has been rerun. In addition to comparing model output to observed data at specific points in time, specific calibration metrics were defined. Application of these metrics demonstrated that the quality of the current calibration is as better than the original calibration. Complete documentation of the Ohio River Water Quality model is contained in Appendix 2.9.3.

Appendix 2.9.2 Wet Weather Impact Study on the Ohio River (Louisville/Southern Indiana Area)

Appendix 2.9.3 Ohio River Water Quality Model Calibration Report

Appendices are the same as the 2012 IOAP Modification and are provided on external USB storage drive.

2.9.6.5. OVERVIEW OF OHIO RIVER WATER QUALITY MODEL RESULTS

The Ohio River water quality model was run to predict fecal coliform concentrations in the Ohio River for a series of alternative loading scenarios. Five scenarios were analyzed, corresponding to baseline, zero overflows per year, two overflows per year, four overflows per year, and eight overflows per year. The baseline simulation corresponds to no additional controls, while the remaining simulations reflect the control of CSOs to a given number per year. Simulations were conducted to represent year 2001 environmental conditions.

These simulations reflect loading reductions from Louisville Metro/Jefferson County CSOs that discharge directly to the Ohio River, as well as CSOs that indirectly reach the Ohio River via Beargrass Creek. O'Brien & Gere provided hydrographs for those CSOs discharging directly to the Ohio River for the baseline condition, as well as the two, four, and eight overflows per year conditions. fecal coliform load loading from these CSOs was simulated by applying an assumed Event Mean Concentration of 650,000 colony forming unit (cfu)/100 ml), based upon previous analysis done during the ORSANCO study. TetraTech provided results from their Beargrass Creek Water Quality Tool to represent the total Beargrass Creek load. These loads reflect both CSO and stormwater loading to Beargrass Creek. Upstream boundary concentrations were based on recently observed data and were set at a concentration of 73 cfu/100 ml when river flows were 200,000 cfs or less, and 655 cfu/100 ml when river flows were greater than 200,000 cfs. All other external loads to the Ohio River (i.e. other tributaries, Indiana CSO, and stormwater loads) were left unchanged from the scenario analysis conducted previously for the ORSANCO Ohio River water quality modeling work.

Figure 2.4-21, which summarized of CSO water quality data, demonstrated the high degree variability in observed fecal coliform concentrations throughout the collection system. Average CSO fecal coliform concentrations at individual CSOs are seen to range from less than 100,000 up to 1,000,000 cfu/100 ml. Given the wide range of the observed data between locations, and the fact that most of the data used to derive the 250,000 cfu/100 ml estimate were collected from the Beargrass Creek watershed, the decision was made to maintain the difference in assumed Event Mean Concentrations between CSOs discharging into Beargrass Creek and those discharging directly to the Ohio River. Insufficient data specific to Ohio River CSOs was available to justify changing the previously estimated values for these CSOs and potentially invalidate the calibration of the Ohio River water quality model.

Results were examined at five locations along the length of the Ohio River, in terms of peak concentration and compliance with existing water quality standards. The locations examined are:

- Upstream of the Louisville Metro area
- Immediately upstream of Beargrass Creek
- At the I-65 bridge
- Downtown Louisville Metro
- Below the Morris Forman WQTC
- At the confluence of the Salt River

Results are summarized in Table 2.9-18 in terms of percentage noncompliance with the single sample maximum water quality standard and the maximum concentration during the recreational season (cfu/100 ml). Percent noncompliance with the geometric mean water quality standard was also evaluated and was 0 percent at all locations for all scenarios.

Table 2.9-18 Summary of Ohio River Model Results, 2007

	% NONCOMPLIANCE WITH MAXIMUM STANDARD DURING RECREATIONAL SEASON					MAXIMUM CONCENTRATION DURING RECREATIONAL SEASON (CFU/100 ML)				
	# OF OVERFLOWS/YEAR					# OF OVERFLOWS/YEAR				
LOCATION	BASE-LINE	8	4	2	0	BASE-LINE	8	4	2	0
Upstream	33	33	33	33	33	650	650	650	650	650
Above Beargrass Creek	33	33	33	33	33	9,900	9,900	9,900	9,900	9,900
I-65 Bridge	33	33	33	33	33	6,600	6,700	6,700	6,700	6,700
Downtown	100	33	33	33	33	6,900	5,300	5,300	5,300	5,300
Below Morris Forman WQTC	100	83	83	83	83	100,000	46,000	46,000	46,000	46,000
Confluence Salt River	67	67	67	67	67	56,000	56,000	56,000	56,000	56,000

These results demonstrate that an improvement in water quality is seen both in downtown Louisville Metro and below the Morris Forman WQTC when moving from baseline conditions to a CSO control scenario of eight overflows per year, both in terms of compliance with water quality standards and maximum concentration. Water quality benefits of CSO control are not observed in the Ohio River when reducing CSO overflows to less than eight per year, nor are the benefits observed in the areas upstream and far downstream of Louisville Metro. These results also indicate that elimination of CSOs will not result in compliance with water quality standards at any of the locations investigated, as background levels, non-point source, and stormwater sources are sufficient to cause water quality standards violations.

Table 2.4.5 Summary of CSO Data for Biochemical Oxygen Demand (BOD), Fecal Coliform and TSS

Site		BOD							Fecal							TSS						
Location	Description	No.	Min	Ave	Max	Stdev	Ave-1 Stdev	Ave+1 Stdev	No.	Min	Ave	Max	Stdev	Ave-1 Stdev	Ave+1 Stdev	No.	Min	Ave	Max	Stdev	Ave-1 Stdev	Ave+1 Stdev
C0000008	CSO 206	38	1	45	303	65	0	110	38	1	195060	3000000	568375	1	763435	39	1	162	1540	328	0	490
C0000009	CSO 209	17	1	23	88	28	0	51	30	1	19220	216000	45283	1	64503	17	0	91	713	173	0	264
C0000011	CSO 108 N Unit	6	8	10	11	1	9	11	6	11000	70000	98000	32150	37850	102150	6	32	49	58	10	39	58
C0000012	CSO 108 S Unit	6	9	11	17	3	8	14	6	3200	56333	93000	39784	16549	96117	6	55	66	83	10	56	77
C0000024	CSO 110	39	1	36	138	33	3	69	39	1	999820	34000000	5432671	1	6432491	40	1	129	567	125	4	254
C0000025	CSO 117	28	1	111	430	127	0	238	30	1	232297	2093000	505435	1	737732	28	1	246	1023	246	1	492
C0000026	CSO 125	15	7	193	1330	462	0	655	16	580	267524	1200000	465486	1	733010	15	28	125	538	140	0	265
C0000027	CSO 127	20	1	59	241	67	0	126	26	1	91631	1200000	246505	1	338136	19	1	214	780	219	0	433
C0000028	CSO 140	8	3	28	85	28	0	57	9	430	158067	1200000	391367	1	549433	9	1	118	312	136	0	254
C0000029	CSO 151	32	1	75	434	80	0	155	39	1	159507	1200000	305968	1	465475	33	1	207	797	202	5	408
C0000030	CSO 152	34	1	51	231	55	0	105	35	1	132094	1200000	273698	1	405792	34	0	137	402	120	18	257
C0000031	CSO 153	1	291	291	291				3	120000	120000	120000	0	120000	120000	1	623	623	623			
C0000042	CSO 016															8	1	325	552	210	115	535
C0000043	CSO 019															6	256	413	548	121	292	535
C0000044	CSO 050															11	49	97	176	45	53	142
C0000045	CSO 189															5	256	296	408	63	233	359
C0000046	CSO 190															2	136	164	192	40	124	204
C0000104	CSO 146	3	336	351	367	16	335	367								3	600	698	865	145	553	843
C0000017	CSO 210															11	1	347	660	227	120	573
C0000016	CSO 211															14	1	468	1260	200	168	768

Table 2.7.4 Overall Summary of the Recreational Use Survey Results

PARK ID	PARK NAME	WATERSHED	# OF SITE VISITS	TOTAL OBSERVED			AVG OBSERVED			NON-CONTACT ACTIVITIES			CONTACT ACTIVITIES			CONTACT	% CHILDREN	% POTENTIAL	% CONTACT
				TOTAL	ADULTS	CHILDREN	TOTAL	ADULTS	CHILDREN	TOTAL	ADULTS	CHILDREN	TOTAL	ADULTS	CHILDREN	OBSERVED		CONTACT	
1	Farnsley - Moremen Landing	Ohio River	104	962	880	82	10	9	1	939	857	82	23	23	0	1	8.52%	2.29%	0.10%
2	Riverview Park	Ohio River	104	2,631	2,411	220	27	24	3	1,630	1,435	195	1,001	976	25	74	8.36%	35.23%	2.81%
3	Waterfront Park	Ohio River	104	4,294	3,703	591	42	36	6	3,302	2,751	551	992	952	40	47	13.76%	22.01%	1.09%
4	Cox Park	Ohio River	104	4,890	4,677	213	48	45	3	2,434	2,240	194	2,456	2,437	19	71	4.36%	48.77%	1.45%
5	Louisville Soccer Park	Muddy Fork BGC	104	829	502	327	9	5	4	827	500	327	2	2	0	1	39.45%	0.12%	0.12%
6	Cherokee Golf Course - Lexington Rd	Middle Fork BGC	104	793	783	10	9	8	1	292	291	1	501	492	9	9	1.26%	62.04%	1.13%
7	Cherokee Park - Shelter	Middle Fork BGC	104	2,427	2,175	252	24	21	3	2,427	2,175	252	0	0	0	0	10.38%	0.00%	0.00%
8	Seneca Park - Scenic Loope	Middle Fork BGC	104	1,220	1,210	10	13	12	1	1,190	1,180	10	30	30	0	0	0.82%	2.46%	0.00%
9	Seneca Park - Big Rock	Middle Fork BGC	104	2,096	1,865	231	21	18	3	1,485	1,301	184	611	564	47	267	11.02%	16.41%	12.74%
10	Seneca Golf Course	Middle Fork BGC	104	1,799	1,792	7	19	18	1	1,785	1,778	7	14	14	0	1	0.39%	0.72%	0.06%
11	Brown Park	-	8	129	129	0	17	17	0	129	129	0	0	0	0	0	0.00%	0.00%	0.00%
12	Joe Creason Park	South Fork BGC	104	976	798	178	10	8	2	976	798	178	0	0	0	0	18.24%	0.00%	0.00%
13	Louisville Junior Academy	-	8	59	59	0	8	8	0	59	59	0	0	0	0	0	0.00%	0.00%	0.00%
14	Eva Bandman Park - Ohio River	Ohio River	94	2,348	2,281	67	26	25	1	2,135	2,068	67	213	213	0	3	2.85%	8.94%	0.13%
15	Eva Bandman Park - BGC	BGC Confluence	94	519	519	0	6	6	0	426	426	0	93	93	0	0	0.00%	17.92%	0.00%
16	Beargrass Creek at Irish Hill	Middle Fork BGC	32	202	190	12	7	6	1	202	190	12	0	0	0	0	5.94%	0.00%	0.00%
17	Butchertown Greenway	BGC Confluence	32	53	52	1	3	2	1	41	40	1	12	12	0	0	1.89%	22.64%	0.00%
		TOTAL =	**1,412**	**26,227**	**24,026**	**2,201**	**299**	**268**	**31**	**20,279**	**18,218**	**2,061**	**5,948**	**5,808**	**140**	**474**	**8.39%**	**20.87%**	**1.81%**

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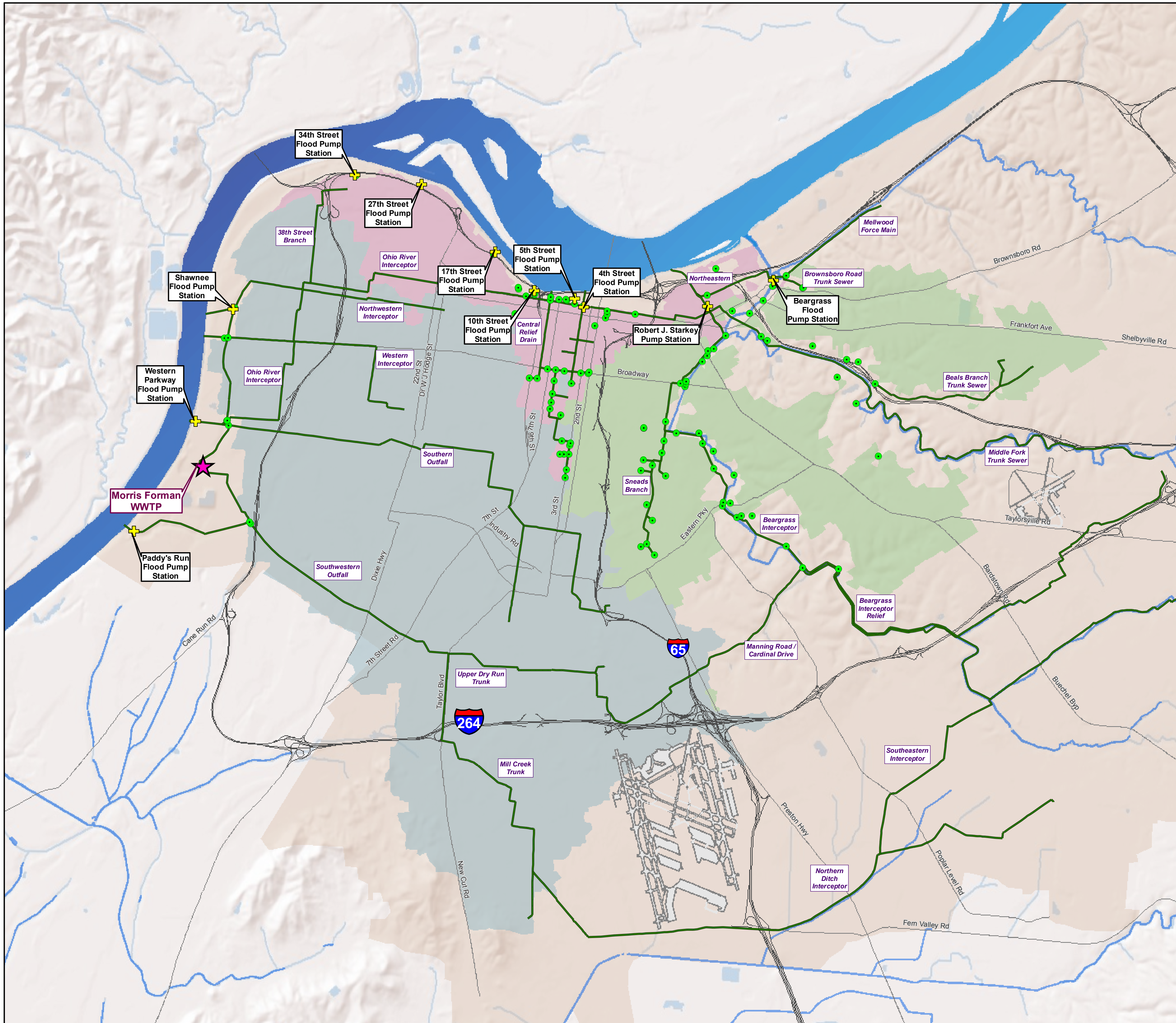
FIGURE 2.3.1
LOCATIONS OF EVALUATED FLOOD PUMP STATIONS



LEGEND

- Active CSO Location
- Flood Pump Station
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

O'Brien & Gere: I:\Lville-Jeff-Msd.10777\40109.Cso-Ltcp-Develo\LTCP PROJECT\GIS\MXDs\for LTCP Document\2.3.1 Locations of Evaluated Flood Pump Stations.mxd

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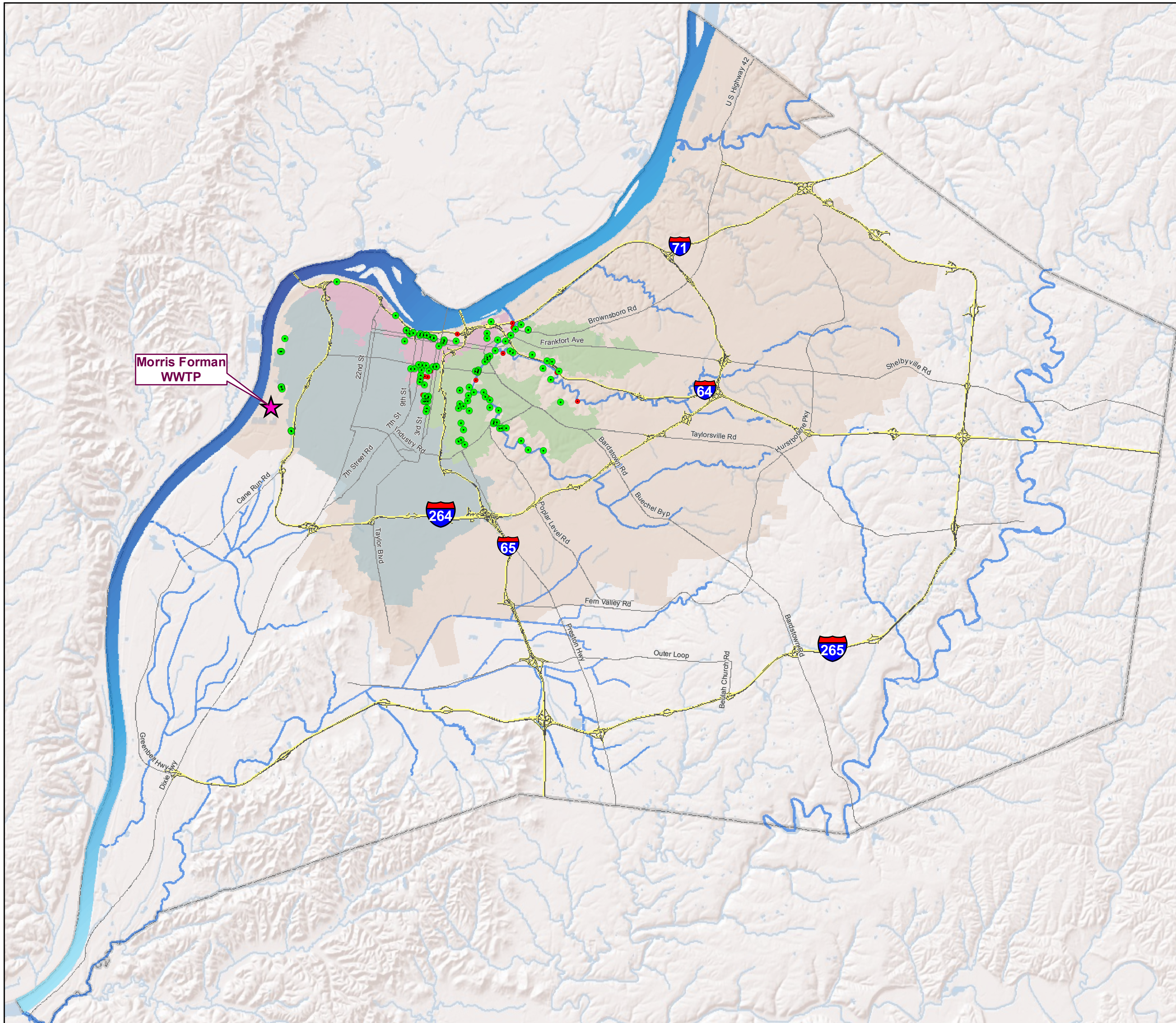
FIGURE 2.4.1
Morris Forman WWTP
SERVICE AREA



LEGEND

- Active CSO Location
- Eliminated CSO Location
- Wastewater Treatment Plant
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature
- County Boundary

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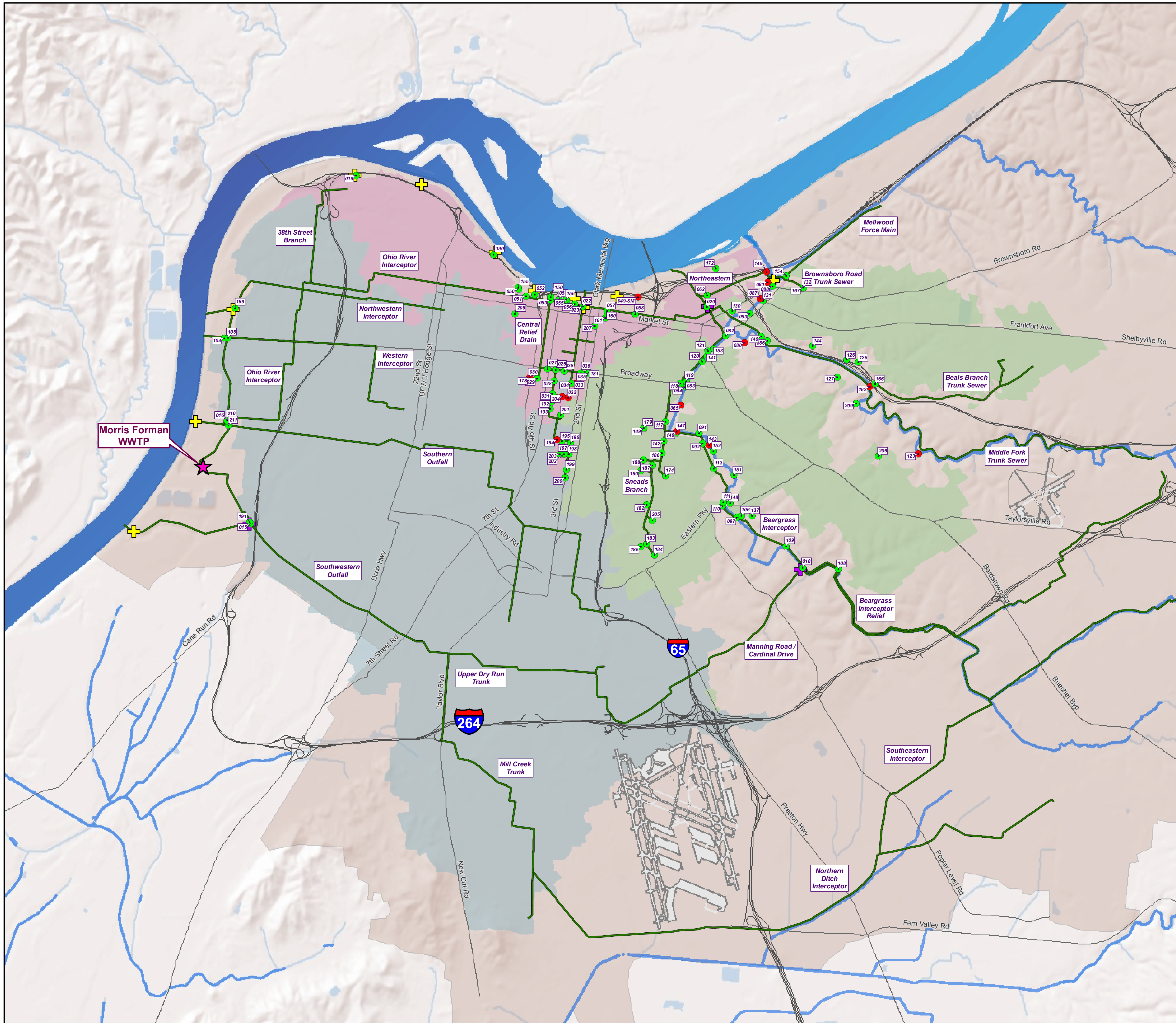
FIGURE 2.4.2
COMBINED SEWER SYSTEM REGION



LEGEND

- Active CSO Location
- Eliminated CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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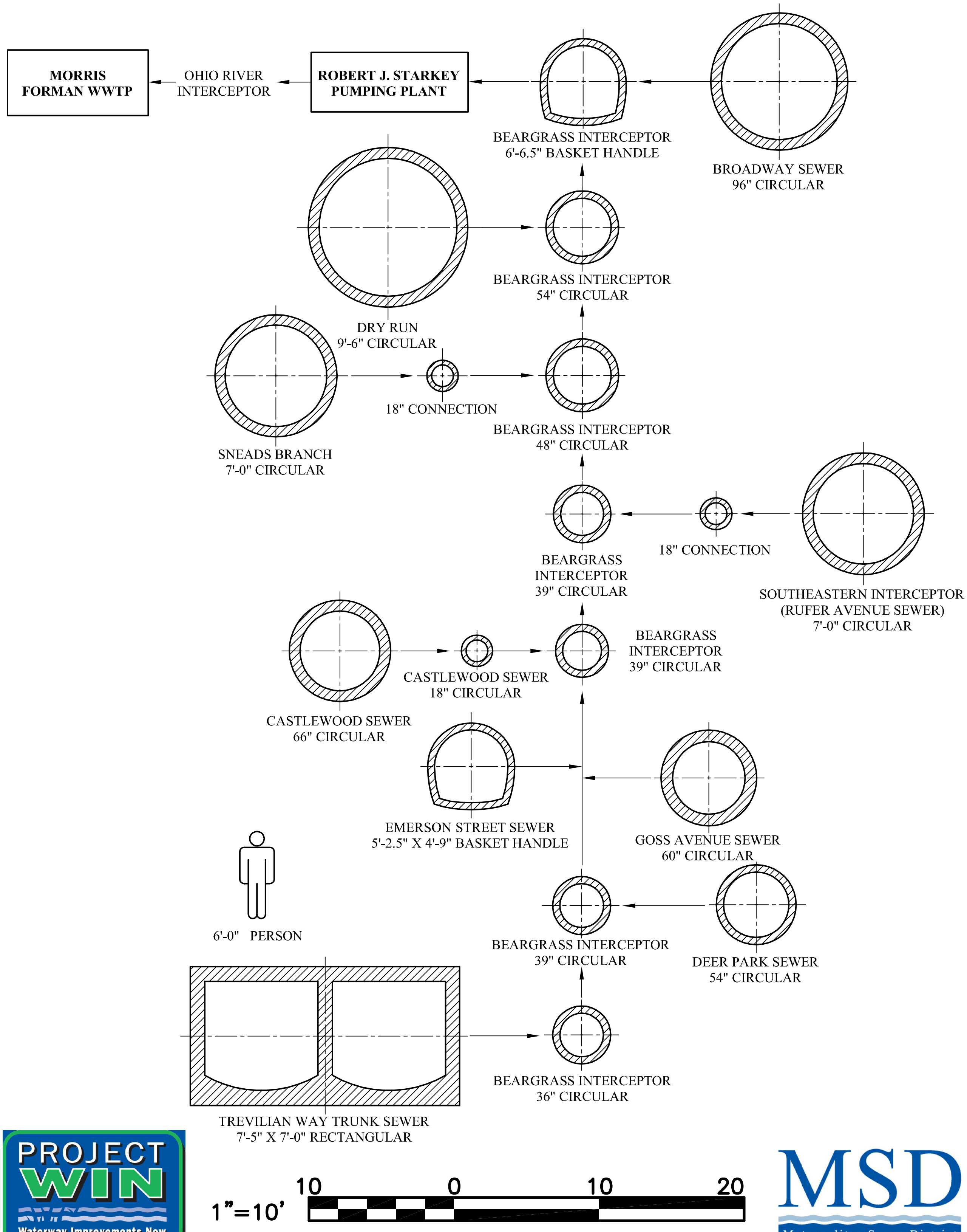
FIGURE 2.4.3
TYPICAL SYSTEM CONSTRICTIONS
BEARGRASS INTERCEPTOR
BEARGRASS CREEK REGION



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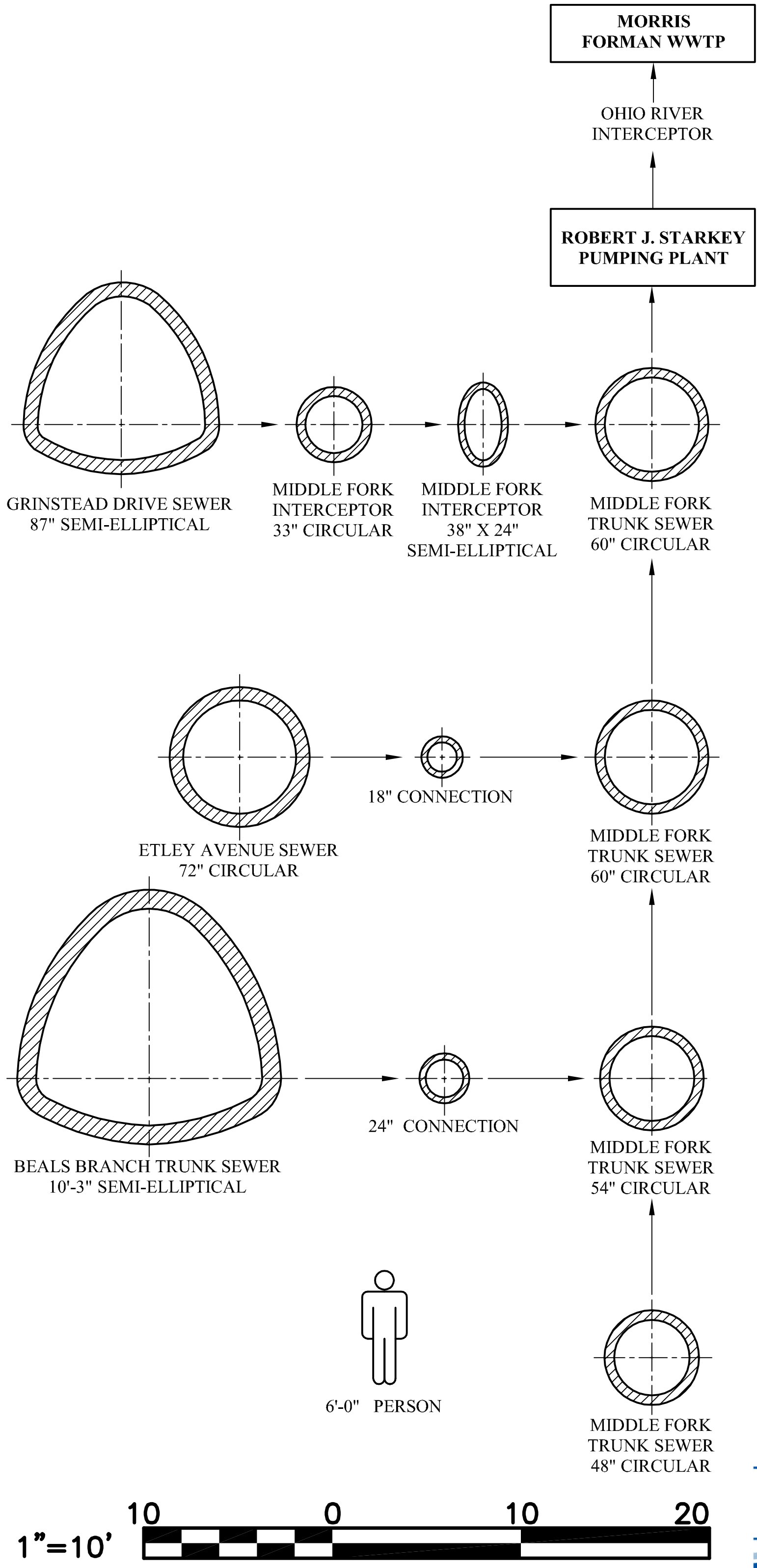
MSD Metropolitan Sewer District

FIGURE 2.4.4
TYPICAL SYSTEM CONSTRICTIONS
MIDDLE FORK TRUNK
BEARGRASS CREEK REGION



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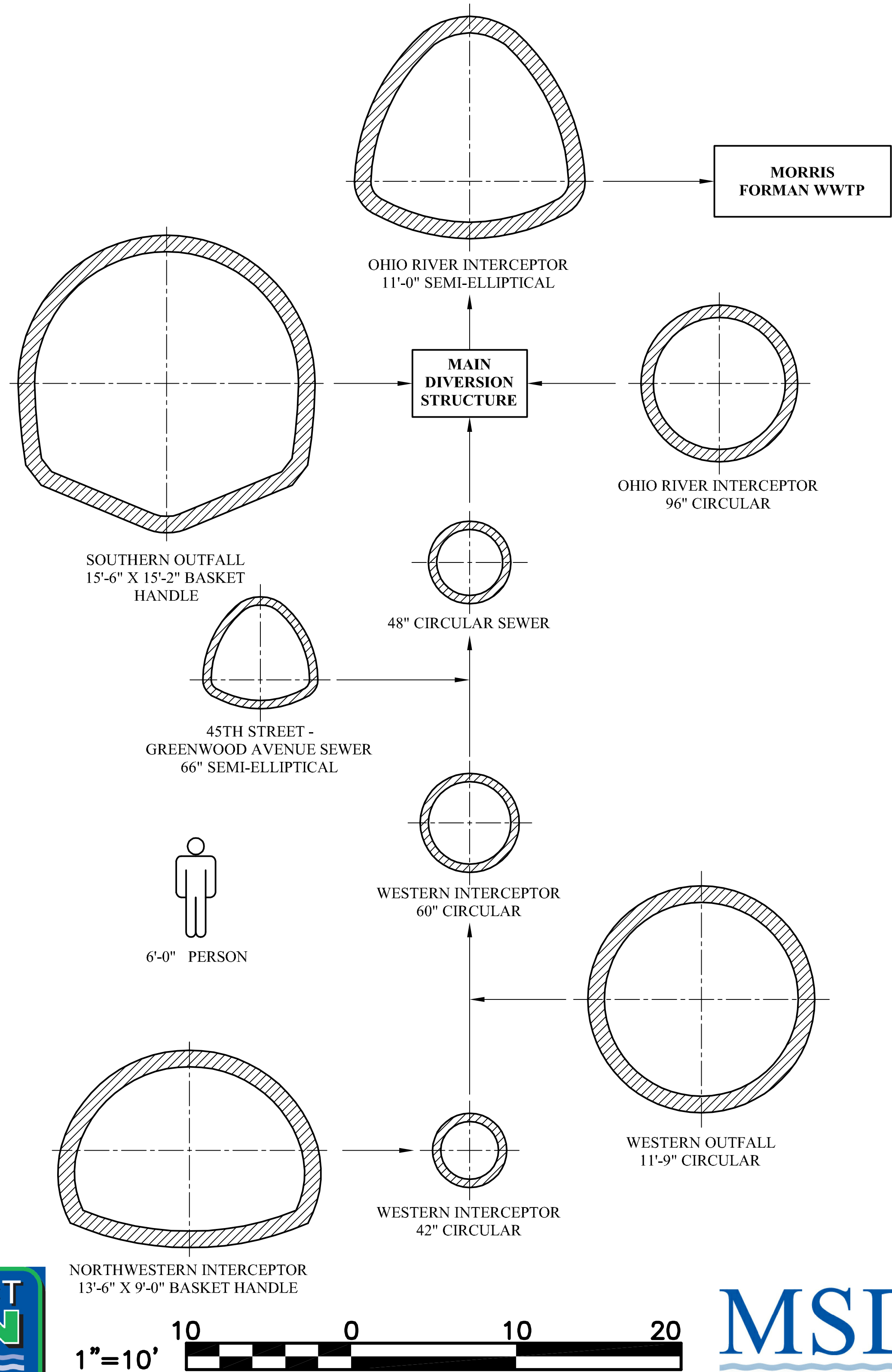
Metropolitan Sewer District

FIGURE 2.4.5
TYPICAL SYSTEM CONSTRICTIONS
NORTHWESTERN CITY
OHIO RIVER WEST REGION



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Metropolitan Sewer District

FIGURE 2.4.6
TYPICAL SYSTEM CONSTRICTIONS
SOUTHWESTERN OUTFALL
OHIO RIVER WEST REGION

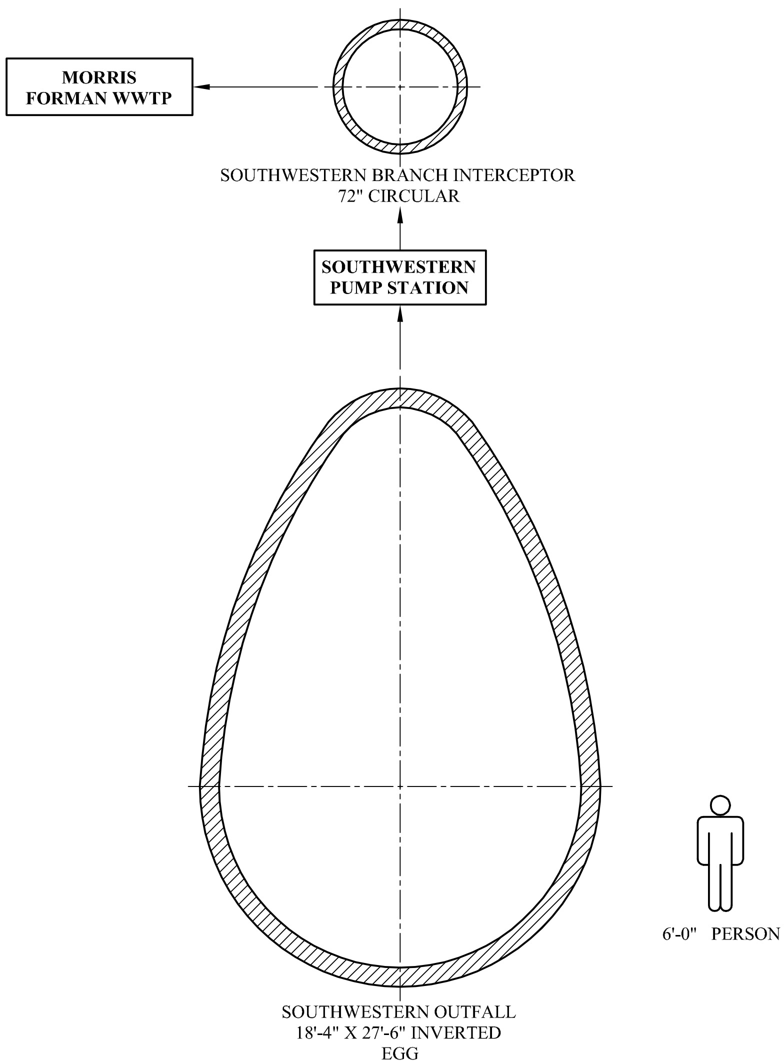

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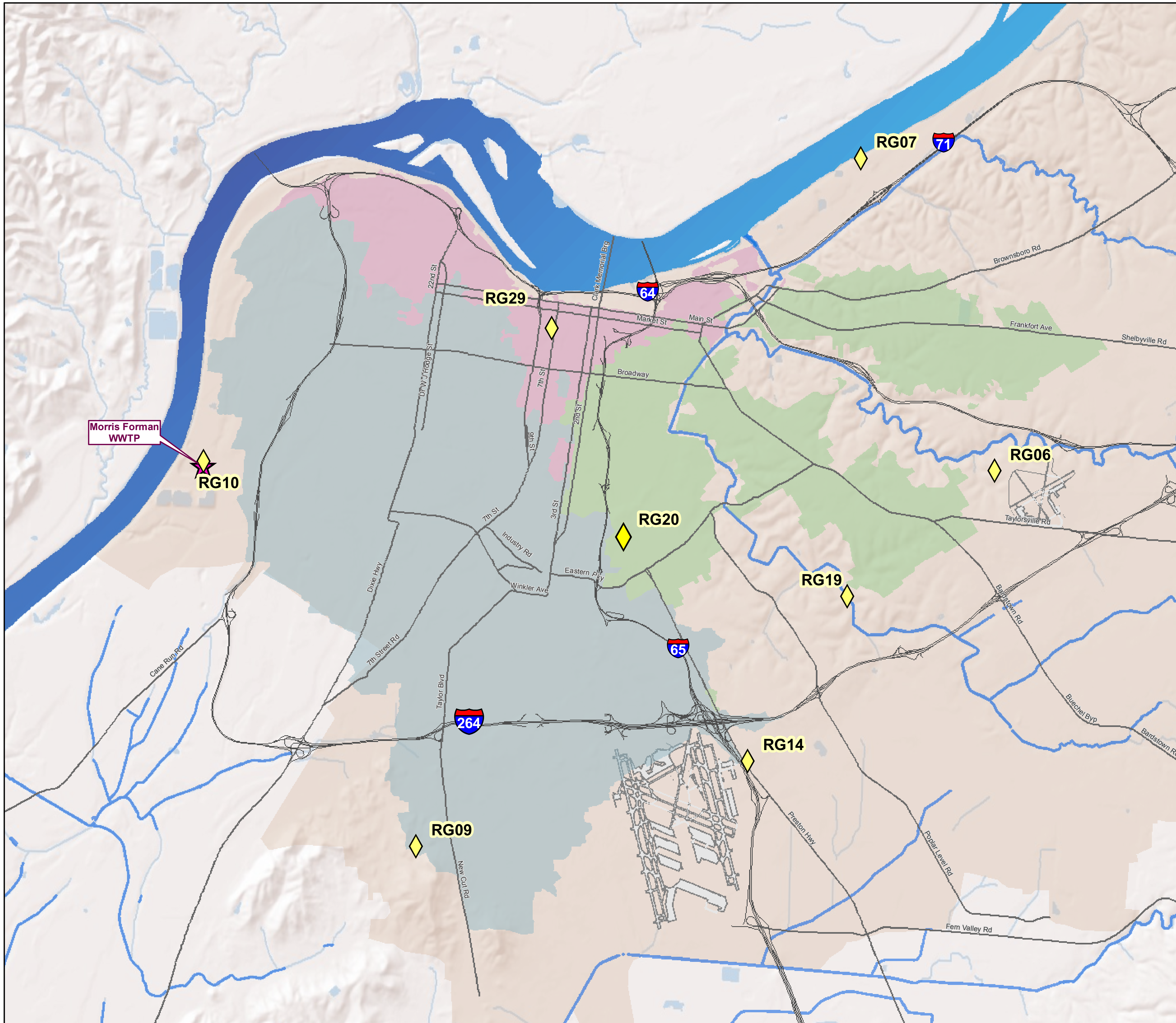
FIGURE 2.4.9
ORIGINAL RAIN GAUGE LOCATIONS



LEGEND

- Rain Gauge Location
- Wastewater Treatment Plant
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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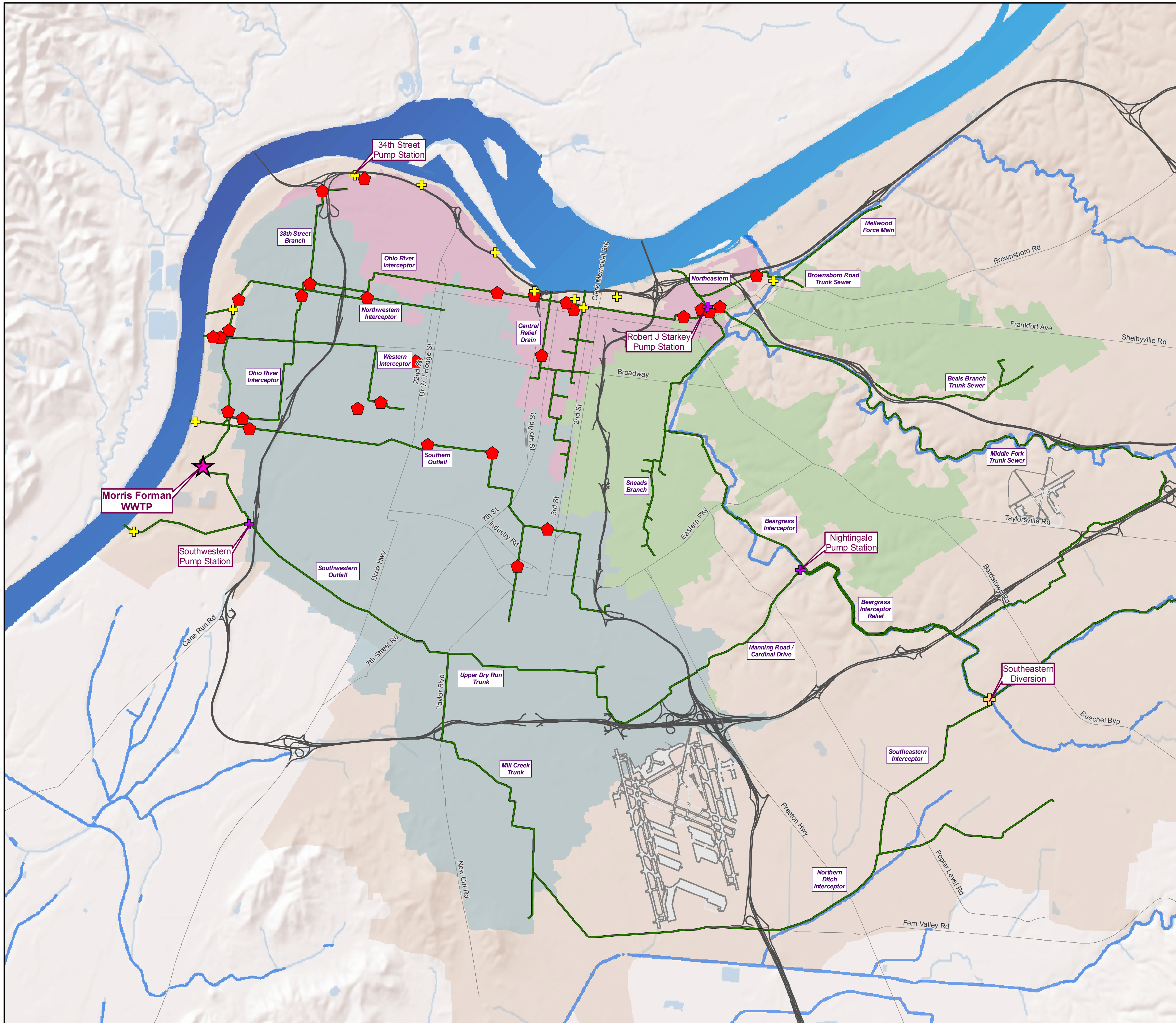
FIGURE 2.4.12
1992 PHASE I
FLOW MONITORING LOCATIONS

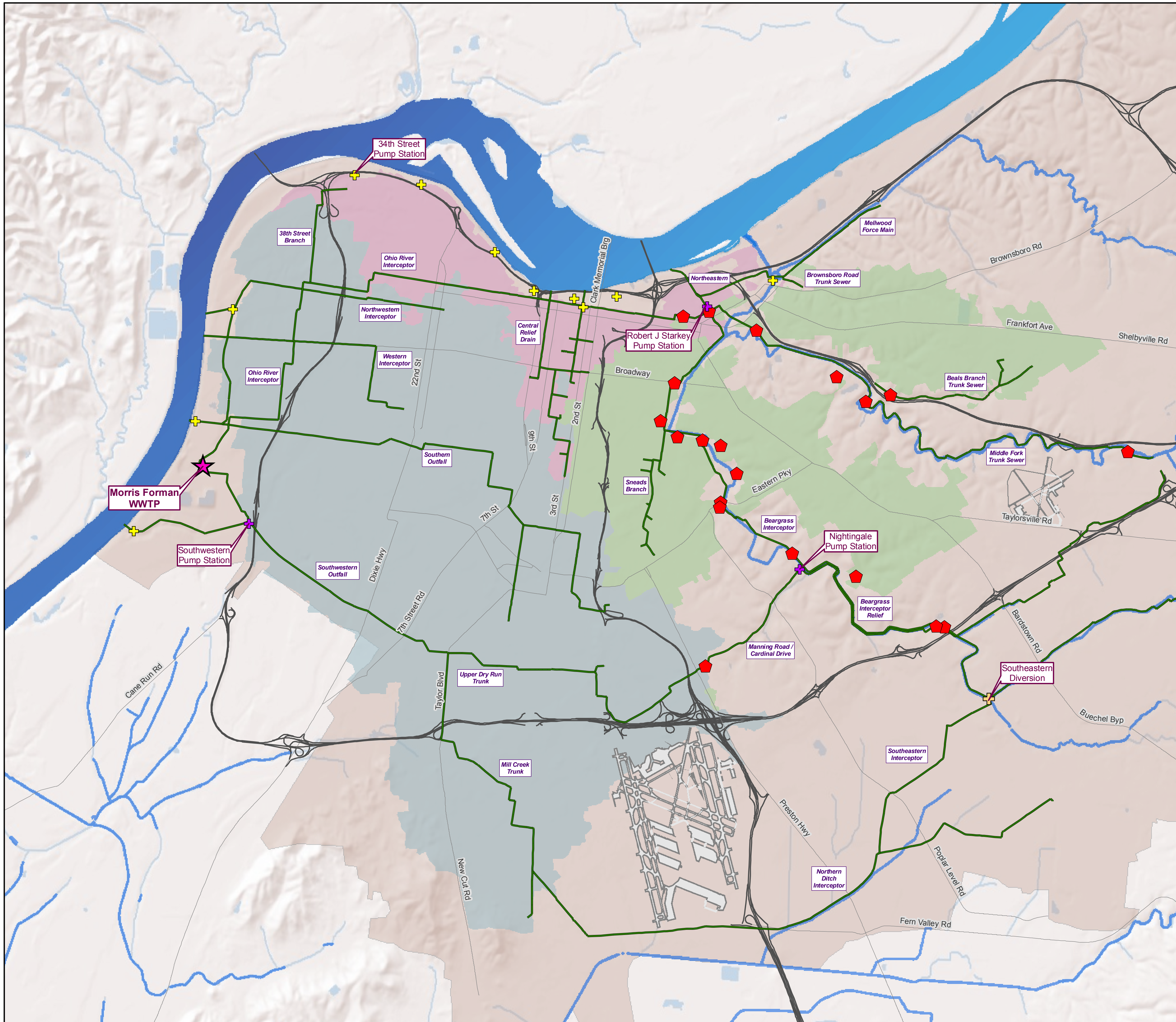


LEGEND

- 1992 Phase I Flow Monitoring Location
- Flood Pump Station
- Sanitary Pump Station
- Southeastern Diversion
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature



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Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.4.13
1992 PHASE II
FLOW MONITORING LOCATIONS

LEGEND

- Flood Pump Station
- Sanitary Pump Station
- Southeastern Diversion
- 1992 Phase II Flow Monitoring Location
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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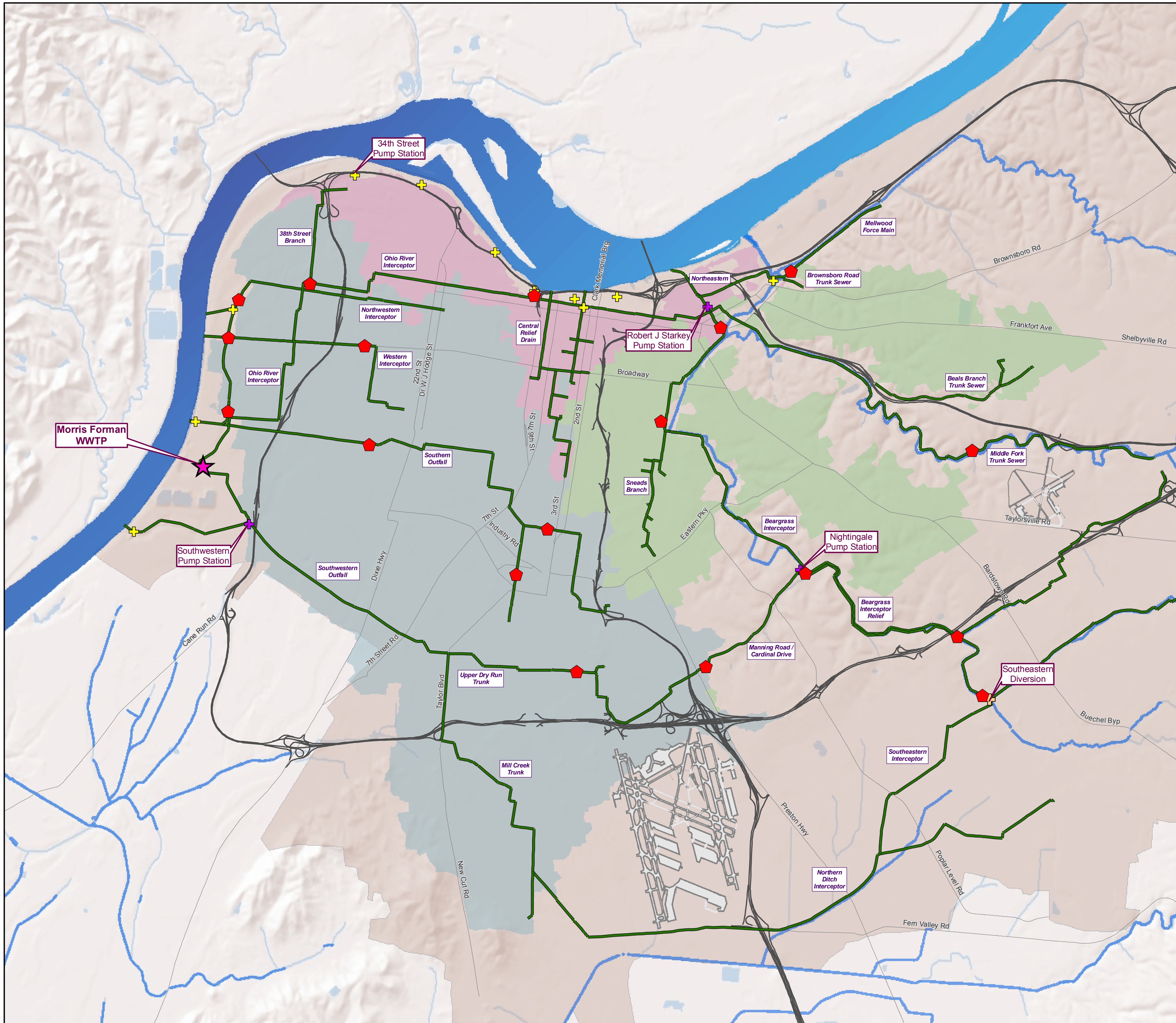
Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.4.14
2002
FLOW MONITORING LOCATIONS



LEGEND

- 2002 Flow Monitoring Location
- Flood Pump Station
- Sanitary Pump Station
- Southeastern Diversion
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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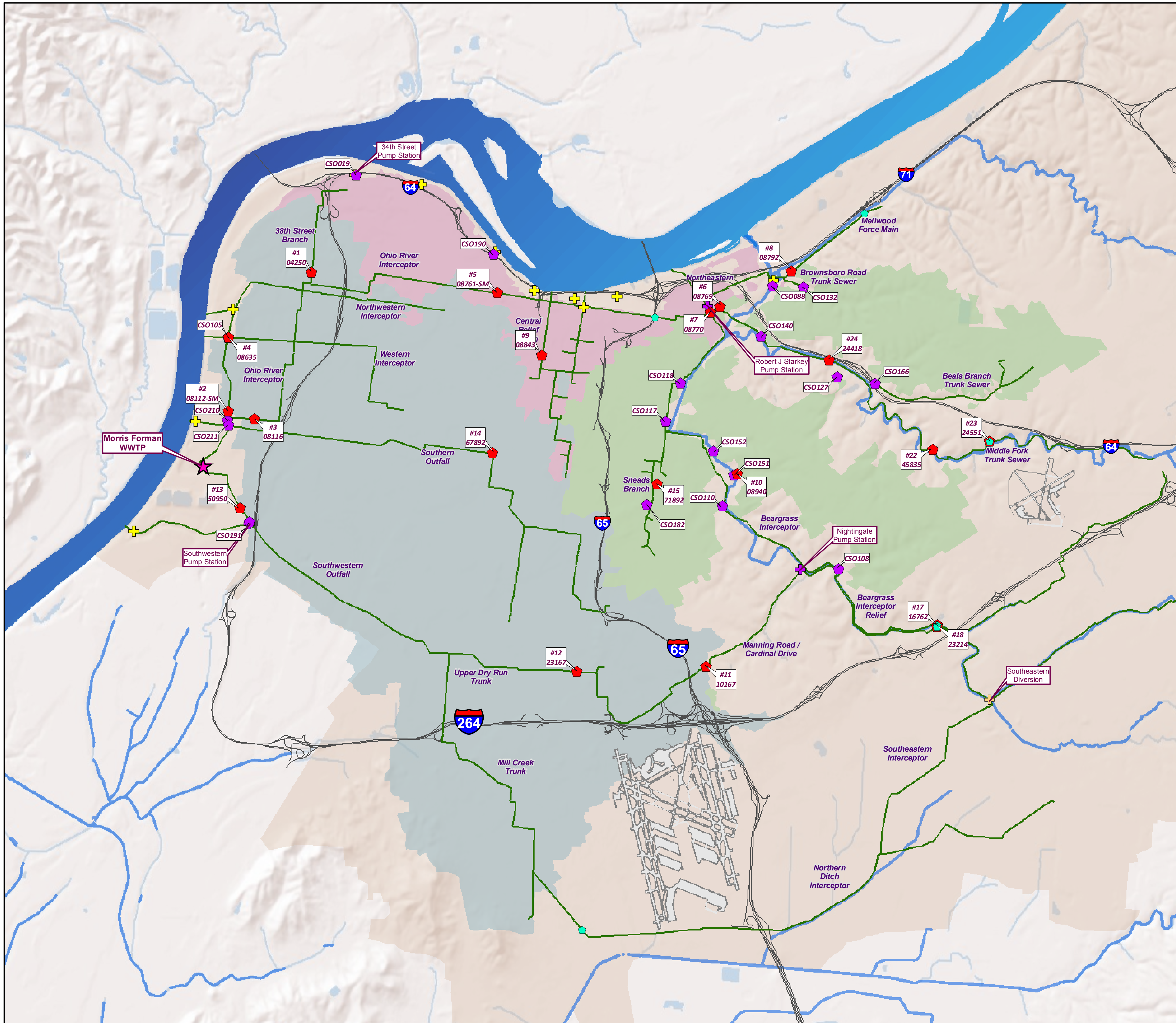

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Vol. 2 - Final CSO Long-Term Control Plan

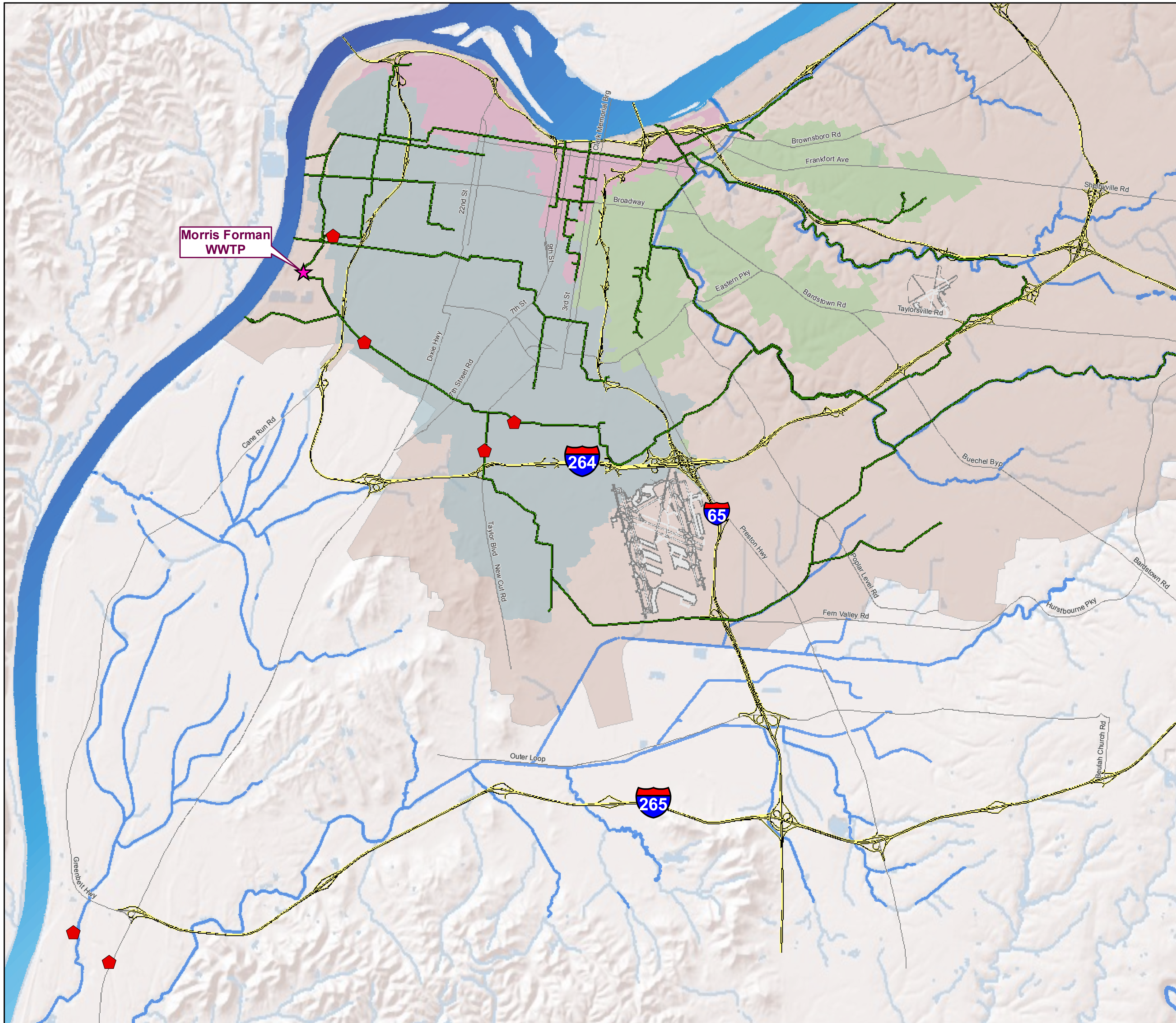
FIGURE 2.4.15
2007 FLOW MONITORING LOCATIONS

LEGEND

- In-System Flow Monitoring
- Overflow Monitoring
- Upstream Boundary
- Flood Pump Station
- Sanitary Pump Station
- Southeastern Diversion
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature



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Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.4.16 PERMANENT FLOW MONITORING LOCATIONS

LEGEND

- Permanent Flow Monitoring Location
- Wastewater Treatment Plant
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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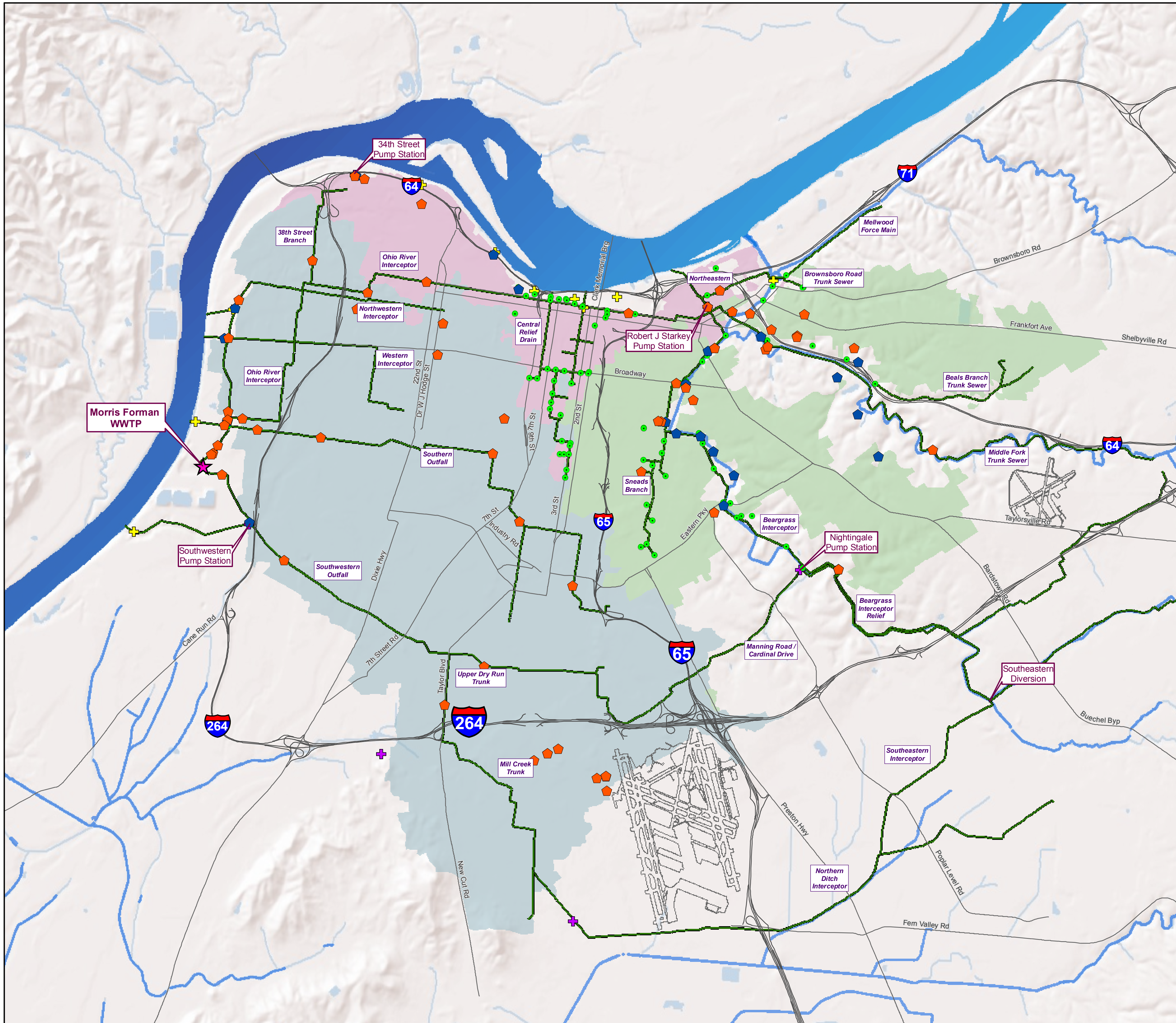
FIGURE 2.4.17
CSO AND CSS
SAMPLING LOCATIONS



LEGEND

- CSS Sampling Locations
- CSO Sampling Locations
- Active CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

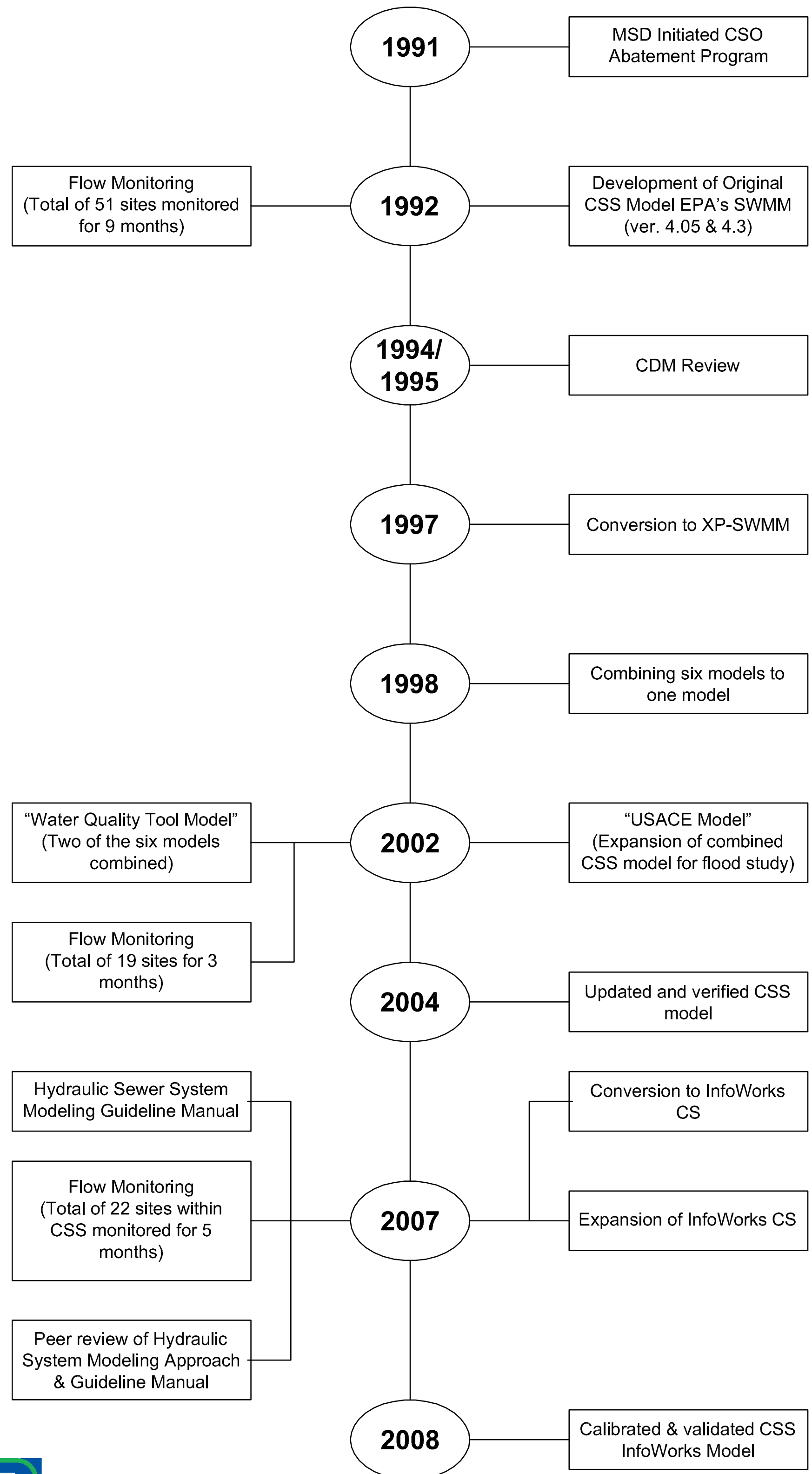
- Beargrass Creek
- Ohio River North
- Ohio River West
- Water Feature

LOJIC MSD Metropolitan Sewer District PROJECT WIN

O'Brien & Gere: I:\Lville-Jeff-Msd.10777\40109.Cso-Ltcp-Develo\LTCP PROJECT\GIS\MXDs\for LTCP Document\2.4.17 CSO and CSS Sampling Locations Map.mxd

This document was developed in color. Reproduction in black and white may not represent the data as intended.

FIGURE 2.4.26
CSS MODEL HISTORY



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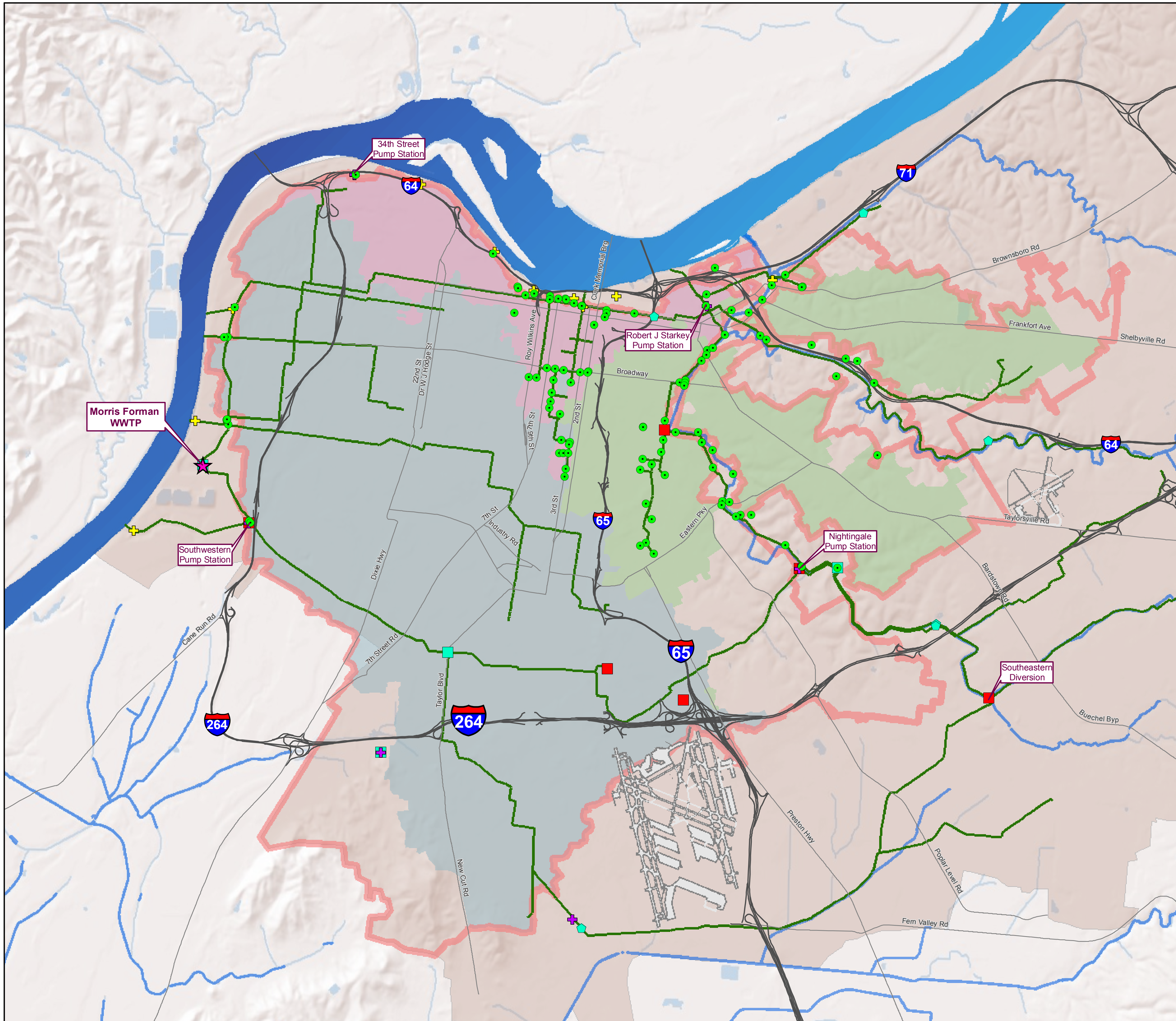
Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.4.27
COMBINED SEWER
SYSTEM MODEL AREA

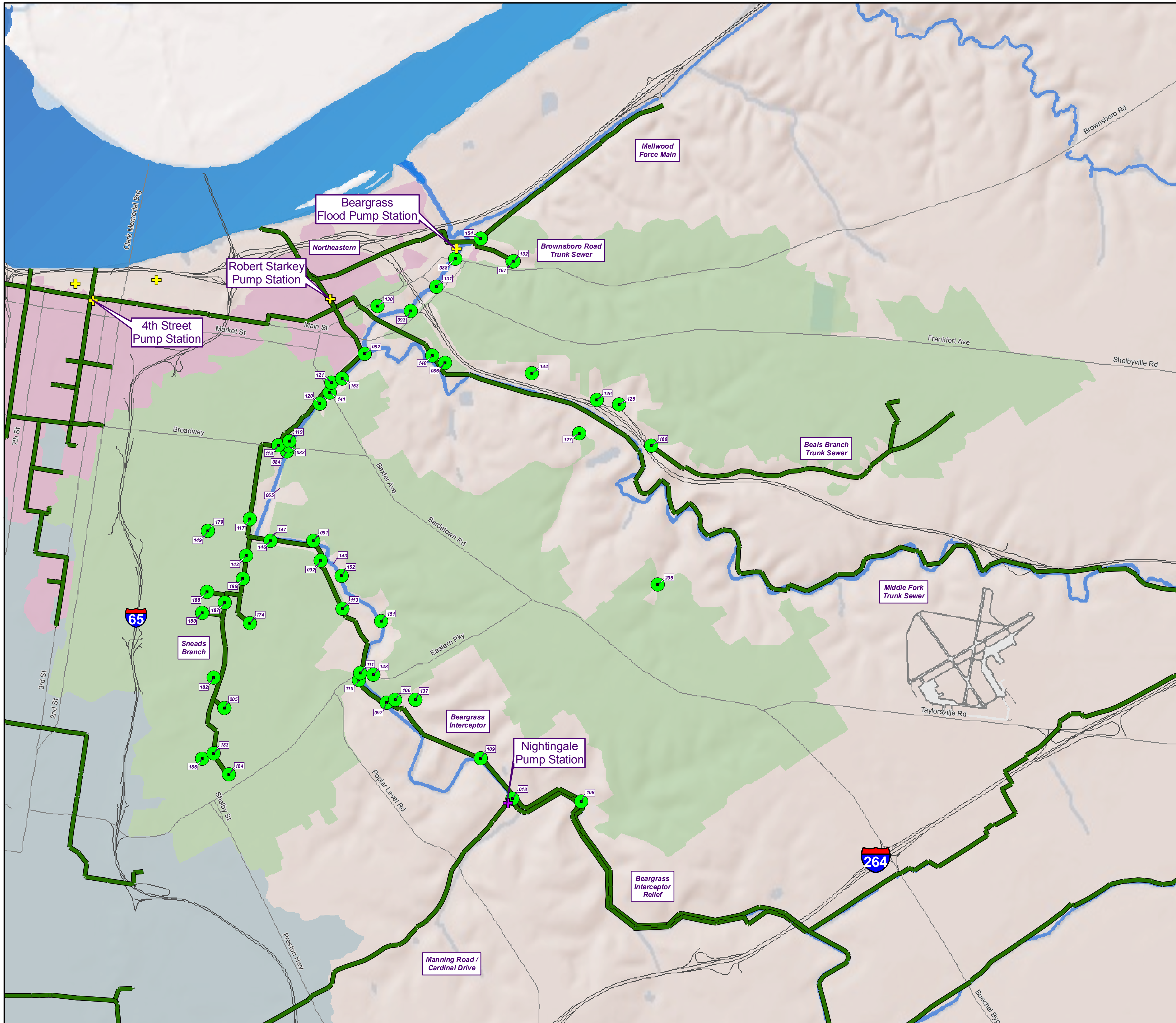


LEGEND

- Upstream Boundary
- Real Time Control Phase 1
- Real Time Control Phase 2
- Active CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- CSS Modeling Boundary
- Morris Forman Service Area
- Water Feature



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Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.5.1 BEARGRASS CREEK REGION

LEGEND

- Active CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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FIGURE 2.5.2
ROBERT J. STARKEY PUMPING PLANT
MSD0088-PS

147 BUCHANAN ST
LOUISVILLE, KY

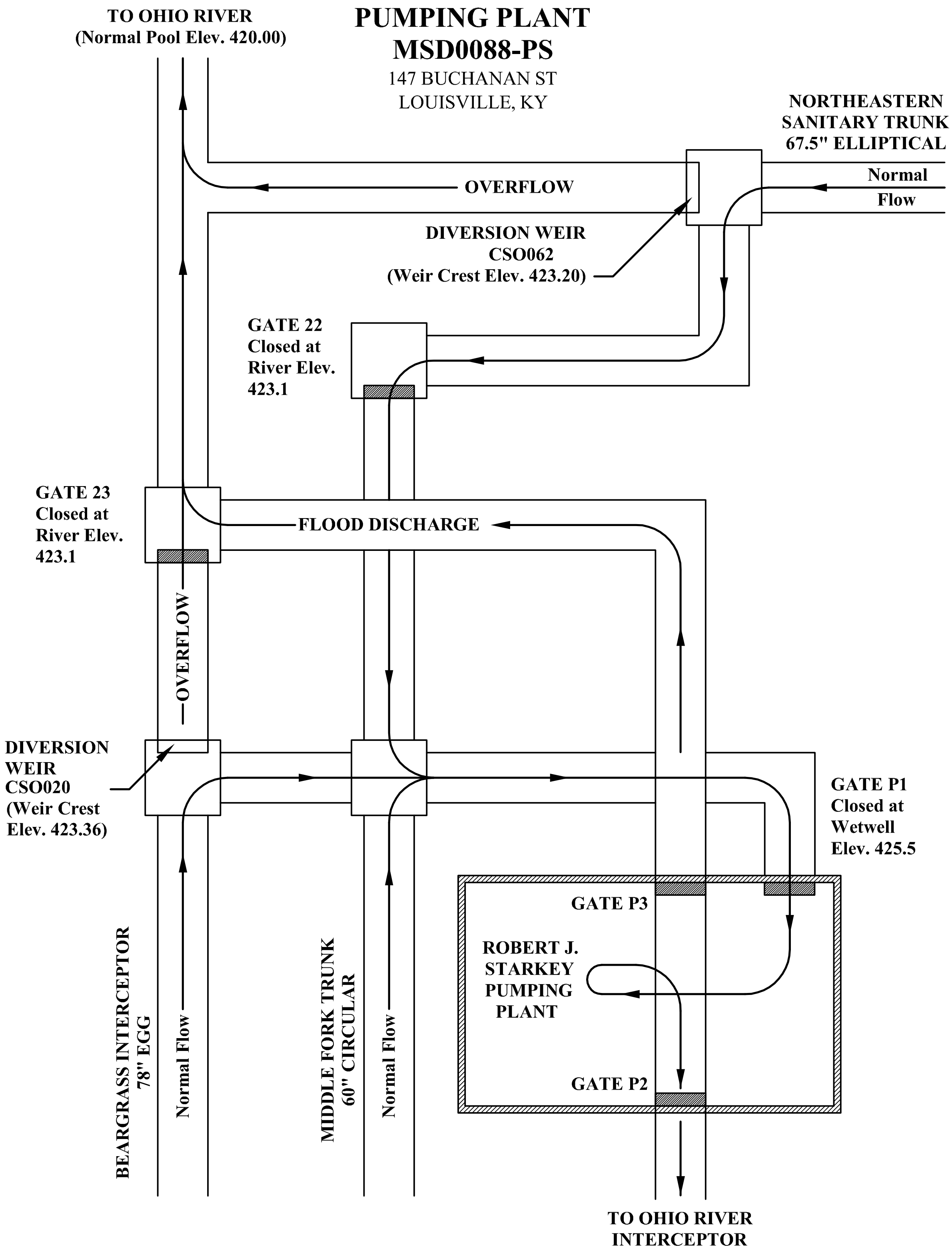
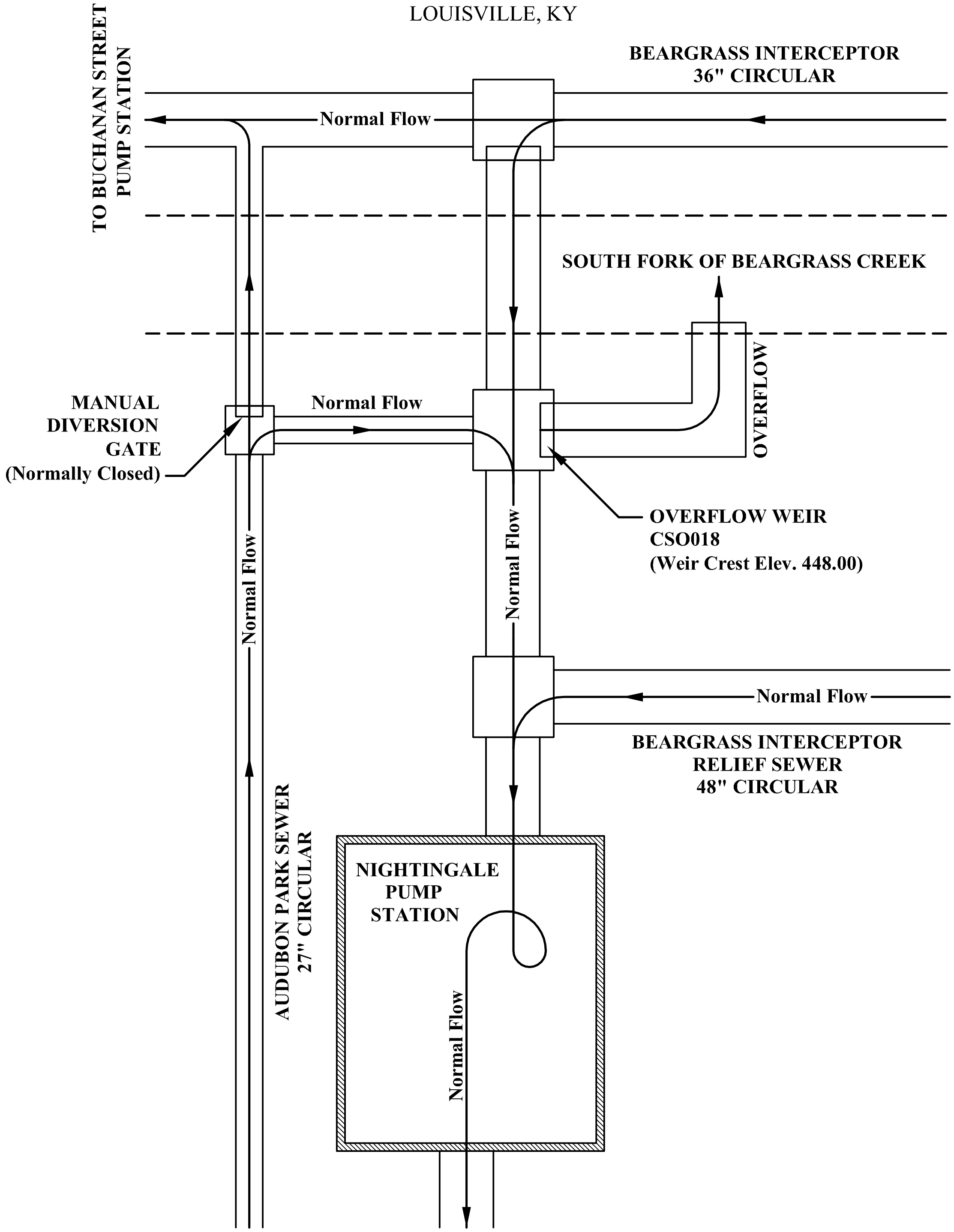


FIGURE 2.5.3
NIGHTINGALE PUMP STATION
MSD0022-PS

1800 NIGHTINGALE RD
LOUISVILLE, KY



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Vol 2. Long Term Control Plan

FIGURE 2.5.4
CSO SAMPLE
DATA SHEET

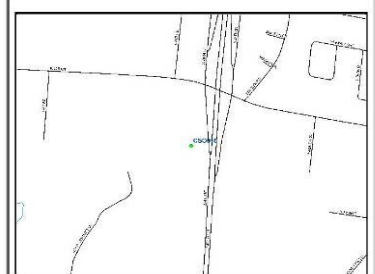
CSO Inspection Sheets

MSD
Louisville-Jefferson County Metropolitan Sewer District

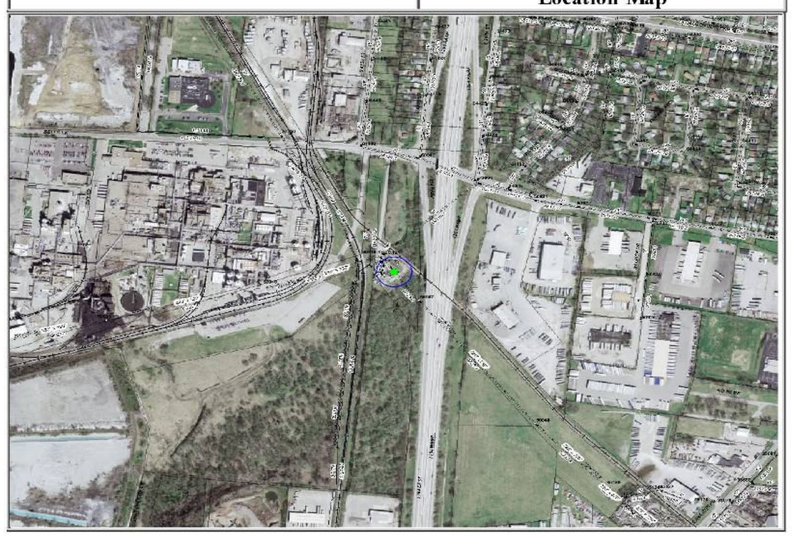
CSO015
4010 BELLS LN

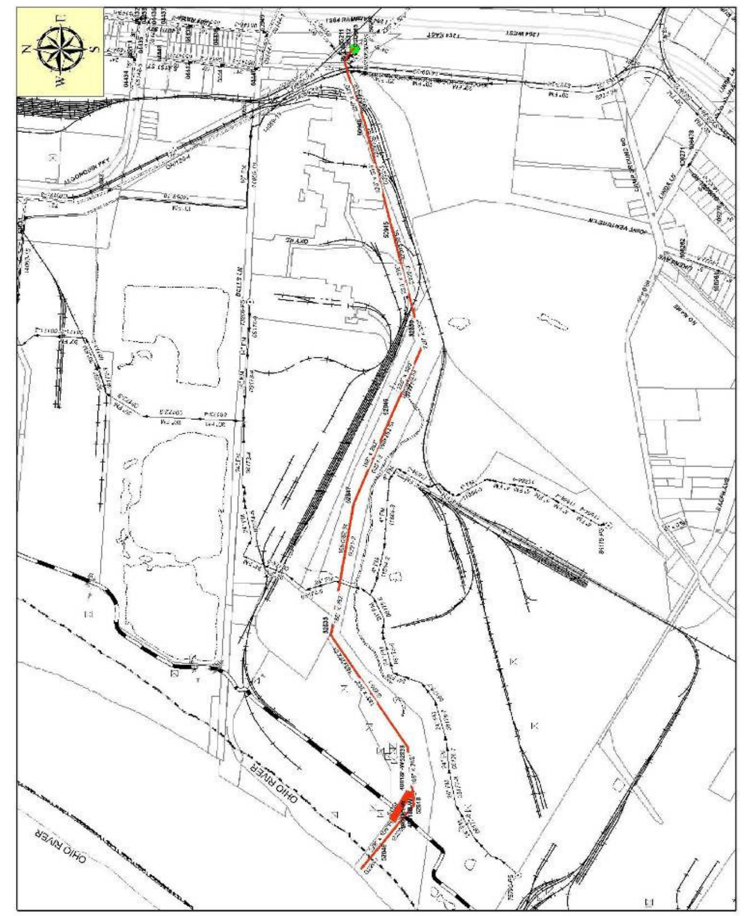
Report as of 10/21/2008

Record#: ORI89-3
MSD Atlas: BC212
Map#: MAL17



Location Map





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CSO 2008 Baseline Characteristics Report

CSO Number: CSO015

CSO Name:	Southwestern Pump Station
Overflow Type:	Diversion Dam
Solids and Floatables Device:	Baffle
Drainage Area (Acres):	7,496.70
Percent Impervious Surfaces:	47.47%
Receiving Stream:	Ohio River
General Location:	Ohio River West
2008 AAOV (in MG/ Yr):	494.56
Number of Overflow Incidents (in Number / Yr):	61
Average Duration of Overflow (in Hours):	7.23
Average Volume per Incident (in 1000 G / Incident):	8,107.52
Residential Landuse:	50.91%
Commercial Landuse:	10.34%
Industrial Landuse:	16.68%
Parks:	2.47%
Vacant Property:	11.03%
Population Estimate:	51,487

Based on LOJIC data as of June 2008 and InfoWorks Version 8 baseline characteristics
CSOs listed having 0.00 Drainage Areas serve as system relief points.
While a CSO may display 0.00 AAOV, nota that this is based on typical year rainfall data.

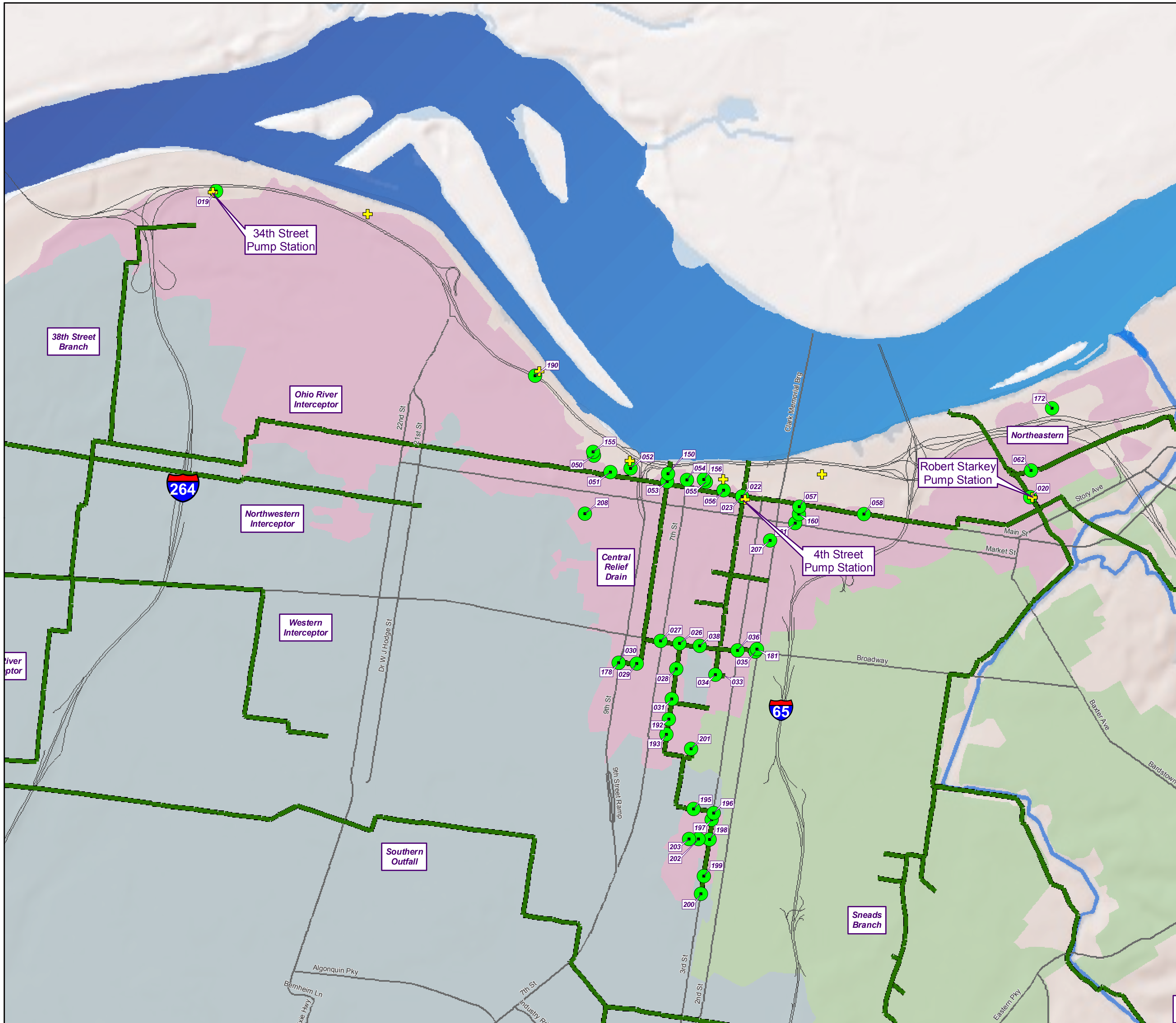
Monday, October 20, 2008 Page 1 of 1

LOJIC MSD Metropolitan Sewer District PROJECT WIN Waterway Improvements Now

Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.6.1
OHIO RIVER NORTH REGION



LEGEND

- Active CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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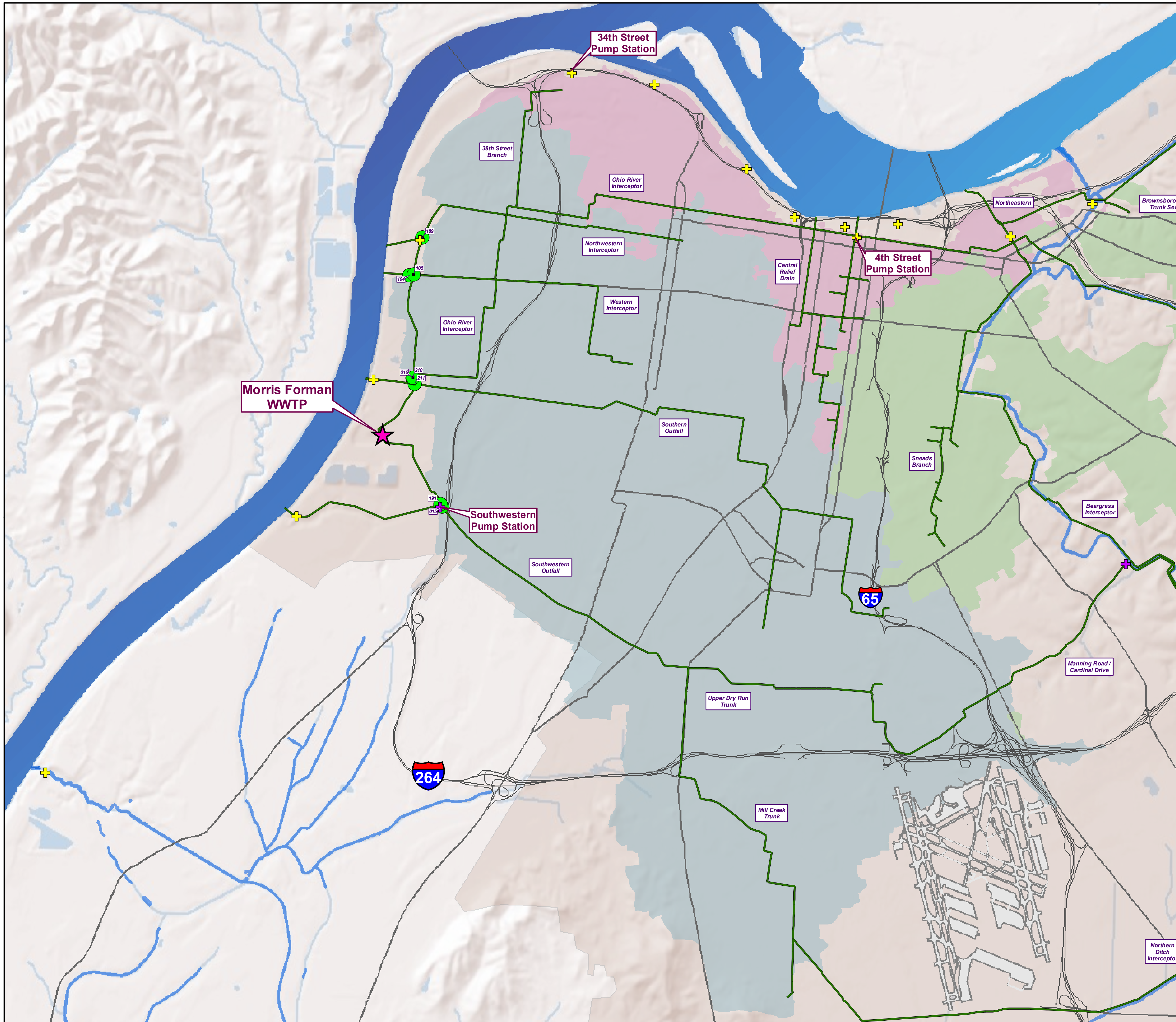
Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.6.2
OHIO RIVER WEST REGION



LEGEND

- Active CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

FIGURE 2.6.3
FOURTH STREET PUMP STATION
MSD0087-PS

342 WEST MAIN STREET
LOUISVILLE, KY

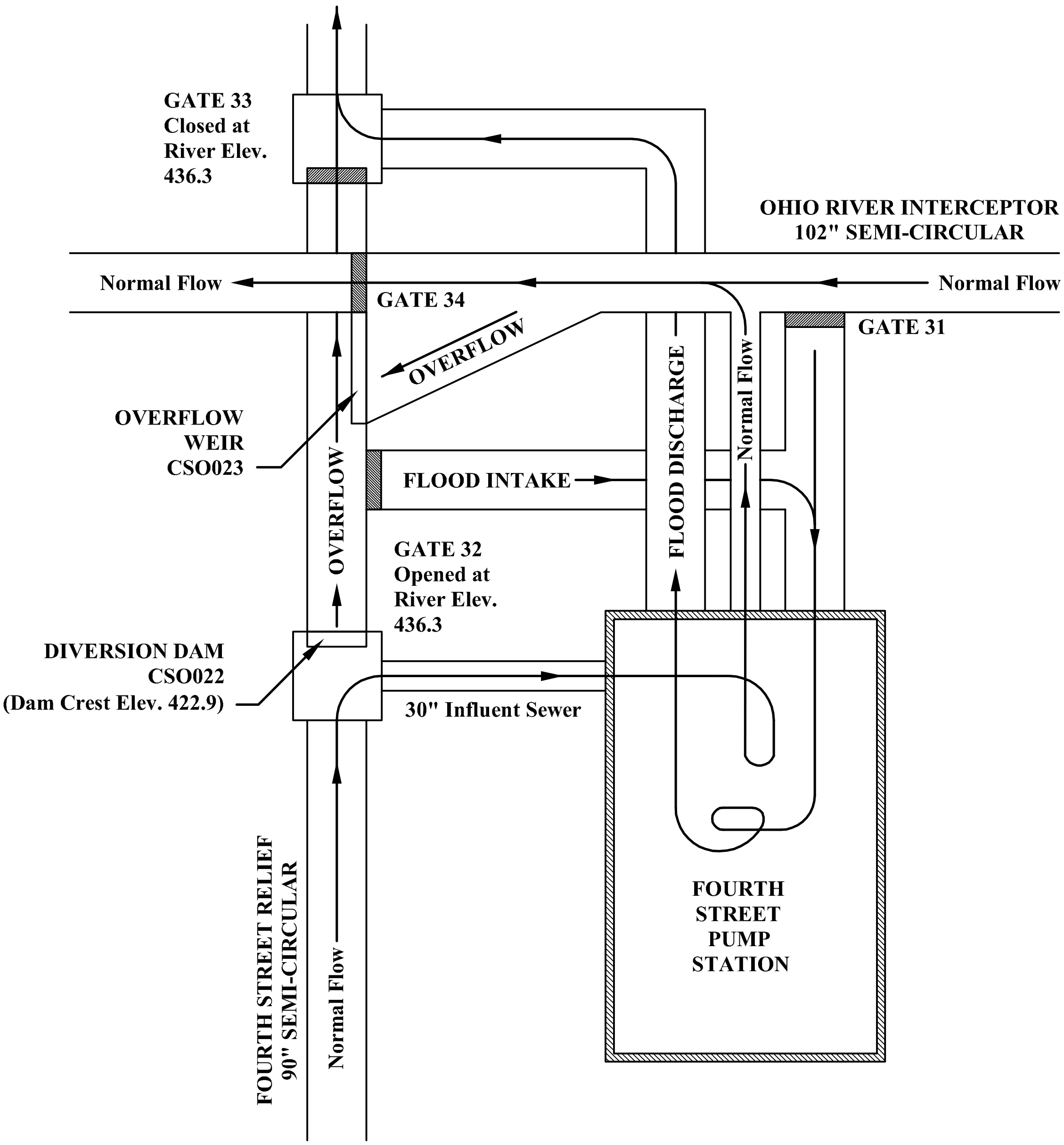


FIGURE 2.6.4
34TH STREET PUMP STATION
MSD0082-PS

816 NORTH 34TH STREET
LOUISVILLE, KY

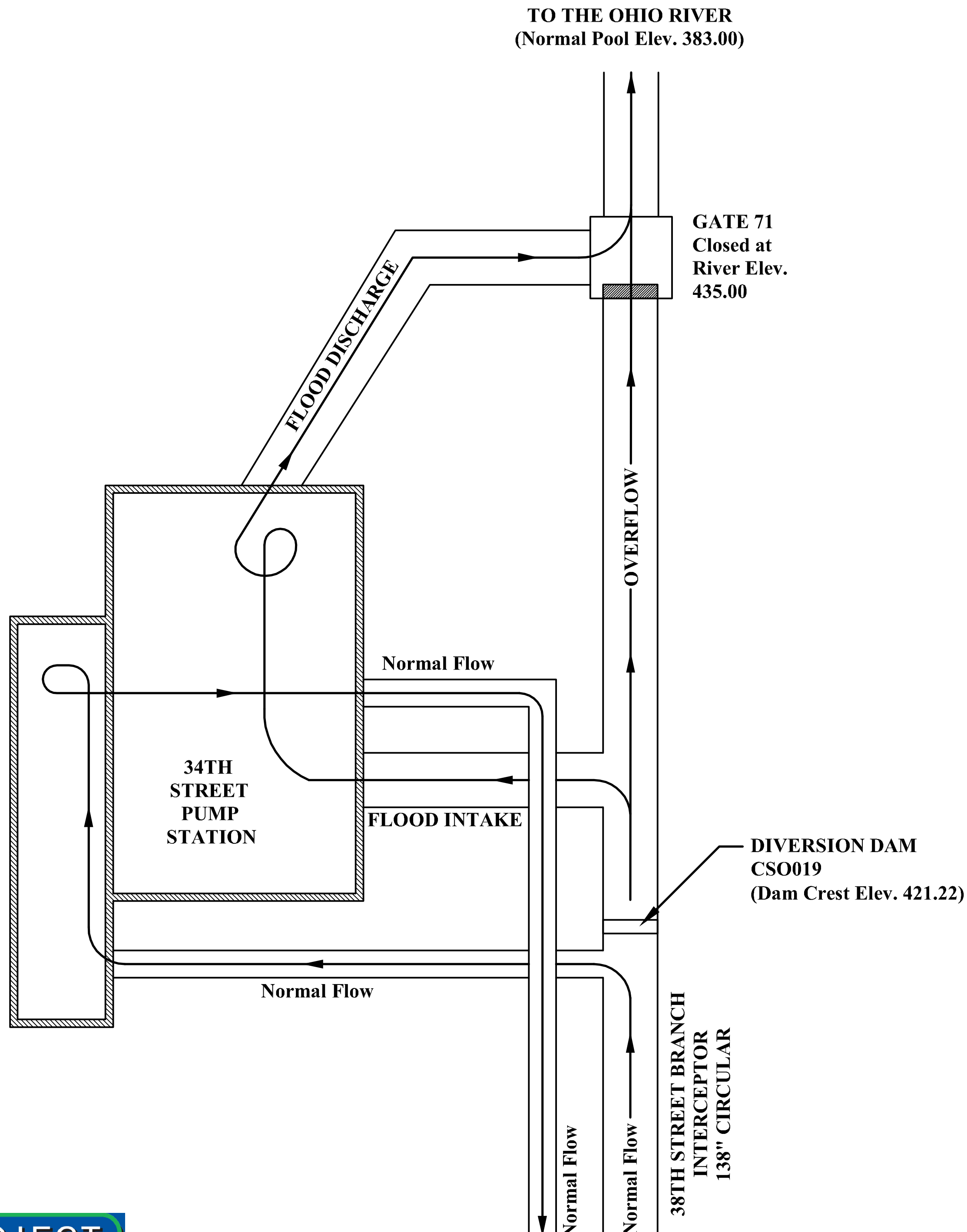


FIGURE 2.6.5
NORTHERN DITCH PUMP STATION
MSD0015-PS

341 MAC BRAE RD
LOUISVILLE, KY

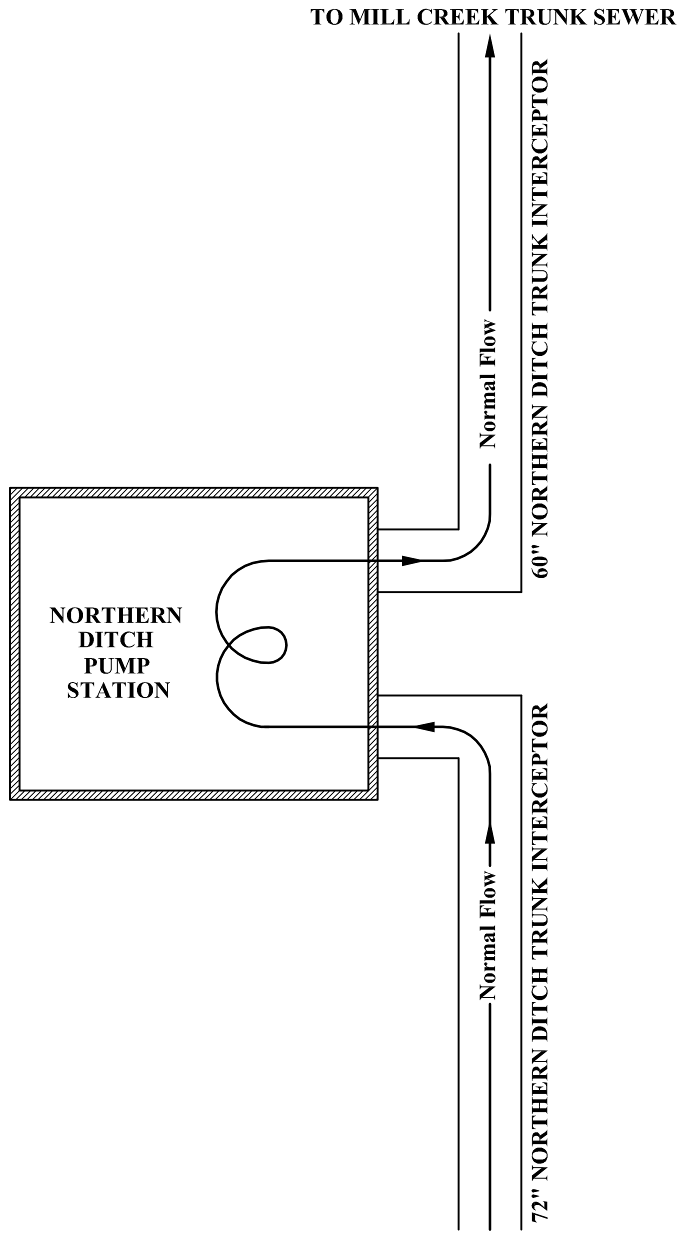
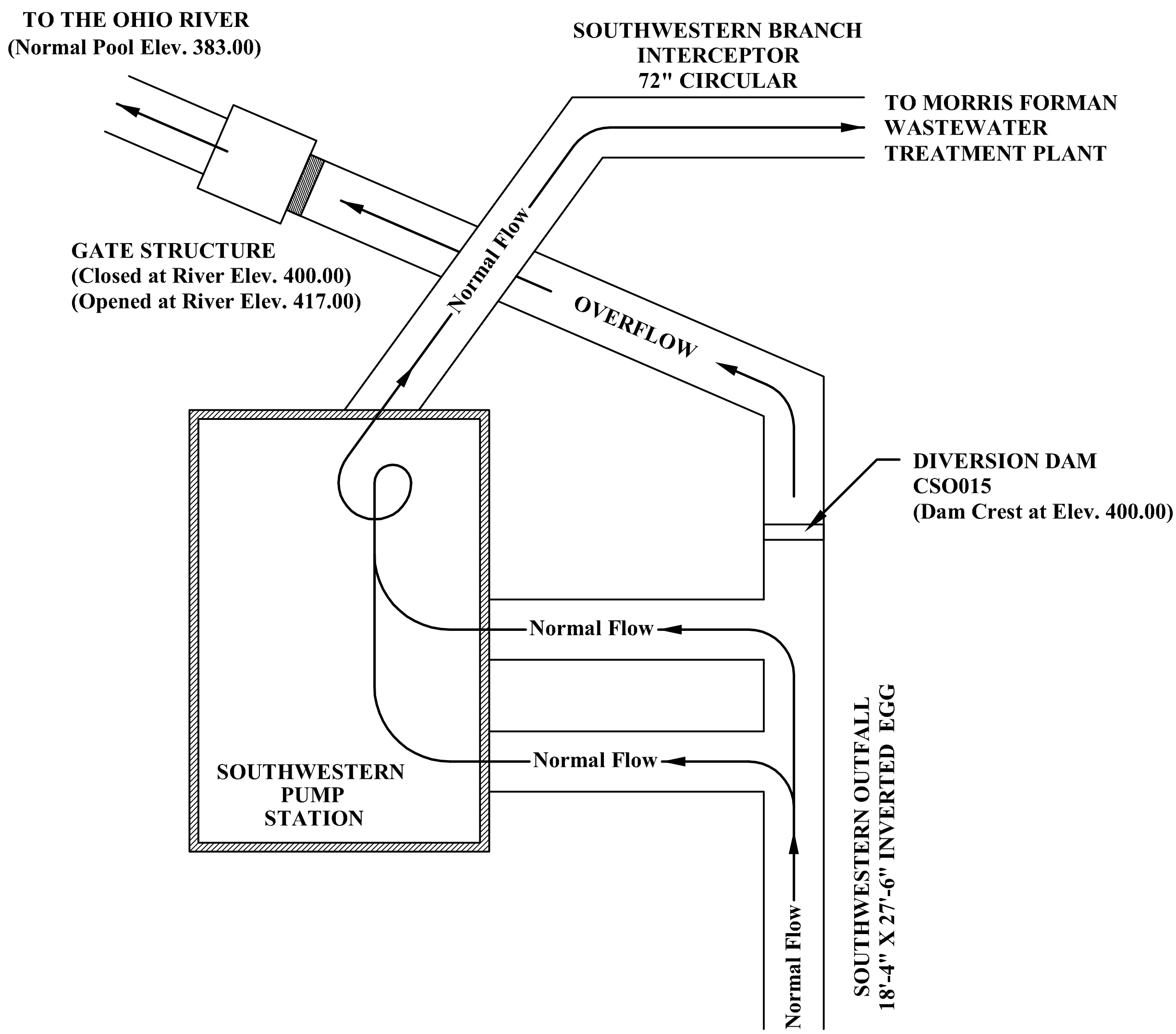


FIGURE 2.6.6
SOUTHWESTERN PUMP STATION
MSD0080-PS

4010 BELLS LN
LOUISVILLE, KY



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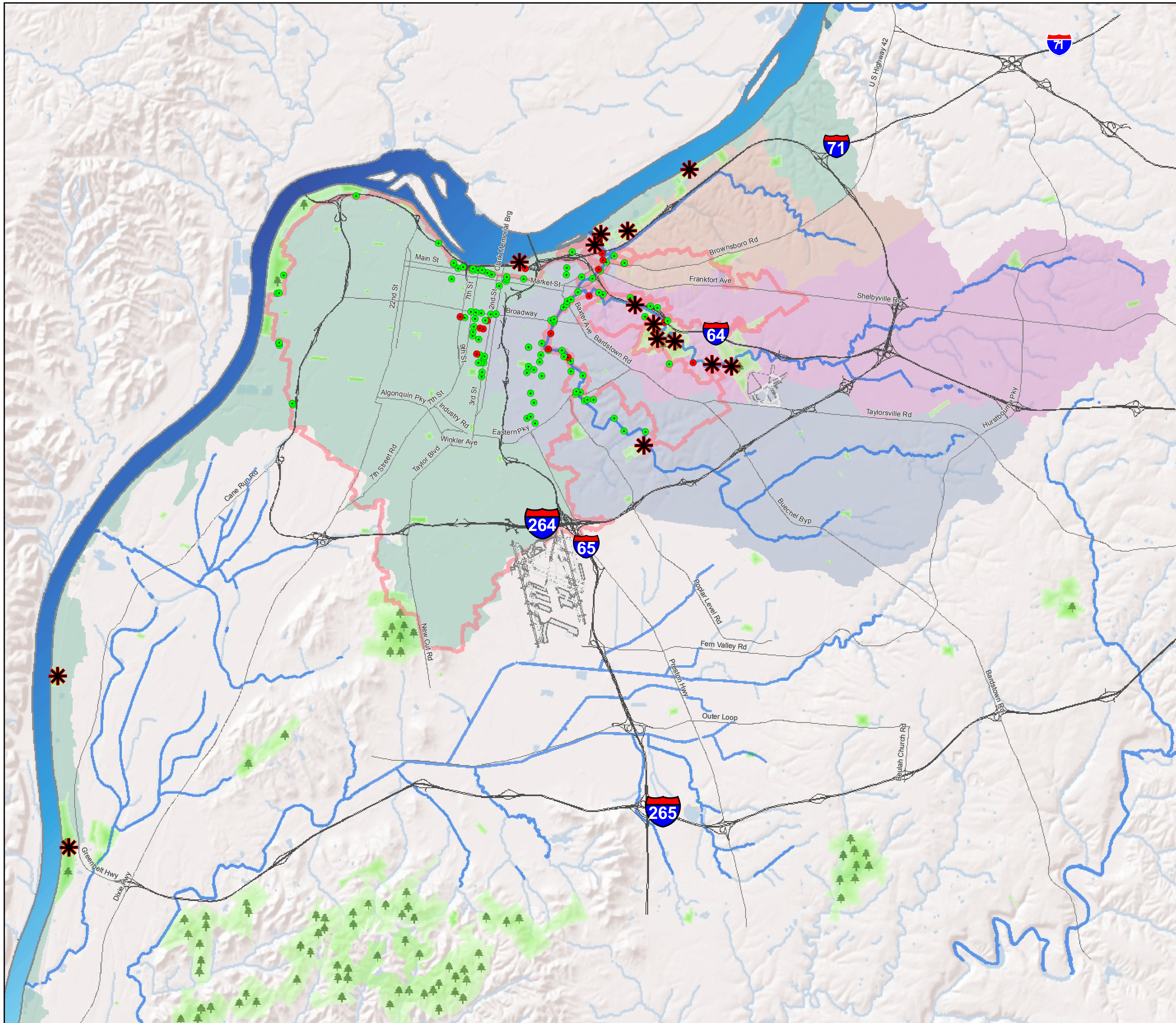
Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.7.1
RECREATIONAL USE SURVEY SITES



LEGEND

- Recreational Use Survey Location
- Active CSO Location
- Eliminated CSO Location
- Interstate
- Major Road

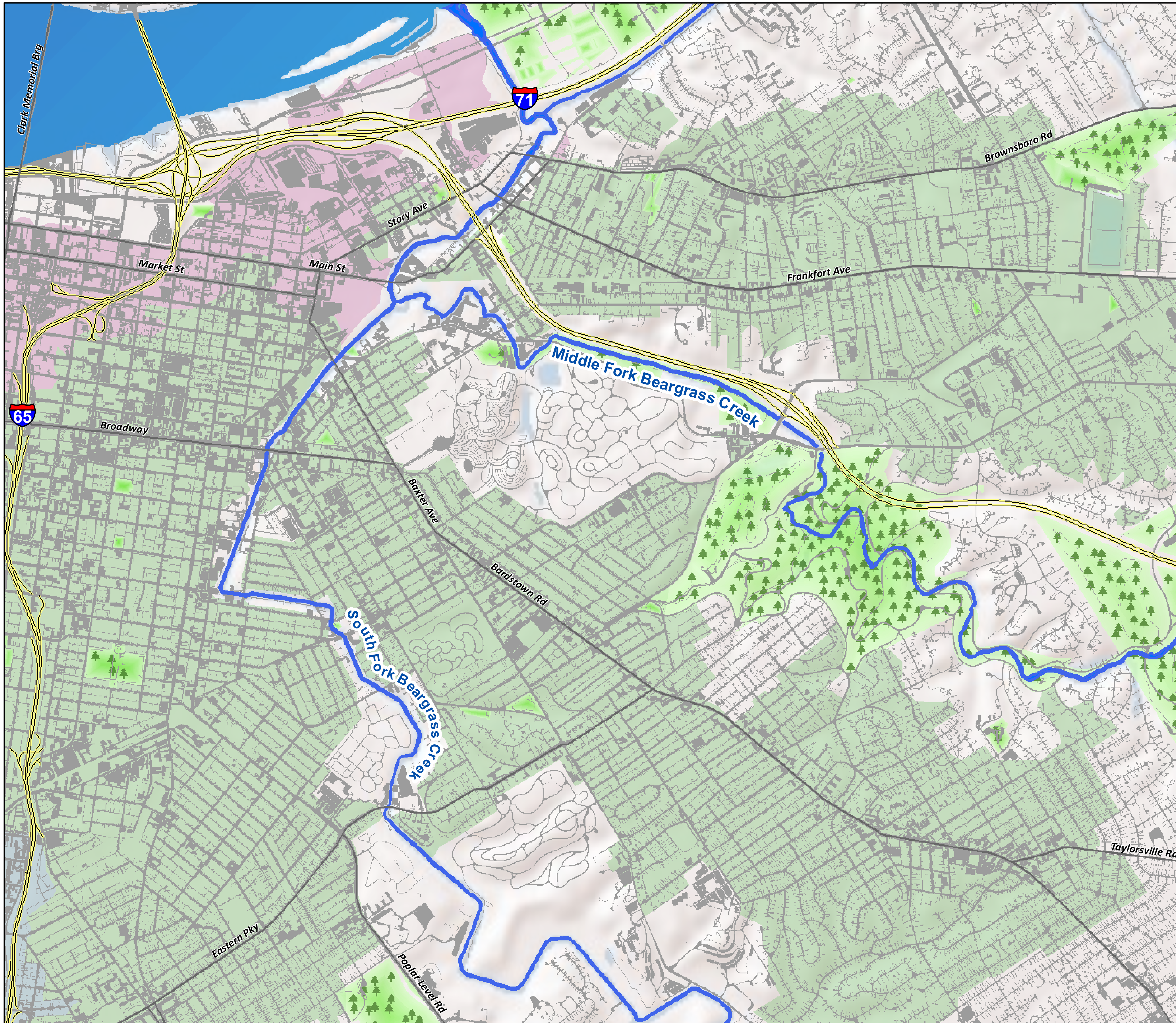
Watershed Boundary:

- Ohio River
- Middle Fork Beargrass Creek
- Muddy Fork Beargrass Creek
- South Fork Beargrass Creek
- CSO General Boundary
- Metro Park
- Water Feature

Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.8.1
PAVED SURFACES AROUND BEARGRASS CREEK



LEGEND

- Interstate
- Major Arterial Street
- Paved Surface

Regional Boundaries

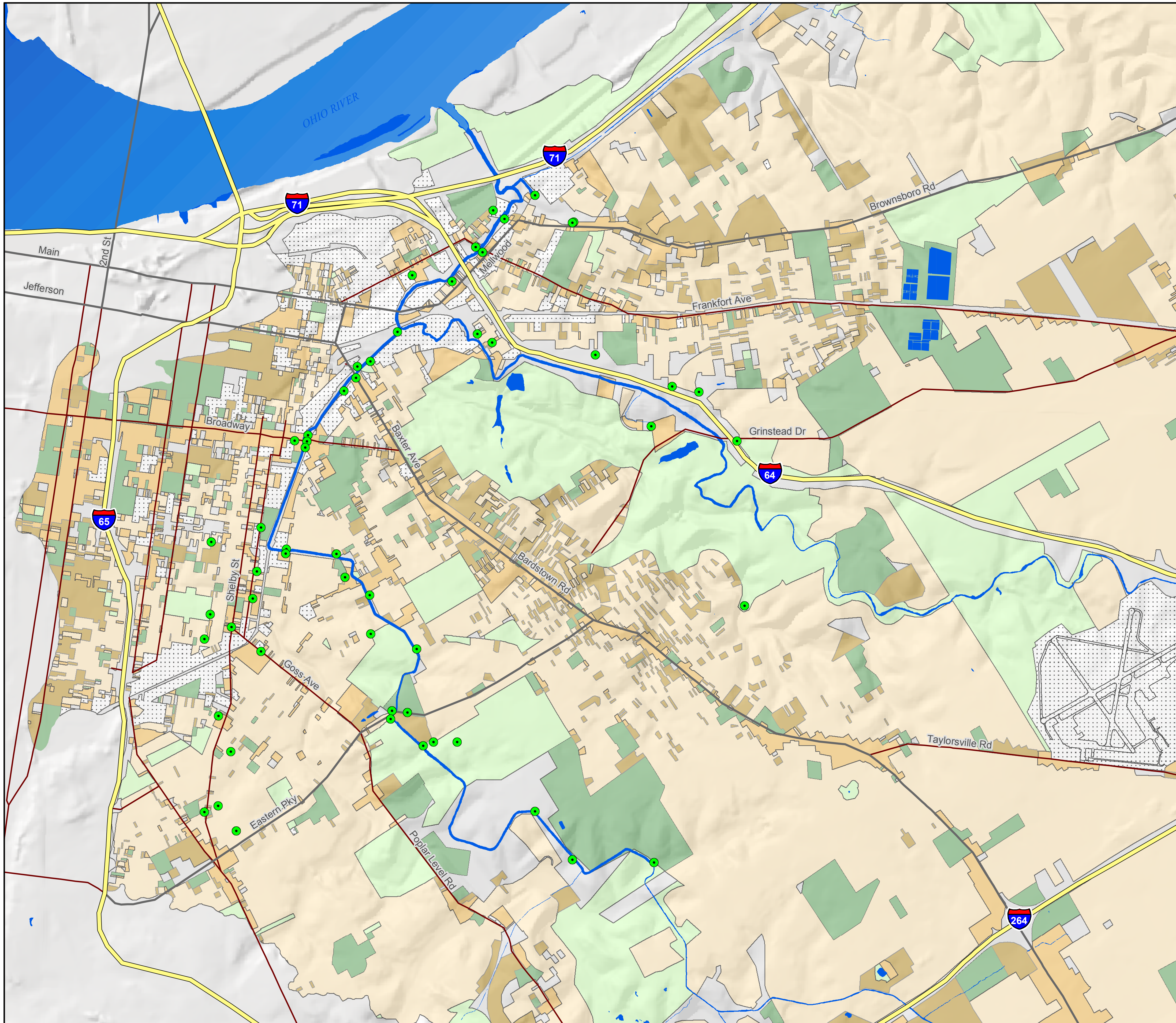
- Beargrass Creek
- Ohio River North
- Ohio River West
- Metro Park
- Water Feature

O'Brien & Gere: I:\Lville-Jeff-Msd.10777\40109.Cso-Ltcp-Develo\LTCP PROJECT\GIS\MXDs\for LTCP Document\2.8.1 Paved Surfaces Around Beargrass Creek.mxd

Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.8.4
BEARGRASS CREEK
LAND USE



LEGEND

- CSO
- Interstate
- Highway
- Major Road
- Parks, Cemeteries, etc.
- Public and Semi-Public
- Single Family Residential
- Multi-Family Residential
- General Commercial and Office
- Industrial
- Vacant and Undeveloped
- Water Feature

NOTE: Land use data were created by Louisville Metro Planning and Design Services in 2005.

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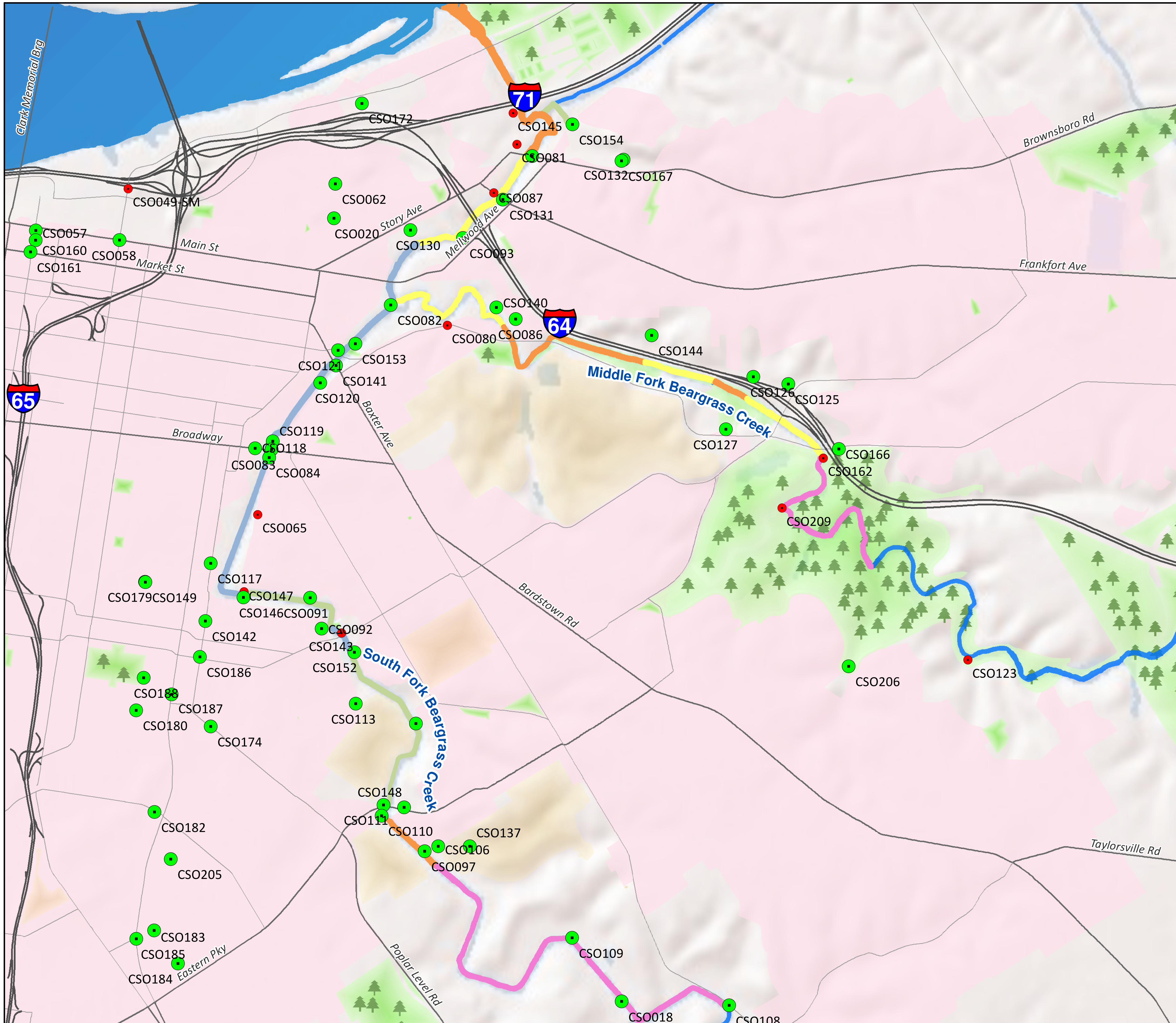
Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 2.8.6
DISTRIBUTION OF STREAM PRIORITY RATING



LEGEND

- Active CSO Location
- Eliminated CSO Location
- Interstate
- Major Arterial Street
- Minor Arterial Street

Stream Priority Rating

- Lowest
- Medium / Low
- Medium
- High / Medium
- Highest
- Stream Segment Not Evaluated
- CSO Boundary
- Metro Park
- Cemetery

Revision Date: August 7, 2009

LOJIC MSD PROJECT WIN

O'Brien & Gere: I:\Lville-Jeff-Msd.10777\STDS\GIS\CSO-LTCP-Phase-II\GRAPHICS\2.8.6 StreamPriority.pdf

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APRIL 30, 2021

2021 IOAP MODIFICATION

VOLUME 2 FINAL LTCP, CHAPTER 3

METROPOLITAN SEWER DISTRICT

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

Note: Appendices shown in italic text were not revised for the 2021 IOAP and remain the same as the 2012 IOAP Modification. All appendices have been provided on a separate USB flash drive and are not included in this report.

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Chapter 3: DEVELOPMENT AND EVALUATION OF ALTERNATIVES FOR CSO CONTROL

Special Note: This chapter was initially developed in 2009. The statistical data for the combined sewer overflows (CSO's) reported, specifically related to individual CSO overflow volumes and frequency in a typical rainfall year, were derived from the CSS model calibrated in 2007. Since then, a more detailed calibration and validation effort has adjusted some of the average annual overflow CSO volumes and frequencies in the Typical Year Modifications made to projects after the 2009 project development based on the updated calibration or other changed conditions are summarized Chapter 4. Detailed information regarding project modifications is contained in project modification letters submitted and approved at the time of the project change. Copies of the letters are included in Appendix 4.0-2. The Volume 2, Chapter 3 appendices remain the same as those provided with the 2012 IOAP.

The Final Long-Term Control Plan (Final LTCP) approach to reduction required by the 1994 CSO Control Policy is based on identifying the solutions that provide the greatest benefit-cost ratio and/or improves overall performance of the combined sewer system (CSS) in containing and treating pollutants. This chapter discusses the approach toward creating the Final LTCP, the process toward development of CSO control alternatives, and the tools used to evaluate CSO control alternatives. The 2009 LTCP produced a final product consistent with the Presumption Approach of the CSO Control Policy by exceeding the 85% capture required under the Presumption Approach.

In accordance with the provisions of the CSO Policy, the 2021 Updated LTCP is based on the Presumption Approach and has been developed to achieve the goal of:

The elimination or the capture for treatment of no less than 85% by volume of the combined sewage collected in the CSS during precipitation events on a system-wide annual average basis.

Current modeling of the Typical Year benefits of the updated LTCP indicate that upon completion of the program, approximately 95% of the combined sewage collected in the system will be captured for treatment under most operating scenarios, which far exceeds the regulatory minimum of 85%.

3.1. LONG-TERM CONTROL PLAN APPROACH

In this section, structured approaches to establish targets for CSO controls that will protect water quality and designated uses are addressed. The processes and tools used to create and convey solutions are discussed.

3.1.1. DEMONSTRATION VERSUS PRESUMPTION APPROACH

The CSO Policy identifies two methods, the "demonstration" and the "presumption" approaches, to establish targets for CSO controls that will protect water quality and designated uses (59 Code of Federal Regulations {CFR} 18688). In developing preliminary CSO alternatives, the Louisville and Jefferson County Metropolitan Sewer District (MSD) initially used one of the presumptive approach criterion that was based on the number of overflows per year.

To establish the best technical solution for each of the 106 CSOs, a range of technical alternatives were developed to achieve an initial control level of four overflows per year. The costs and benefits of each technical alternative were developed, and a benefit-cost tool used to select the preferred technical approach for each CSO. The preferred alternative may be a project to control a single CSO outfall, or a project that consolidates control of a cluster of several CSO outfalls. Each of the preferred alternative solutions was then resized to achieve varying levels of control, namely zero, two, four, and eight overflows per year. The benefit-cost evaluation was repeated for each level of control, and the optimal level of control then established for each solution.

Concurrently, water quality models were utilized to predict water quality effects of the various levels of control. The Beargrass Creek water quality simulation results demonstrated that reductions in CSOs did have an effect on water quality, but the differences between the levels of control were small. Similar to the Beargrass Creek water quality model results, the Ohio River water quality model demonstrated that reducing CSOs beyond eight overflows per year provided no tangible improvement to water quality standards compliance. The water quality modeling evaluation confirms the presumption that the proposed LTCP program provides an adequate level of control to meet the water quality-based requirements of the CWA and provides the regulatory agencies the confirmation that this presumption is reasonable.

Based on the water quality model results and benefit-cost evaluation results, MSD selected a system-wide solution which exceeds the minimum Presumption Approach of 85 percent capture of combined sewage collected in the CSS during precipitation events on an average annual basis. The planned program is anticipated to capture 95 percent of combined sewer overflow in a Typical Year, and water quality models for the Ohio River and Beargrass Creek predict that CSOs will not cause exceedances of the water quality standards with background pollutant loads from other sources removed. Benefit-cost evaluation and water quality modeling of the control plan demonstrate that the selected plan provides the maximum pollution reduction benefits reasonably attainable.

Upon completion of the LTCP, MSD will perform flow metering of the system to reflect the impact of the implemented controls and use this information to update the hydraulic model of the collection system. This updated collection system model will be used to calculate the Typical Year percent capture on a system wide basis to confirm that the regulatory target of 95 percent “elimination or capture for treatment” objective has been achieved in the post LTCP condition.

Decision Process

The risk management-based decision process that was applied to develop and evaluate CSO control alternatives for the Final LTCP utilized institutional knowledge of the CSS, Water Environment Federation (WEF) Guidance documents, U. S. Environmental Protection Agency (EPA) Guidance documents, and tools developed by the MSD’s program technical team. The process addressed benefit determination, cost analysis, and public participation. The risk management-based decision process is described in detail in Volume 1 of the Integrated Overflow Abatement Plan (IOAP).

A 2009 LTCP project list was established by reviewing numerous documents compiled over the previous 20 years related to both CSS and associated watershed studies. Workshops were conducted March 2007 and May 2007 with a group comprised of MSD senior management and technical personnel from the engineering firms having historical experience with the CSS. The historical knowledge by personnel was applied to create an initial wide range of control technologies resulting in 198 projects. A screening exercise reduced this list to 136 viable alternatives. These 136 projects were conceptually designed, followed by determination of related costs and benefits. These projects consisted of CSO-specific, CSO-consolidation, and CSO-regionalization projects across an array of control technologies, including storage, treatment, separation, etc. A matrix of the control technologies reviewed by CSO was included in the 2009 LTCP. In addition, a Green Infrastructure Program considered multiple solutions to reduce the volume of stormwater entering the CSS. This program approach is described in detail in Section 3.2.5.

There were other elements of the 2009 LTCP that were not subject to the evaluation process, primarily because no alternatives were considered. These were related primarily to the U. S. Army Corp of Engineers (USACE) Flood Protection System Infrastructure, combined sewage pump-back to the CSS following a wet-weather event, and completion of downspout disconnection programs that are partially complete as of December 31, 2008.

Regarding Flood Pump Stations, physical modifications were recommended and implemented to five existing stations developed per the Consent Decree. Modifications involve new gates, actuators, and operating guidelines, therefore, there were no comparative alternatives.

In 2009, downspout disconnection programs were in progress in two CSO drainage areas contributing to Beargrass Creek Middle Fork. Two other projects were recommended and implemented to complete the downspout disconnection programs under the Final LTCP.

3.1.1.1. COST ANALYSIS

The "Wet Weather Plan Project Cost Estimating Reference Document" (May 2007, CH2M Hill) was used to prepare conceptual cost estimates of proposed projects. The cost model utilized standard construction cost estimating unit factors, based on the "Engineering News Record – Construction Cost Index" (ENR-CCI), and was calibrated to MSD's history of construction costs.

The cost model was used to generate capital and 20-year present worth costs for each project under consideration for consistent comparison between projects and technologies. In anticipation of construction initiation by 2010, an ENR-CCI of 8550 was applied to advance planning-level costs into 2010 dollars. Following selection of the final gray infrastructure project list, these project costs were recalculated at the 2008 ENR-CCI of 8136, plus project/site-specific cost data and allowances in order to create a present-day program cost. This allowed MSD to apply an escalation factor over the life of the program in order to establish cash flow and funding requirements.

3.1.1.2. BENEFIT-COST ANALYSIS

Following establishment of the initial project list and subsequent conceptual designs and cost estimates, the benefits of the CSO control were determined to generate ultimately, a benefit-cost ratio for eventual project ranking and recommendation. For instance, the project list included a variety of technologies and project sites and addressed single-CSO vs. multiple-CSO project groupings. The discussion of the benefit determination process is discussed extensively in IOAP Volume 1, Chapter 2, Section 2.5.6 and is only discussed in this section in terms of application to the Final LTCP. These considerations remain valid and have not been updated for the 2021 IOAP Modification.

Eleven community-based, project-specific and programmatic values (benefits) were established by the Wet Weather Team (WWT), including asset protection, customer satisfaction, eco-friendly solutions, economic vitality, environmental enhancement, environmental justice and equity, financial equity, financial stewardship, public health enhancement, public education, and regulatory performance. Of these values, five were ultimately selected to calculate a project's array of impacts to the community. To enhance the benefit-cost ratio process, the WWT assigned weighting factors on a 0-10 scale to each of the five project values to reflect the degree of importance to the overall control plan impact to the community. The values and assigned weights that were used to score benefits were as follows:

- Asset Protection 6

- Eco-Friendly Solution 6
- Environmental Enhancement 8
- Public Health 10
- Regulatory Performance 8

Information and data utilized to score three performance values: Asset Protection, Public Health, and Regulatory Performance, were generated by the hydraulic model of the CSS. Additionally, to account for the significant magnitude of scale of receiving stream flow, separate scales were established for the Ohio River and Beargrass Creek.

Regulatory Performance and Public Health were scored on a 25-point severity-frequency matrix according to CSO discharge volume and frequency. The baseline characteristics of the CSS were initially scored, followed by scoring the remaining overflow/frequency resulting from the proposed control. The difference in these values was the benefit score, with a higher score indicating a higher reduction in risk, or higher value of benefit.

The Asset Protection value was also scored on a 25-point severity-frequency scale (design storm versus damage impact) to account for reduction in surface flooding conditions by a proposed CSO control. This value was scored using one of two methods. Method 1 utilized design storms versus basement backup potential (hydraulic grade line) of the CSS during precipitation events. Method 2 utilized design storm versus customer flooding complaints.

- To score Method 1, the baseline condition was first established by the CSS model, followed by determination of the sewer hydraulic grade line during various precipitation scenarios. A basement backup was considered possible if the hydraulic grade line reached a level within six feet of a manhole rim. As with the Regulatory Performance and Public Health values, the benefit was the difference in the two scores, with a higher score indicating a greater benefit.
- To score Method 2, MSD Customer Information System complaint data was compiled according to storm event. The level of damage (ranging from standing water to severe structural damage) was plotted against the storm frequency. Higher degrees of damage during high frequency storms were considered the worst-case outcome. The scores from the two methods were compared and the worst-case condition was applied to a project. In practice, it was found that the hydraulic condition score (Method 1) governed the outcome as Customer Information System complaints were difficult to use to fully assess the nature of damage reported by the customer.

The Environmental Enhancement and Eco-Friendly Solution values were scored using several performance metrics that represent a variety of aspects related to the environment or ecosystems. Each of the aspects were scored on a 10-point negative-to-positive scale (-5 to +5). Environmental Enhancement primarily assesses aquatic impact, while Eco-Friendly Solutions assesses broader land/energy impacts of proposed CSO control alternatives. To score these subjective aspects, a diverse, objective group of professional engineers, certified ecologists, and aquatic biologists from different consultant entities were assembled. This group established methodologies of scoring, and then participated in scoring a majority of the alternatives.

3.1.1.3. PUBLIC PARTICIPATION

In order to educate and engage the community in CSO control alternatives development, a series of public meetings were held throughout the Fall of 2007.

The public was also involved through the Stakeholder Group membership in the WWT. The WWT was extensively involved in CSO controls alternatives development and selection of the recommended plan. Their engagement, plus a list of meeting dates with associated agenda topics, is discussed fully in IOAP Volume 1, Chapter 3.

3.2. EVALUATION OF CSO MITIGATION ALTERNATIVES

In this section, the green and gray infrastructure technologies that control CSO discharges are discussed. Various alternatives exist in today's market; a brief description of the processes and performances of these technologies is presented. In addition, programmatic elements, such as source control/reduction and collection system storage are discussed.

MSD received a strong appeal from the WWT to integrate green technologies into the Final LTCP to reduce the frequency and volume of CSO discharges. Because of this encouragement, plus commitment by MSD leadership to consider all solutions, a Green Infrastructure Program was evaluated and implemented in conjunction with the Final LTCP. Along with the presentation of both technologies, this section also begins discussion of the initial CSO controls considered.

3.2.1. GENERAL CONSIDERATIONS AND CSO CONTROL MEASURES

Over the years, those involved with CSO abatement programs, such as consultants, equipment manufacturers, and CSO communities, have developed various practices and technologies for control and treatment of CSOs. The earliest technologies were in response to the nine minimum controls (NMC) requirements in the 1990s including technologies such as netting, screens, and trash racks for floatables control. As NMC technologies were implemented, the industry began to develop new technologies that represented the second generation of control strategies. Many of these next generation technologies are under consideration for application to MSD's CSS. The following Sections 3.2.2 through 3.2.4 review those technologies.

Each technology evaluated for applicability is grouped within one of three categories: Collection System Controls, Storage, and Supplemental Treatment. A detailed summary of each technology is presented along with examples of MSD's experience with applicable technologies.

3.2.2. AVAILABLE TECHNOLOGIES - COLLECTION SYSTEM CONTROLS

Collection system control technology is designed to increase the capacity of the sewer system and/or minimize extraneous flows into the system. The reasons behind the need for collection system modification or rehabilitation may include:

- Change in design philosophy, from a combined system to a separate system
- Inadequate capacity (e.g., land development exceeded expectations)
- Poor construction practices (e.g., improper bedding)
- Root intrusion (e.g., causing open joints)
- Chemical attack on the system (e.g., Hydrogen Sulfide)
- Normal aging and deterioration
- Damaged and leaking pipes

- Soil movement (e.g., causes joint separation)

Methods of collection system control include infiltration reduction, inflow reduction, and new sewer construction. The techniques are described in the following sections.

3.2.2.1. INFILTRATION REDUCTION

Infiltration is the introduction of groundwater into a sewer through defects in the sewer pipe or a manhole. Groundwater can enter a sewer through various sources such as defects or cracks in the pipe or manhole barrel, open joints caused by soil movement or root infiltration, or loose construction castings. As a result, groundwater utilizes the available capacity in the sewer that was intended for sanitary sewage and/or stormwater. Infiltration therefore results in loss of capacity to convey combined sewage flow. There are several rehabilitation methods of reducing groundwater infiltration.

Chemical Grouting

A quick-setting liquid is injected into defects in the pipe or manhole, open joints and/or minor cracks. Once set-up, the grout seals the joint and prevents groundwater from entering into the sewer at the point of repair.

Relining

If there are multiple defects in the sewer system, or if there is loss of structural integrity of the sewer or manhole, a liner can be installed over the entire length of the pipe/manhole. Relining can take the form of cured-in-place-pipe liners or prefabricated high-density polyethylene (liners (slip lining). The cured-in-place-pipe liners are easier to install within sewers since they do not require excavation but do require heated curing. On the other hand, slip lining requires some excavation to allow the installation of the high-density polyethylene pipe. The installation of a liner reduces the inside diameter of the sewer and, theoretically, the capacity of the sewer. However, the installation of the liner may reduce the resistance to flow (Manning’s Roughness Coefficient) such that there is no net loss of, or even a slight increase in, capacity. Infiltration can still occur at service lateral connections, so a comprehensive assessment should be undertaken when considering relining as an infiltration reduction method. MSD has applied sewer-relining technology with some success within the sewer system. MSD has been very successful applying sewer relining using in-house resources on sanitary house sewer lines that connect to the main sewer.

Pipe Bursting

If the installation of a liner, as previously described, reduces the inside diameter of a sewer and adversely impacts the sewer’s capacity, it may be possible to perform an in-situ replacement of the sewer with a new pipe of the same, or slightly larger, diameter. Pipe bursting uses a pneumatic, hydraulic, or static busting tool to fracture the existing pipe. Concurrent with the shattering of the existing pipe, a polyethylene pipe is pulled into the void. The size of the new polyethylene pipe is dependent on the surrounding soil conditions and the ability for the bursting tool to create a void that is sufficiently large to accommodate the new pipe. This no-dig process is suitable for enlarging the size of utility pipes, existing sewers, or other pipelines without excavation. MSD has applied pipe-bursting technology in limited applications with some success. Additional excavations are required to reconnect building lateral sewers.

3.2.2.2. INFLOW REDUCTION

Inflow is water that enters into the sewer system through undesirable connections, such as downspouts and basement sump pumps. Inflow is generally a term that is associated with separate sanitary sewers, since stormwater is not supposed to be conveyed by a sanitary sewer. In relation to a combined sewer, stormwater flow from downspouts, surface runoff into catch basins and cross connections with storm sewers are sources that often can be disconnected and redirected to other natural drainage systems or, be allowed to soak into the ground. The reduction of the wet weather flow component of a CSS leads to a potential reduction in CSOs.

Green infrastructure techniques include the disconnection of downspouts from the combined sewer. Once disconnected, the discharge is allowed to drain across the lawn and stormwater infiltrates into the ground. Downspouts can be rerouted to rain barrels or cisterns. The rainwater can then be stored and used to water gardens during dry periods. Rain gardens can be planted to absorb stormwater runoff. Porous pavement also can reduce runoff rates to attenuate peak flow within the combined sewer system. MSD investigated several green infrastructure technologies to be implemented as part of the Final LTCP, which are discussed later. MSD has conducted downspout disconnection programs, sump pump disconnection programs, as well as rain barrel, rain garden, and porous pavement pilot projects.

3.2.2.3. NEW SEWER CONSTRUCTION

Sewer separation is the conversion of a CSS into a system of separate sanitary and storm sewers. Sewer separation, in theory, eliminates a CSO and this alternative is most likely to prevent sanitary wastewater from being discharged to receiving waters. Additionally, sewer separation advantages include increasing available plant capacity and reducing the public's exposure to raw sewage. Construction of new sewers may cost much more than other viable treatment technologies. In addition, when combined sewers are separated, storm sewer discharges potentially contribute more untreated pollutant load to the receiving waters. In addition, partial sewer separation may not eliminate the overflow, but actually cause the overflow to be redefined as a sanitary sewer overflow (SSO). Sewer separation is typically the most expensive CSO control measure. Because of the high cost and the negative impacts of major construction projects on local traffic, sewer separations are traditionally planned for small areas or as part of a greater infrastructure rehabilitation project.

In practice, there are two distinct approaches to sewer separation:

- **Full Separation** - new sanitary sewer lines are constructed, and the existing CSS becomes a storm sewer system. This is probably the most widely used form of separation. Another option involves an entirely new storm sewer system is constructed with the existing CSS remaining as a sanitary sewer system. This form of separation is not often used because the capacity of the existing CSS was designed to accommodate stormwater runoff, which exceeds what is required to accommodate sanitary flows.
- **Partial Separation** - a new storm sewer system is constructed for street drainage, but roof leaders and basement sump pumps remain connected to the existing CSS.

MSD has successfully implemented sewer separation projects as part of the CSO Program. However, as stated above, projects have typically been part of major redevelopment efforts in downtown Louisville Metro or implemented where circumstances made it cost effective. For example, the sewer systems for CSO206 and CSO209 already had separate pipe networks for both storm and sanitary sewage although these networks had common manholes. The scope of the projects, in these cases, consisted of separating the manholes, reconnecting some drainage basins, and correcting private property connections.

3.2.3. AVAILABLE TECHNOLOGIES - STORAGE

The objective of storage is to reduce overflows by capturing combined sewage during wet weather for controlled release into wastewater treatment facilities after the storm flows subside. Storage technology has three major sub-groups: in-line, off-line and on-site. While the NMC requirements in the 1990s required the implementation of low-cost optimization of in-line storage such as raising an overflow dam, current storage technology is much larger in scale and more complex utilizing real-time controls (RTC) technology and flow control structures. A typical modern storage facility may include an RTC controlled diversion regulator and an open or covered storage unit, an RTC controlled return regulator and an emergency relief point. The emergency relief point may be equipped with netting, disinfection or other CSO control devices.

Storage facilities are widely used as CSO control because they effectively reduce the volume, frequency, and duration of CSO events. Storage facilities can provide a relatively constant flow into the treatment plant and thus reduce the size of required treatment facilities. A storage facility may be located at overflow points or near treatment facilities. A major factor determining the feasibility of using storage facilities is land availability. Operation and maintenance costs are generally small; requiring only collection and disposal cost for residual sludge solids, unless inlet or outlet pumping is required. The following sections outline the technologies that are important in regard to storage.

3.2.3.1. REAL TIME CONTROL

RTC seeks to optimize sewer system performance during wet weather events. RTC is applicable in CSSs because these systems typically include large pipes for transport of wet weather flows. RTC uses system-wide dynamic controls to implement control tasks such as in-line storage flow maximization and flow diversion. There are two types of system wide dynamic RTCs: reactive systems and predictive systems.

In reactive RTC, sewer level and flow data are measured in “real time” at key points in the sewer system. The collected data is transferred to a central computer where custom software applies feedback loops and optimization rules to operate system elements to maximize use of the existing sewer system and to limit overflows.

Predictive control goes one-step further by incorporating weather forecast data to allow for advanced planning of control tasks and control tasks sequencing. RTC technologies are capable of reducing the frequency, duration, and volume of CSOs through optimization of sewer system operations. CSSs use RTC technology to control system regulator elements such as weirs, gates, dams, valves, and pumps in a real-time environment.

RTC may be more effective in areas with excess capacity and level terrain where it is more practical to store wastewater in existing sewers. RTC has proven useful to divert flows to and from storage systems during wet weather. Some other advantages of RTC include the ability to manage storage facilities in such a way as to minimize overflows; hydraulic models can be integrated into RTC control techniques to refine operational strategies; and, system response can be predicted through use of rainfall forecast and gauge data.

While the initial costs of enhanced RTC can be significant, the monitoring costs will likely be a fraction of the cost of large capital projects that would achieve similar levels of CSO reduction. MSD completed Phase I and II of a major CSO Predictive RTC program in 2006 and 2008, respectively. MSD completed all RTC phases identified in the Final LTCP. MSD continues to look for opportunities to enhance and optimize new storage basins. Updates related to MSD’s progress regarding RTC storage continue to be provided in MSD’s Consent Decree progress reports.

3.2.3.2. IN-LINE STORAGE

In-line storage is the term used to describe storage of wet weather flows within the sewer system. Taking advantage of this type of storage may reduce the frequency and volume of CSOs without a large capital investment. The amount of potential storage available in the sewer system largely depends on the available capacity of the pipes that will be used for storage, the grade of the pipes, and on the availability of suitability sites for installing regulating devices. In-line storage techniques typically use RTC to control the use of flow regulators, in-line storage units or basins, and parallel relief sewers.

Storage units and basins constructed in-line are typically governed by flow regulators which optimize in-line storage during wet weather events by damming or limiting flow in specific areas of the sewer system. Dry weather flows pass directly through in-line storage facilities. In-line storage units and basins may be either tanks or open or closed basins and may include facilities to minimize their aesthetic and environmental impact. These may include odor control systems, washdown/solids removal systems, and access for cleaning and maintenance.

Closed tanks are constructed below grade such that the surface at grade can be used for parks, playgrounds, parking, or other light uses. In-line capacity can also be created by installing relief sewers parallel to existing sewers or by replacing older sewers with larger diameter pipes. One factor that may limit the applicability of in-line storage is the possible increase in basement backups and street flooding (EPA 1999).

In-line storage may also slow flow, which allows solids to settle in the sewer. If allowed to accumulate, these solids can reduce available storage and conveyance capacity. Therefore, it is important to design the facility in such a way that adequate flow velocities are provided during dry weather service to move the solids to the Water Quality Treatment Center (WQTC).

Prior to the 2009 LTCP, MSD had already constructed and installed inflatable dams as in-line storage controls at the Sneads Branch Relief Drain and in the Southwestern Outfall. These projects have been very successful as means to reduce the volume and frequency of CSOs. The inline storage projects constructed as part of the Final LTCP are presented in Table 4.1.7 of Volume 2, Chapter 4.

3.2.3.3. OFF-LINE STORAGE

Off-line storage is the term used to describe facilities that store wet weather flows adjacent to the sewer system. Off-line storage facilities have broad applicability and are adapted to site-specific conditions by changing basin shape, size, inlet or outlet type, and disinfection mechanism. Off-line storage may consist of a large single unit or several smaller units operating in an "as-needed" parallel configuration. The multiple-unit configuration allows the first unit to capture the highly polluted first flush. Diversion devices are typically used to pass flow to the other units after the first unit has reached capacity. The use of off-line storage tends to be more expensive than inline storage and is usually considered in areas where in-line storage is insufficient or unavailable. Off-line storage units are an integral part of this Final LTCP. Where feasible, off-line storage units have been optimized in size based on the efficient use of in-line storage and green technologies. The off-line storage units that are included in this Final LTCP are generally located in vacant lots and below grade, which reduces the potential for odors and allows the land above the unit to be utilized for low impact recreation and other uses. MSD currently operates several open basins within the CSS.

Deep tunnel storage facilities are used where large storage volumes are required and opportunities for near-surface storage are unavailable. Deep tunnels are located 100-feet to 400-feet below ground. Tunnel diameters range from 10-feet to 50-feet and many are several miles in length. During dry weather, untreated wastewater is routed around, not through, these off-line storage facilities. In contrast, during wet weather, flows are diverted from the sewer system to the off-line storage facilities by gravity drainage or with pumps. The wastewater is detained in the storage facility and returned to the sewer system once downstream conveyance and treatment capacity become available.

Overflows can occur once the capacity of off-line storage structures is exceeded. Some treatment is provided through settling; however, the primary function of such facilities is storage and the capture of peak wet weather flows. In 2009, storage tunnels were evaluated for the control of CSOs, but were initially found to be cost prohibitive compared to in-line or off-line storage units. Around 2016, MSD re-considered the tunnel option as an alternative to avoid significant offline storage construction in multiple locations, and ultimately selected a tunnel as part of the Final LTCP. A summary of the LTCP project modifications made over time is provided in Table ES-1.3 of the Executive Summary.

3.2.3.4. ON-SITE STORAGE

On-site storage is storage developed at the WQTC. It is most applicable in systems where conveyance capacity exceeds treatment capacity. On-site storage provides operators with the ability to manage and store excess flows. The methods of on-site storage may be either new construction or rehabilitation of under-utilized or abandoned equipment. The costs associated with the development of on-site storage are typically lower than for other storage facilities built outside the bounds of the WQTC. Utilizing abandoned treatment facilities may reduce costs even more. Much of the cost savings derive from siting storage facilities on land already owned by the utility. Sewer system conveyance capacity is a limiting factor with on-site storage and should be analyzed early in the design. In addition, availability of suitable land can be a barrier to on-site storage.

3.2.4. AVAILABLE TECHNOLOGIES - SUPPLEMENTAL TREATMENT

The recent development of wet weather treatment systems presents an alternative to storing excess flows. Supplemental treatment technologies are end-of-pipe controls used to provide some level of physical, biological, or chemical treatment to excess wet weather flows immediately prior to discharge from a CSS. This level of treatment, while less than expected from a conventional WQTC, may significantly reduce the pollutant loads from a CSO. Specific treatment technologies can address different pollutants, such as floatables, settleable solids, and pathogens. However, a major factor determining the feasibility of using treatment facilities is land availability and adjacent land use.

3.2.4.1. PRIMARY CLARIFICATION

The objective of clarification is to produce an effluent treated by gravitational settling of the suspended particles. Sedimentation also provides storage capacity as well as an opportunity for disinfection. Clarification is adaptable to chemical additives, such as lime, alum, ferric chloride, and polymers, which provide higher rates of suspended solids and biochemical oxygen demand, or allow “equivalent primary clarification” to occur at higher loading rates than typically used for primary clarifier sizing.

3.2.4.2. SWIRL CONCENTRATORS/VORTEX SEPARATORS

Vortex separators (swirl concentrators) are designed to concentrate and remove suspended solids and floatables (S&F) from wastewater or stormwater. Flow enters the unit at a controlled tangential velocity and is directed around the perimeter of a cylindrical shell, creating a swirling, vortex pattern. Vortex separators use centrifugal force, inertia, and gravity to divide combined sewage into a smaller volume of concentrated sewage, solids, and floatables, and a large volume of more diluted sewage and surface runoff. The swirling action causes solids to move to the outside wall and fall toward the bottom, where the solids concentrated flow is conveyed through a sewer line to the WQTC. The overflow is discharged over a weir at the top of the unit. Various baffle arrangements capture floatables that are subsequently carried out in the underflow. Removal effectiveness is a function of the hydraulic loading rate with better performance observed at lower loading rates. These devices may be considered "equivalent primary treatment" in some cases, but the variable performance makes this questionable in many applications. Principal attributes of the swirl concentrator are the ability to treat high flows in a very small footprint, and a lack of mechanical components and moving parts, thereby making it less operational and maintenance intensive. This technology, when coupled with disinfection, may provide an acceptable level of supplemental treatment. However, the configuration of most of the CSO outfalls in MSD's system is not conducive to the use of vortex separators, and consistent biochemical oxygen demand and total suspended solids (TSS) removals cannot be assured; therefore, they were not evaluated for selection.

3.2.4.3. HIGH RATE PHYSICAL/CHEMICAL TREATMENT

High rate physical/chemical treatment under this Final LTCP considered two treatment technologies: Ballasted Flocculation and Retention Treatment Basin. Both are traditional gravity settling processes with enhanced flocculation and settling aids to increase loading rates and improve performance. The pretreatment processes for high rate physical/chemical treatment are screening and degritting.

In the first stage of ballasted flocculation a coagulant is added and rapidly mixed into solution. This is followed by a flocculation stage where polymer is added and mixed to form floc particles that will settle in the following stage. Finally, the wastewater enters the gravity settling. Sludge is collected at the bottom of the clarifier and either pumped back to the flocculation stage or removed periodically when sludge blanket depths become too high. Disinfection is applied downstream of clarification, followed by disinfectant residual neutralization. Performance varies with treatment rate and chemical dosages, but in general, removal rates of 80 - 95 percent for TSS and 60 - 80 percent for biochemical oxygen demand can be expected.

Retention treatment basin is considered equivalent primary treatment. For this treatment, polymer only is injected into the wastewater stream, followed by gravity sedimentation. Disinfection is applied downstream of clarification, followed by disinfectant residual neutralization. Performance varies with treatment rate and chemical dosages, but in general, removal rates of 50 percent of TSS and 30 percent of biochemical oxygen demand.

Removal efficiencies for each technology are also dependent on start-up time. In general, the start-up time for ballasted flocculation units, coupled with the high influent peak flow rates, require a substantial storage basin upstream of the treatment unit. There are several locations; however, where retention treatment basins could be effective due to the reduced land requirements of the technology, particularly the CSO015 and CSO191 common outfall, where substantial outfall storage is available to reduce peak inflow rate.

3.2.4.4. DISINFECTION

The objective of disinfection is the control of the discharge of pathogenic microorganisms into receiving waters. The disinfection methods considered for use in CSO treatment include chlorine gas, calcium or sodium hypochlorite, chloride dioxide, ozone, ultraviolet (UV) radiation, and electron beam irradiation. The chemicals are all oxidizing agents that are corrosive to equipment and in concentrated forms are highly toxic to both microorganisms and people. Each disinfection method is described below.

- **Chlorine Gas** - Chlorine gas is effective; however, it is extremely toxic, and its use and transportation are strictly controlled. In addition, it is a respiratory irritant and in high concentrations can be deadly.

- **Calcium or Sodium Hypochlorite** - Hypochlorite systems are common in wastewater treatment installations. For years, large, densely populated metropolitan areas have employed hypochlorite systems in lieu of chlorine gas for safety reasons. The hypochlorite system uses sodium hypochlorite in a liquid form much like household bleach and is similarly effective as chlorine gas although more expensive. It can be delivered in tanker trucks and stored on-site.
- **Chlorine Dioxide** - Chlorine dioxide is an unstable and explosive gas and must be generated on site. The overall system is relatively complex to operate and maintain compared to more conventional chlorination.
- **Ozone** - Ozone is a strong oxidizer and must be applied as a gas. Due to the instability of ozone, it must also be generated on site. Ozone disinfection is relatively expensive with high primary capital cost and high-power consumption during operation. Ozonation is also relatively complex to operate and maintain compared to chlorination.
- **UV Disinfection** – UV disinfection uses light with wavelengths between 40 and 400 nanometers for disinfection. Light of the correct wavelength can penetrate cells of pathogenic organisms, structurally altering DNA and preventing cell function and replication. Because UV light must penetrate the water to be effective, the TSS level of CSOs can affect the disinfection ability. UV disinfection is most applicable downstream of a settling technology.
- **Electron Beam Irradiation** - Electron Beam Irradiation uses a stream of high-energy electrons directed into a thin film of water. The electrons break apart water molecules and produce a number of reactive chemical species, which can kill pathogenic organisms.
- **Emerging Technologies** – Several other disinfection systems are being developed for use in CSO disinfection applications. For example, combinations of hydrogen peroxide and peracetic acid provide effective disinfection of wastewaters with less contact time required as compared to chlorination. MSD is evaluating this technology for potential application in CSO treatment and supplemental disinfection for both chlorination and UV systems during periods of high flow. MSD will continue to monitor the application of emerging technologies as part of the “adaptive management” process. If future developments in disinfection technology indicate that a change in direction in disinfection practice is warranted, MSD will consider modifying its approach to CSO and treatment plant effluent disinfection.

Disinfection reduces potential public health impacts from CSOs however, to protect aquatic life in the receiving waters, dechlorination facilities must be installed whenever chlorination is used as a disinfectant. Dechlorination is typically accomplished by injection of sodium bisulfite in the flow stream before discharge of treated CSO flow to waterways. Dechlorination with sodium bisulfite is rapid; hence, no contact chamber is required since the reaction with chlorine is immediate.

3.2.4.5. DEEP BED FILTRATION

A deep bed filter system consists of a series of large tanks filled with coarse medium; typically sand or anthracite. Excess wet weather flows are directed to the top of each tank and exit at the bottom of the tank. Pollutants either may attach to the filter media or become trapped in the interstitial space of the filter; the filter is later cleaned through backwashing. Chemical additives can be used to improve removal rates.

3.2.4.6. TRICKLING FILTERS

Trickling filters are biological treatment technology for treating excess wet weather flows. In a trickling filter system, microorganisms are maintained as a biological film attached to a fixed media. Supplemental treatment facilities with any biological process must operate continuously with a minimum flow rate to maintain the biomass necessary for treatment of wet weather flows. During dry weather, effluent from biological supplemental treatment facilities is typically returned to the sewer system for further treatment and discharged at the WQTC.

3.2.4.7. CONSTRUCTED WETLANDS

Constructed wetlands use natural biotic systems to treat wastewater. Aquatic plants and bacteria utilize the organic wastes, nutrients, greases, and bacteriological pollution found in CSOs in much the same way as in a traditional WQTC. Constructed wetlands act as both storage and treatment for CSO flows. There are two types of constructed wetlands: subsurface flow and free water surface.

Subsurface flow wetlands consist of a series of planted cells. They are two feet to three feet deep basins filled with rock or other media and vegetated with aquatic plants. These plants hide the rock and feed off the sewage flowing below the surface. These wetlands are designed to not have any exposed sewage. This reduces odor and vector problems making them more acceptable to the public. The downside is that the wholly subsurface requirement greatly reduces the volume treated or stored per acre.

Free water surface wetlands consist of two types of cells. The first type is the open water cell that contains submerged aquatic vegetation. It has a design depth of four feet and cannot tolerate floating aquatic vegetation. The large air to water contact area and penetrating sunlight raise dissolved oxygen and allow for the release of nitrogen gas to the atmosphere. This cell has a high rate physical/chemical treatment of two - three days. Extending the high rate physical/chemical treatment beyond three days, especially in sunny conditions, may cause an algae bloom that would blanket the cell and prevent gas exchange.

The second cell type in a free water surface wetland is the fully vegetated cells. It is heavily vegetated with aquatic plants that either float or grow from the bed and break the surface of the water. Fully vegetated cells are approximately two feet deep. Up to 30 percent of the cell volume is taken up by the flora planted in it. The purpose of the vegetated cell is to prohibit sunlight, drop the dissolved oxygen level, allow anaerobic processes, and kill the algae.

Typically, free water surface wetlands are constructed as alternating open-water and vegetated cells with the first cell being vegetated to trap S&F and enhance settling. The high rate physical/chemical treatment for each cell is two - three days. The process is primarily settling in the first cell with nitrification-denitrification cycle processes beginning as well. The second cell is an open-water cell, which allows for sunlight, algae, and release of nitrogen gas. The cells continue in an alternating series to the point at which the design goals are met. The last cell will always be vegetated to kill any algae. Aeration and disinfection may be added prior to the outfall.

Little energy is required to maintain treatment processes. Typically, energy consumption is limited to pumping if required to deliver CSOs to the wetland area and clear water recirculation pumping during periods of low flow to maintain the health of the facility. Additionally, wetlands provide a storage component with the treatment component. A wetland will typically provide one-million gallons (MG) of storage per acre of wetland. They also provide sanctuary for aquatic flora and fauna. Drawbacks with constructed wetlands are (1) they require relatively large areas of land; (2) treatment processes are slow (especially in cold winter environments); and (3) CSO effluent is left open to the environment.

3.2.4.8. WQTC MODIFICATION

Excess wet weather flows cause sudden changes in the hydraulic and pollutant loads impacting the WQTC. Modifications to existing wastewater treatment facilities can increase their ability to handle wet weather flows. Modifications may involve changes to the physical configuration of various treatment processes and/or the operation of specific plant processes during wet weather. Most modifications require the active involvement of the treatment plant operator to ensure effective implementation. Example modifications that maximize the treatment of wet weather flows include:

- Baffles to protect clarifiers from hydraulic surges and ensure the even distribution of flow
- Using metal salts and polymers to increase suspended solids removal
- Switching the mode of delivering flow from the primary to the secondary treatment units
- Switching from “series” operation to “parallel” operation during wet weather flows

Performance evaluations are required to determine whether additional capacity can be obtained from existing facilities. While facility modifications are generally more cost effective than new construction, some modifications that improve wet weather performance may result in increased concentrations of pollutants in treatment plant effluent during dry weather. For example, if not properly designed, a clarifier modified for wet weather flows may have inadequate settling characteristics during dry weather (Metcalf and Eddy 2003). Further, modifications that require operator attention before and after a wet weather event may interrupt regular dry weather operations and potentially compromise the quality of treated wastewater during dry weather.

MSD has made a significant investment in various unit processes to maximize the treatment capacity of the Morris Forman WQTC to make the best use of the asset that exists and to make the process as effective as possible.

3.2.4.9. INTERACTION WITH OTHER COLLECTION AND TREATMENT SYSTEM OBJECTIVES

The Final LTCP developed is based on a “system-wide, annual average basis” in accordance with EPA‘s CSO Control Policy (1994) using system characterization model (i.e. CSS model) with watershed approach. The CSS model was utilized to explore the following elements, which affects baseline flows and loads:

- Interaction with upstream separate sewer systems
- Integration of current CSO control efforts
- Incorporation of Green Demonstration Projects and Green Infrastructure Program
- Morris Forman WQTC wet weather treatment capacity
- Integration with NMC Program

The CSS provides approximately 46 percent of the total sanitary flow conveyed to Morris Forman WQTC. The remaining flow is contributed by upstream separate sanitary sewer systems (SSS). There are six boundary points in the CSS model where SSS flows contribute to the CSS. The details on model development and location of these boundary points are in Chapter 2, Section 2.4.6.3.

The existing SSSs upstream of the CSS are susceptible to significant wet weather inflow and infiltration. Therefore, the quantities of flow entering the CSS from the SSSs are substantially greater during wet weather periods than during dry weather periods. IOAP Volume 3, the Final Sanitary Sewer Discharge Plan (SSDP), addresses the excessive rainfall-derived infiltration and inflow (RDI/I) in the SSS upstream of CSS.

Because of the interaction between SSSs and CSS within Morris Forman WQTC service area, both LTCP and SSDP controls were developed with the understanding that selected controls for one program will likely affect the other program. Sewer models for both LTCP and SSDP were developed with defined boundary points where information such as flows, and level were exchanged to establish the appropriate boundary conditions for various alternatives.

One example of the coordination between the CSS and the SSSs upstream is the incorporation of Interim Sanitary Sewer Discharge Plan (Interim SSDP) projects into the separate sewer system model to redefine the inflow contributed to the CSS system. Projects defined in the Interim SSDP reduce the significant amount of wet weather inflow contribution to CSS system by reducing RDI/I within the new sewer system and diverting more wet weather flow to Derek R. Guthrie WQTC. Another example was during alternative evaluation phase for SSO controls in the Beargrass Creek Middle Fork watershed. The hydraulic grade line in the upper reach of the CSS was analyzed to determine the maximum water surface elevation and peak flow rate required from the upstream SSS to reduce surcharging and eliminate SSOs near a boundary point.

To establish the “baseline” condition prior to implementation of the Final LTCP, current CSS operating parameters were determined by the hydraulic model to provide a reference for evaluating proposed controls. Current CSO control efforts such as RTC Phase II projects, CSO206 (Cherokee Park) sewer separation project, and other CSO elimination projects that are scheduled are incorporated in the baseline model. More details are documented in Appendix 3.2.1.

Appendix 3.2.1 2008 LTCP System Hydraulic Modeling Condition Technical Memo

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

For the Final LTCP, the watershed approach is multi-scale, ranging from a site-specific solution, to a regional program and it incorporates both “gray” and “green infrastructure” solutions. System-wide green infrastructure opportunity evaluations were performed and a set of specific green projects as well as the Green Infrastructure Program components were identified. The CSS model incorporated the elements of a Green Infrastructure Program such as downspout disconnection, rain gardens, bio-swale, green roof, porous pavement, and dry wells to simulate the reduced stormwater runoff to the CSS. The wet weather treatment capacity at Morris Forman WQTC was confirmed to be 350 MG per day (MGD) peak, and 325 MGD sustainable through stress tests of total plant flows. A firm capacity of 240 MGD was established based on an analysis of available equipment at the plant. Expansion of the Nightingale Pump Station and redirecting wet weather flow to Derek R. Guthrie WQTC was evaluated to increase CSO wet weather flow to the Morris Forman WQTC and reduce CSO to the Beargrass Creek.

3.2.5. APPROACH TO GREEN INFRASTRUCTURE

2021 Update: This section describes the 2009 approach to green infrastructure incorporation in the LTCP. Some updates to dates and numbers are incorporated into this section, where applicable, but the general process is remaining the same as that discussed in 2009. A comprehensive update of the evolution of the program is include in Volume 2, Chapter 4.

Green Infrastructure Projects

- Achieve multiple objectives and provide multiple benefits including:
- Reduction of sewer overflows
- Improvement in air and water quality
- Increased green space and wildlife habitat
- Reduced heat island effect in the urban core
- Additional overflow volume reduction by capture of the initial rainfall
- Community beautification

The purpose of MSD's green infrastructure initiative is to develop a program that reduces CSO frequency, duration and volume utilizing environmentally sensitive techniques that more closely mimic natural hydrologic processes when compared to more traditional engineering solutions or "gray" infrastructure solutions that are typically employed in CSO control programs. Gray infrastructure solutions for CSO control typically consist of large pipes, storage tanks, tunnels, and high rate treatment facilities.

Although conventional engineering alternatives such as high rate treatment, sewer separation, tunnels, and remote storage facilities represent the core elements of MSD's wet weather control program, the opportunities to supplement these conventional engineering solutions with green infrastructure are abundant.

A fundamental principle of the MSD approach is that, while green infrastructure best management practices (BMP) on individual sites are a step in the right direction, a green infrastructure plan that establishes connectivity between neighborhoods, watersheds and ultimately the entire MSD service area results in far greater benefits to the community than the sum of the individual components. Additionally, when compared to gray solutions, the green infrastructure techniques have a much greater potential for leveraging funding from sources other than sanitary sewer and stormwater user fees.

3.2.5.1. GREEN INFRASTRUCTURE INITIATIVE

MSD's proposed green infrastructure initiative involved three main components. These components are a compilation and review of pertinent information, identification, and exploration of green infrastructure opportunities, and development of a recommended green infrastructure plan.

Major Elements of MSD's Proposed Green Infrastructure Plan

- Downspout disconnection program
- Rain barrel program
- Rain garden program
- Vegetated roof program
- Green streets
- Green parking lots
- Green alleys
- Urban reforestation

The recommended plan is the result of comprehensive evaluations of local conditions including soils, geology, hydrology, natural systems, impervious area, topography, parcel ownership, and canopy cover within the CSS area. The proposed green infrastructure plan contemplates a considerable investment by MSD in the design, construction, and implementation of green techniques across the service area to achieve significant reductions in CSO activity. This investment is supported by a "business case" evaluation of the green infrastructure investments to ensure that money spent supporting the Green Infrastructure Program is cost-effective when compared to equivalent levels of CSO reduction achieved through traditional gray solutions.

Conservative estimates indicate that implementation of a long-term green infrastructure plan may remove nearly one billion gallons (BG) of stormwater runoff from the CSS annually at a cumulative cost to MSD of approximately $0.09/gallon to MSD. Preliminary reductions in stormwater volume based on the use of green infrastructure were developed using a green infrastructure costing tool developed as part of the business case evaluation. Based on assumed performance levels of green controls the cost tool takes into account the implementation of various green controls and the drainage area to the BMPs to determine a reduction in stormwater runoff for a Typical Year of rainfall. This is different from the CSS hydraulic model which provides a more conservative estimate of the benefit of the green infrastructure plan because the model represents a continuous simulation and accounts for antecedent moisture conditions, infiltration limitations, and pervious connectivity to storm drains. Additionally, the CSS model is utilized to predict the effects of green infrastructure implementation on the Average Annual Overflow Volumes (AAOV) for each CSO. This AAOV reduction does not match the stormwater reductions into the CSS due to specifics stated above as well as the attenuation and peak flow timing.

Partnering and working with local entities allows MSD to cost share the greater overall investment in green infrastructure lowering MSD's effective cost per gallon. This cost per gallon estimate is comparable to and in many cases much less than, more conventional gray alternatives, such as pipes and storage facilities. In addition, this analysis is based solely on a cost/gallon basis and does not consider the many other benefits that green infrastructure provides.

3.2.5.2. GREEN INFRASTRUCTURE BACKGROUND

The terms of this Consent Decree included the requirements to eliminate SSOs and minimize CSOs. While there are no specific requirements in the Consent Decree regarding the use of green infrastructure BMPs, EPA is certainly encouraging communities to explore innovative techniques and practices such as Low Impact Development and green infrastructure to reduce CSO discharges.

At the national level, the Natural Resources Defense Council released a report titled “Rooftops to Rivers” (June 2006) which identified green infrastructure as a viable strategy for reducing the impacts of CSO discharges on the water quality of our nation’s waterways. This report provides case studies from numerous communities that have successfully incorporated green infrastructure strategies into their CSO reduction programs.

On March 5, 2007, Benjamin Grumbles, the Assistant Administrator of Water for the EPA released a memorandum to the EPA Regional Administrators regarding “Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and other water programs.”

In this memorandum, Mr. Grumbles stated:

> *“Green infrastructure can be both a cost effective and environmentally preferable approach to reduce stormwater and other excess flows entering combined or separate sewer systems in combination with, or in lieu of, centralized hard infrastructure solutions.”*

Mr. Grumbles went on to say:

> *“I strongly support the use of green infrastructure approaches described in the Natural Resource Defense Council report…”*

As MSD initiated the development of the Interim LTCP, a decision was made to aggressively explore green infrastructure opportunities within the CSS area with the goal of developing a comprehensive Green Infrastructure Program that would be integrated into the Final LTCP. While it is recognized that traditional gray solutions will play a major role in the Final LTCP, MSD is committed to maximizing the use of green infrastructure elements in the overall solution matrix. The following is a description of this green infrastructure planning effort and the recommended green infrastructure components.

3.2.5.3. GREEN INFRASTRUCTURE PHILOSOPHY

Estimates indicate that the CSS discharges approximately 2.8 per year of untreated flow to local waterways. As plans were developed to minimize these discharges and comply with the terms of the Consent Decree, MSD realized that a considerable amount of local ratepayers’ dollars was going to be invested in pipes, storage, and treatment facilities throughout the community. While these traditional engineering solutions are effective at reducing the volume of untreated flow discharging to local streams, these techniques may not provide benefits in other important areas such as air quality, wildlife habitat, or urban beautification. Considering the significant community resources that will be directed toward CSO mitigation, it seemed logical to explore innovative approaches that would maximize the benefits to the community for the dollars invested.

The WWT Stakeholder Group assisted MSD in the development of the Final LTCP, supporting and encouraging the development of a Green Infrastructure Program as part of the Final LTCP. Based on a review of local conditions, feedback from the WWT and a review of green infrastructure case study information, MSD identified four principles to guide the development of the Final LTCP Green Infrastructure Program:

- Enhance and preserve natural systems
- Implement green roadways, rooftops, and parking lots
- Foster strategic partnerships
- Connect green infrastructure systems to other community assets

3.2.5.4. STRATEGY

With the guiding principles established, MSD created a strategic approach for the development of the Green Infrastructure Program. MSD recognized that while many communities had successfully implemented green infrastructure elements targeting CSO control, few, if any, had developed comprehensive Green Infrastructure Programs during the initial phases of their LTCPs. MSD viewed this as an opportunity to maximize the role of green infrastructure and the associated benefits to the community.

MSD emphasized the importance in evaluating and integrating green infrastructure opportunities at a variety of physical scales including sites, neighborhoods, sewersheds and regions in order to establish a connected network of green components that merge into a single regional vision. See Figure 3.2-1 for a graphical depiction of the vision that emerged from this effort.

Figure 3.2-1 Graphical Depiction of Green Infrastructure Strategy

Figure is located at the end of this chapter.

MSD used this regional vision to develop a Green Infrastructure Program in order to reduce the amount of stormwater entering the CSS. For the purpose of evaluating the potential stormwater reductions achievable through the use of green infrastructure, the regional evaluation used a 15-year planning horizon. However, as discussed later in the chapter, MSD will assess the performance of green infrastructure demonstration projects and programs during the first six years of implementation with the goal of evaluating and adjusting financial allocations for particular programs based on a benefit-cost analysis. While green infrastructure is an important component of the Final LTCP, MSD's long-range commitment to this program will be based on how green technologies perform in comparison to more traditional gray solutions.

Developing a comprehensive, regional Green Infrastructure Program at the front end of a LTCP effort is an innovative and progressive approach to CSO mitigation and one that is consistent with the recommendations of the Natural Resource Defense Council and EPA.

3.2.5.5. REGIONAL EVALUATION

The regional evaluation process is relatively complex and involves a thorough understanding of site-specific issues within the community including physical, political, financial, and technical parameters. The following section provides a discussion of the eight key steps in completing this process.

Regional Evaluation Step 1 – Identification of Existing Green Infrastructure Programs

The regional evaluations began with a compilation of existing information on current green infrastructure projects and programs throughout Louisville Metro. Numerous green infrastructure activities already underway provide an important stepping-stone for the implementation of MSD's green infrastructure initiative.

Following is an explanation of some of the existing initiatives in Louisville Metro.

1. **Kentucky Green and Healthy Schools**

   According to the Kentucky Green and Healthy School's website, "The Kentucky Green and Healthy Schools Program is a new, voluntary effort to empower students and staff with the tools needed to take action and make their school operate at peak efficiency." Kentucky Green and Healthy Schools incorporates a two-pronged approach as follows:

   - New or renovated schools may include a "green and healthy" design from the start.

- o Existing schools allow students to inventory current school operations and environments in an effort to implement action plans that will improve school health and sustainability."

2. **City of Parks**

   According to **www.LouisvilleKy.gov** the City of Parks is a visionary and aggressive expansion of Louisville's Metro's park system, adding thousands of acres of green space, a 100-mile paved trail encircling the city, and improvement projects at hundreds of existing parks all over the Metro area.

3. **Partnership for a Green City**

   According to the Jefferson County Public School (JCPS) Center for Environmental Education, "the Partnership for a Green City began in August 2004, as a major step toward overcoming challenges to Louisville's environmental practices. The Partnership represents a collaborative effort to improve environmental education, environmental health, and environmental management by three of Louisville's largest public entities: Louisville Metro Government, the University of Louisville, and the JCPS. Most recently, the Partnership, and the three agencies have adopted a *Statement of Environmental Principles*. The *Principles* will be used to guide policy, budget, and program decisions being made by the Partners to incorporate sustainable ideas."

4. **21st Century Parks**

   According to its website, 21st Century Parks was "founded in 2005, and is a Kentucky-based, private, non-profit corporation, created to bring a fresh vision to the preservation and development of new public parklands. Their current project is *The Fork*; planned for eastern and southern Louisville Metro, it will be one section of a new 100-mile loop creating one of the largest new urban park systems in the nation. Building on the visionary effort of former Lt. Governor Steve Henry and The Future Fund, Inc. and joining in partnership with Louisville Metro Government and Louisville Metro Parks; *The Fork* encompasses over 3,000 acres of preserved lands in southeast Louisville."

Each of these existing initiatives has the potential to impact MSD's CSO control efforts and the green infrastructure initiative in particular. MSD will continue to explore opportunities with these key stakeholders to identify mutually beneficial partnerships. See Table 3.2-1 for a partial list of existing programs.

Table 3.2-1 2009 Green Infrastructure Programs With MSD Involvement

ACTIVITY	PARTICIPANTS
Rain Gardens	Youth Build, ACTIVE Louisville
Rain Barrels	Youth Build, Louisville Nature Center
Outdoor Classrooms	Jefferson County Public Schools (JCPS), Partnership for a Green City
Riparian Buffers	Metro Parks/Olmsted Parks Conservancy
Invasive Species Removal	Metro Parks, Olmsted Parks Conservancy, Living Lands and Waters
Stream Clean-Up	Living Lands and Waters
Litter Clean Up/Beautification	Operation Brightside
Community of Trees	Louisville Metro Council, Metro Parks, Housing Authority, Muscular Dystrophy Association, Operation Brightside

The importance of these partnerships and strategic collaboration on projects with other entities is further discussed below.

Regional Evaluation Step 2 – Establish Project Awareness and Potential Project Partners

Impervious surfaces such as streets, parking lots, and rooftops are the major source of runoff in the CSS Area. While a considerable amount of land within the CSS is publicly owned, (nine percent), MSD owns a very small percentage (0.2 percent) of this land. Therefore, in order for MSD to implement effectively a source control strategy, partnerships with local property owners are essential.

In recent years downtown Louisville Metro has been the beneficiary of considerable redevelopment activities. As the trend continues, development and re-development projects in the CSS represent opportunities for MSD to partner with both public and private entities to encourage, incentivize and/or fund the construction of green infrastructure to reduce stormwater runoff entering the CSS. Incorporating green techniques into a site plan is most effectively accomplished if the green components are developed early in the process.

A key element of MSD's overall green strategy is to identify partnership opportunities throughout the community. There are numerous public agencies in Louisville Metro with plans to invest significant amounts of money over the next decade in the construction and upgrade of public infrastructure including streets, schools, parks, highways, and public housing. Each public project represents an opportunity to incorporate green infrastructure. By coordinating the design and construction of green controls into planned public projects, MSD will realize stormwater reduction benefits at a fraction of the cost compared to retrofitting green controls after the planned projects are built.

MSD staff has put considerable effort into the development of partnerships with other local public agencies to evaluate the potential to incorporate green components into planned capital improvement projects. For example, JCPS has a five-year capital improvement plan budget of $50 million for upgrades to local schools. There are 45 public schools located in the CSS and JCPS has budgeted $5.5 million for roof and site improvements for these schools.

MSD and JCPS have agreed to work together to create "win-win" projects that meet the needs of the school district while reducing the runoff from the sites. Numerous green infrastructure concept plans have been developed, including those for Roosevelt Perry Elementary and Engelhard Elementary schools.

MSD has also initiated discussions with other agencies including Louisville Metro Housing and Metro Public Works. Both agencies have expressed considerable interest in green techniques and a willingness to incorporate green elements into planned capital projects where feasible. Other agencies MSD has met with include:

- Mayor's Office
- Economic Development
- Private Developers/Architects/Engineers/Landscape Architects
- Metro Parks/21st Century Parks/Future Fund
- City of St. Matthews
- ACTIVE Louisville
- Partnership for a Green City

- Kentucky Association of Festivals
- Neighborhood Associations

These entities are potential project partners that could become “green ambassadors” promoting the inclusion of green infrastructure throughout the community.

Regional Evaluation Step 3 – Existing Green Infrastructure Initiatives Mapping

Awareness of other activities, developments, and programs within the MSD service area will allow MSD to make informed decisions about where their green efforts should be focused and how they may incorporate green infrastructure components into others’ activities. This is an ongoing effort intended to identify opportunities for MSD to promote the incorporation of green infrastructure techniques into projects being funded by other local agencies at their earliest stages. In certain instances, MSD may decide to partner with these agencies to design and/or construct green infrastructure elements into these projects.

MSD has compiled information on existing Green Infrastructure Programs and planned projects and created Geographic Information System (GIS)-based maps to facilitate the integration of these projects into the community-wide green vision. Figure 3.2-2 displays some of these key programs and opportunities in the community that support and augment MSD’s green vision. These include the Community of Trees planting plan, proposed urban redevelopment projects, bikeways, existing and proposed green infrastructure projects, rain barrels, and other green infrastructure initiatives.

Figure 3.2-2 Existing Potential Green Activities (August 2009)
Figure is located at the end of this chapter.

Regional Evaluation Step 4 – Impervious Area Evaluations

MSD’s Consent Decree mandates the minimization of overflows from the CSS. Wet weather CSOs occur when too much stormwater runoff enters the CSS and the system capacity is exceeded resulting in discharges directly to local receiving streams. A root cause of the excessive stormwater runoff is impervious surfaces. As landscapes are developed and natural vegetation is replaced with pavements and rooftops, the rate and volume of stormwater runoff that occurs during precipitation events dramatically increases.

Ideally, post construction green infrastructure techniques would be designed to match the pre-development hydrology of the system in terms of infiltration, evaporation, and runoff. Obviously, this is not realistic, particularly from the perspective of retrofitting a highly urbanized environment. However, a Green Infrastructure Program designed to reduce CSOs must decrease the amount of impervious surface and/or reduce the volume of runoff entering the CSS.

Impervious Surfaces in the CSS

The following is a breakdown of the primary land use types and distribution of the total impervious area throughout the CSS.

- Roads – 26 percent impervious
- Single Family – 27 percent impervious
- Industrial Property – 17 percent impervious
- Commercial Property – 13 percent impervious
- Other – 17 percent impervious

A detailed impervious area evaluation was performed for the entire combined sewer area – which totals approximately 37 square miles utilizing available information in the Louisville Jefferson County Information

Consortium (LOJIC) GIS database. The objective of this evaluation was to determine the distribution of impervious surfaces and their relative significance throughout the CSS. This information is critical in identifying major categories of impervious surfaces and in selecting appropriate green techniques to reduce stormwater from these sources. This evaluation was a significant factor in the development of the regional plan.

The result of this exercise revealed that the CSS contains approximately 500 million square feet (sq. ft.) of impervious area, which represents approximately 19 square miles, or 51 percent, of the combined system. This total impervious area was further divided into specific categories including rooftops, roadways, and parking lots. The area of each surface type was determined, along with the relative percentages of each, in relation to the total impervious area contained within the CSS. Roads represent 135 million square feet, buildings 187 million sq. ft. and parking, sidewalks and driveways represent another 183 million sq. ft. of hard surface.

Additionally, an impervious area evaluation by land use type was performed. This evaluation showed that 36 percent of the impervious surfaces in the CSS are located on publicly owned property, including roadways. Schools account for over eight million sq. ft. of impervious surface while MSD owned property comprises only 1.2 million sq. ft. of hard surface, underscoring the importance of partnerships.

See Appendix 3.2.2 for a detailed description of the impervious area distribution within the CSS. Figure 3.2-3 is a map showing the extent of impervious surfaces within the combined system.

Appendix 3.2.2 Impervious Area Evaluation

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Figure 3.2-3 Impervious Surfaces within the CSS

Figure is located at the end of this chapter.

In summary, in order for the Green Infrastructure Program to have a major impact on CSO reduction in Louisville Metro, the program will need to target roads, residential properties, and some percentage of industrial/commercial land uses.

Regional Evaluation Step 5 – Natural Systems Evaluations

Natural systems such as stream networks (existing and historical), soils, geology and wetlands were evaluated and considered in the identification of opportunities to implement green infrastructure. With the stated goal of promoting techniques that are consistent with the natural hydrologic cycle, an important first step in the green evaluation process was to develop an understanding of natural systems. This understanding involves reviewing locations, capacities, and suitability to accommodate additional runoff, including historic resources that are now less visible.

Historic maps were reviewed in an effort to better understand the evolution of natural drainage systems for the CSS Area. Information was compiled showing the location of stream networks, historic wetlands, and major pond features from over one hundred years ago. Many of these streams and drainage features are no longer evident.

Appendix 3.2.3 Historic and Natural Systems Mapping

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Figure 3.2-4 is map from the Civil War era that shows where streams once existed west of downtown and how the Beargrass Creek and other features have been modified over time. Appendix 3.2.3 contains other historic and natural systems mapping that were compiled as part of this effort.

Appendix 3.2.3 Historic and Natural Systems Mapping

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Figure 3.2-4 Historic Civil War Map

Figure is located at the end of this chapter.

A general philosophy of MSD's green approach is to capitalize on these natural systems to allow them to function more as nature intended to provide beneficial functions. The urbanization of cities has involved the systematic replacement of streams and wetlands with hard surfaces and piping networks. The result has been a lower groundwater table, lower base flows in our streams, higher peak flows in the streams during wet weather and an overall change in the natural hydrologic and hydraulic cycle.

As shown in Figure 3.2-5, under natural conditions a large percentage of annual precipitation either infiltrates or evaporates with only approximately ten percent of rainfall resulting in runoff. Land use changes associated with urbanization can have a dramatic effect on this overall water balance resulting in large increases in runoff volumes and corresponding decreases in infiltration and evaporation.

Figure 3.2-5 Runoff Scenario in Natural Conditions

Figure is located at the end of this chapter.

A key objective of MSD's green infrastructure approach is to protect this natural water balance in less developed and undeveloped areas of the community especially with anticipated land use changes. The second half of the objective is to restore, where supported by the business case, the natural hydrologic balance that existed in the downtown area prior to major urbanization. By understanding the natural systems, specific practices can be implemented to restore or enhance the pre-developed function of the land.

The Green Infrastructure Program contemplates the use of existing natural systems and the replacement of impervious surfaces with vegetated surfaces to both minimize runoff and to convey redirected runoff from the CSS to existing natural systems. Both of these approaches should assist in reducing CSOs.

Regional Evaluation Step 6 – Tree Canopy Coverage

As discussed above, downtown Louisville Metro is comprised of significant amounts of impervious surfaces. With the increase of hard surfaces such as roads, parking lots and buildings there is usually a corresponding decrease in tree canopy cover. The loss of canopy cover can have a significant impact on stormwater runoff.

As noted on EPA's website: [See EPA fact sheets in Appendix 3.2.4].

> *"A study done by the U.S. Department of Agriculture's Center for Urban Forest Research found that a medium-sized tree can intercept 2,380 gallons of rain per year" (Center for Urban Forest Research 2002).*
>
> *"Trees also absorb carbon dioxide, decrease temperatures, and provide habitat for urban wildlife. Urban forestry also reduces noise levels and provides recreational benefits."*

Appendix 3.2.4 EPA Tree Canopy Fact Sheets

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

With the proper tools, types of plants, planting, and maintenance, reforestation can effectively reduce both the pollutants in, and the volume of, stormwater. The nonprofit organization American Forests conducted a study in the Houston area to document urban forest covering a 3.2-million-acre area. They also analyzed 25 specific sites with aerial photography using CITYgreen software to map and measure tree cover. Study results show that trees provide significant benefits relative to the quality and quantity of stormwater runoff and energy savings. The study found that Houston's tree cover reduces the need for stormwater management by 2.4 billion cubic feet per peak storm event, saving $1.33 billion in one-time construction costs (ENN, 2001).

A CITYgreen evaluation was performed for the CSS area. CITYgreen is GIS software that analyzes the ecological and economic benefits of tree canopy and other green space. CITYgreen was developed by American Forests, a pioneer in the science and practice of urban forestry. The software works only in conjunction with analysis software from the Environmental Systems Research Institute. In addition to computing air pollution removal and carbon storage, this software application computes stormwater runoff using the Natural Resource Conservation Service model. CITYgreen software has been successfully used by major cities across the nation to implement Green Infrastructure Programs.

The results of the CITYgreen exercise, summarized in Table 3.2-2, indicate that the current canopy cover, which is only 11 percent of the CSS area (2,600 acres), represents over $30 million in one-time stormwater storage benefits to the community, in lieu of constructing stormwater detention facilities. The evaluation further indicates that by increasing canopy cover to the point where it represents 26 percent of the CSSA, or 6,200 acres would provide an additional $43 million in stormwater storage benefits. For more information about the CITYgreen exercise please see Appendix 3.2.5.

Appendix 3.2.5 CITYgreen Analysis

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Table 3.2-2 Stormwater Storage Benefits Based on an Increase in Tree Canopy (2009)

	TREE CANOPY		ONETIME STORMWATER STORAGE BENEFITS
	ACRES	% OF CSSA	CITYGREEN EXERCISE
Existing Conditions	2,600	11%	$30,000,000
Increase Tree Canopy	6,200	26%	$73,000,000

In addition to the increase in stormwater storage benefits, other benefits associated with a 26 percent tree canopy cover include:

- Carbon stored: 266,600 tons total
- Carbon sequestered: 2,100 tons per year
- Air pollution removal: 629,700 lbs per year

The Clifton neighborhood, located on the east side of the CSS, was selected as a pilot area to conduct a more detailed and accurate CITYgreen evaluation. Canopy cover values were developed by manually digitizing aerial photographs. It was determined that approximately 45 percent of the study area has impervious surfaces and 20 percent is tree canopy. The CITYgreen analysis indicated that the current canopy represents $1.1 million in stormwater storage benefits. This benefit could be increased by $500,000 if only 15 percent or 29 acres of the existing impervious surface area were replaced with tree canopy.

As part of the evaluation, a review of Louisville Metro’s Land Development Code for canopy cover requirements for various land uses were compared to target values established by American Forests, Inc. Louisville Metro’s current regulations exceed recommended values for urban residential land uses but have significantly lower requirements than suggested for suburban land uses (refer to Figure 3.2-6).

Figure 3.2-6 Tree Canopy Evaluation Results

Figure is located at the end of this chapter.

Regional Evaluation Step 7 - Stormwater Redirection

Sewer separation is a common technique used to reduce CSOs. While this is an effective technique from a CSO discharge reduction perspective, it may simply move the additional stormwater runoff from one pipe system to another and can aggravate a number of other concerns associated with urbanization such as water balance, loss of habitat and low base flows in local streams.

In order for redirection of runoff from the CSS to be a viable part of the CSO control program, an alternative conveyance system to transport stormwater flows needs to be identified. The natural systems mapping exercise revealed: with the exception of the Beargrass Creek, few natural drainage features remain within the CSS. However, a number of local streams, particularly in the southwest section of Louisville Metro, are located in close proximity to the outer edge of the CSS boundary.

Figure 3.2-7 shows the delineation of the CSS system and the local stream networks. A review of this map indicates that there may be potential to separate stormwater from areas near the outer boundary of the CSS and redirect this flow to existing streams located outside the CSS area. This approach is referred to as "offloading." Further evaluation of these streams will need to be performed to ensure that the additional flows do not create new or aggravate existing problems such as hydromodification or flooding prior to actual implementation of these types of projects.

Figure 3.2-7 CSS System and the Local Stream Networks

Figure is located at the end of this chapter.

A study area, delineated by a dashed line in Figure 3.2-8 that parallels the CSS boundary but is located ¼ mile inside the existing perimeter, was established for the purpose of further exploring this option. Figure 3.2-8. This zone contains approximately 8,000 acres and generates approximately four BG of stormwater runoff annually. Successful redirection of even a small percentage of the runoff generated in this area would result in significant reductions in flow to the CSS. Several focus areas along this boundary were identified through this process and will be discussed further in Section 3.2.5.7.

Figure 3.2-8 Study Area to the CSS for Stormwater Redirection

Figure is located at the end of this chapter.

Regional Evaluation Step 8 – Subsurface Evaluations

Many green infrastructure techniques rely on infiltration as the primary mechanism to achieve runoff volume reductions. Soils and geology are important components in determining if and where stormwater runoff can be infiltrated into the subsurface. Soil permeability plays a major role in the design configuration and the functionality of certain green control techniques. High permeability rates can reduce the footprint and/or profile of a proposed green component resulting in very cost-effective designs. Understanding local soil characteristics is very important in the development of a recommended program. Unfortunately, adequate soils information was not readily available for the CSS area. The soil information contained in the LOJIC database for the CSS area simply showed a single polygon with the classification of "urban soils." The Natural Resource Conservation Service database showed slightly more detail, but the core downtown region of Louisville Metro was still labeled "Urban Area."

Therefore, MSD worked with a local geotechnical engineer with years of experience in the Louisville Metro area to evaluate further the soils and geology in this region. A generalized map of soil and rock conditions was generated using a combination of published subsurface data, engineering experience, and local records of excavations and soil test borings within the CSS boundaries. This map, while somewhat coarse, provides a general guide for directing the types of green techniques that are applicable in the different regions throughout the Louisville Metro area. While this evaluation is an important tool to guide the selection of BMPs, it is only a preliminary delineation and site-specific evaluations will be necessary for final design.

Figure 3.2-9 is a geologic map of Kentucky, which shows that the Louisville Metro is located on the western edge of the geological formation known as the Cincinnati Arch. The eastern portion of the Louisville Metro is located in the uplifted fringe of this formation. In addition to having greater topographic relief than the western part of the City, the geologic characteristics of east Louisville Metro differ significantly from the rest of the City. The eastern portion of the CSS, particularly in the Beargrass Creek area, is dominated by bedrock forming karst uplands with sinkholes. The karst geology in this area contains limestone bedrock with sinkholes that may be considered for infiltration if supplemented with biofiltration strategies.

Figure 3.2-9 Kentucky Geologic Map

Figure is located at the end of this chapter.

The following is a brief description of the results of the subsurface evaluation:

- The Louisville Metro area is composed of two basic geologic settings: deposits related to past activities and alignments of the Ohio River (alluvium) and residual soils (soils weathered in place) derived from limestone and shale layers.
- The downtown area is immediately adjacent to the Ohio River and lies on deep sand and gravel layers extending down about 100 feet to limestone.
- The west part of the city also was formerly located in the riverbed but has more recently been part of backwater, or slower, depositional characteristics. These conditions produced silt and clay layers over the deeper alluvial strata.
- To the south, the depth to rock becomes much shallower, and the upper rock surface is composed of relatively impermeable shale. The combination of the fine-grained backwater soils and the impermeable rock creates very soft, poorly drained conditions. Easily weathered shales on the slopes along the southern edge of the CSS area add slope instability to the soft conditions.
- The eastern and southeastern portion of the Louisville Metro is composed mainly of fine-grained soils, but these are residual soils weathered from shale and limestone. The soils typically are moderately to highly plastic clays, low in permeability. The residual deposits are relatively thin and overlay variably solutioned limestone. Sinkhole development is common, particularly in those areas underlain by the Jeffersonville limestone formation.

Published data from the United States Geological Survey (USGS) and the Natural Resource Conservation Service were used to draw approximate boundaries between the aforementioned conditions. Experience with soil test borings and excavation was referenced to refine those boundaries and define a number of "classifications" for soil conditions within the CSS project area. Those classifications indicated that:

- Several areas in the center and the west of the CSS area would be suitable for green methodologies involving discharge of surface water runoff into the subsurface.

- Some sections in the north-central and southwest portions of the subject area were found to be suitable for shallow infiltration methods, such as bioswales, green streets, and green parking lots.
- Areas in the west and north central were identified as appropriate for applications, which discharge runoff deeper in the subgrade (drywells) where shallow fine-grained (lower permeability) deposits overlay more permeable sands and gravels.
- The eastern and southeastern sections of the CSS area were considered to be very sensitive due to the possibility of sinkhole development with the introduction of runoff into subsurface conditions where subsidence over karst terrain is possible.
- The subsurface conditions map (see Appendix 3.2.6) divides the CSS area into six different zones based on shallow soils and geology types.

Appendix 3.2.6 Regional Soils Evaluation

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

The six zone delineations are as follows:

- Zone 1 – Alluvium: shallow infiltration due to recent deposits of sand, gravel, and silt
- Zone 2 – Clay: typically, 5 - 20 ft. of low permeability, risk of sinkhole activity
- Zone 3 – Clay with shallow shale: no shallow infiltration, unstable on slopes
- Zone 4 – Loess: unconsolidated silt over shallow shale
- Zone 5 – Outwash: silts and clays in the upper 15 - 20 ft., sands below grading to gravel
- Zone 6 – Terrace: silts and clays in upper 15 - 20 ft., over shale

Special conditions, such as second- or third-generation redevelopment and old underground utilities, were noted as being pertinent with regard to the suitability of subsurface discharge methods and the possible corresponding problems. These conditions were identified as being characteristic of particular areas so that they became considerations when green methods were suggested for specific sites. Most of the northern part of downtown Louisville Metro is second- or third-generation construction, and past demolition methods involved razing old buildings and pushing the debris into the subsurface on the site. Typically, fine-grained fill soils, such as silty clays, have been compacted over the debris-filled layers to create building pads. The resulting subsurface conditions include large voids. Runoff flowing down through such deposits can transport the fine-grained fill into the voids in the deeper strata, causing subsidence to occur under existing structures. In addition, numerous old utilities are present throughout downtown, most of which act as conduits for water flowing down through the soil. Increasing runoff to zones containing such utilities can cause dropouts and large volumes of subsidence. Known sites containing old debris and abandoned utilities were avoided when considering potential sites for green demonstration projects.

A number of older buildings in downtown also were constructed at a time when excessive groundwater was not considered in design. Infiltration of significant volumes of runoff into the foundation bearing soils and basement wall backfill around such buildings could cause structural problems, so the general locations of these buildings were considered when evaluating specific green application locations.

A final condition evaluated for the soils map was the presence of large contamination zones in the sand and gravels layers in the center and western portions of the combined sewer service area. Published environmental records were reviewed to identify areas of significant contamination so that green measures, such as dry wells, would not expand contamination plumes or otherwise exacerbate existing problems. Refer to Appendix 3.2.7 for a map showing the contaminated regions in the CSS. Refer to Figure 3.2-10, at the end of this chapter, showing the hydric soils result in a soil with distinctly different properties than non-hydric soils.

Figure 3.2-10 Flood Zones

Figure is located at the end of this chapter.

Appendix 3.2.7 Contamination Regions

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Regional Evaluation Summary

The eight steps in this regional evaluation process are a unique effort that was designed specifically for the MSD's green infrastructure process. By completing a comprehensive regional green infrastructure planning initiative at the front end of the Final LTCP, MSD is poised to be a national model for the use of green infrastructure in the control and mitigation of combined sewer overflows. A graphical depiction summarizing the results of this complex regional evaluation has been developed and is presented in Figure 3.2-11. This regional plan will serve as the roadmap to guide Louisville Metro to a greener, more livable, and sustainable future.

Figure 3.2-11 Graphical Depiction of Regional Evaluation

Figure is located at the end of this chapter.

3.2.5.6. CSO SEWERSHED EVALUATIONS

Much of the data generated during the regional sewershed evaluation provided valuable information that opened opportunity for detailed assessments of green opportunities at a smaller scale. The CSS area is divided into over 100 smaller sewersheds that generally represent the local drainage area to a particular permitted overflow point. These individual sewersheds provided logical study units for performing this detailed evaluation.

Each sewershed with an active overflow was reviewed for potential green opportunities. For the purpose of consistency, a standard set of criteria was developed to evaluate each sewershed basin. The following is a brief description of the criteria that were used for this exercise:

- Public alleys were considered for porous pavements.
- Publicly owned buildings were candidates for green roofs.
- Mapped sinkholes were considered for stormwater offloading.
- Publicly owned green spaces were considered for biofiltration techniques.
- Publicly owned parking lots were considered for biofiltration techniques.
- Catch basins in Zone 5 were considered for dry wells.
- Residential housing in Zone 5 was considered for downspout disconnection.

In addition to this standardized set of criteria, the following information was included on each opportunities map, to assist in with the green evaluation:

- Overflow characterization (volume, duration, and frequency)

- Percent tree canopy
- Number of catch basins
- Population

The purpose of this assessment was to objectively examine each sewershed and identify the potential opportunities to implement green infrastructure within that particular study area. The result of this exercise was the generation of approximately 100 maps of individual sewersheds, each with specific green infrastructure opportunities identified. Refer to Appendix 3.2.8 for Individual CSO Basins for the green infrastructure opportunities maps for each sewershed.

Appendix 3.2.8 Green Opportunities Maps for Individual CSO Basins

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

This assessment task was not intended to provide a detailed evaluation of each of the identified opportunities but rather to understand the various types of opportunities and their relative significance across the CSS. With this understanding, MSD identified a short list of green infrastructure techniques along with candidate locations to evaluate further for the implementation of various demonstration projects.

Information obtained from LOJIC data served as the basis for this evaluation and included the following data:

- Imperviousness
- Land use
- Public ownership
- Single family homes
- Commercial/Industrial property

Each of these categories is described in more detail below.

Imperviousness

As discussed earlier, an impervious area is a root cause of CSOs. The result of increased impervious surface is an increase in both peak discharge rates of stormwater runoff and an increase in the overall volume of stormwater runoff. In the CSS, all this additional stormwater runoff must be conveyed by a pipe network that in some cases is over 100 years old. When the capacity of the CSS is exceeded, overflows occur. Therefore, developing a Green Infrastructure Program that emphasizes source control requires that the distribution of impervious surfaces within each sewershed be determined.

The data contained in the LOJIC database allowed for a more detailed evaluation of imperviousness for individual basins. In general, impervious areas were divided into three major categories: rooftops, roadways, and miscellaneous transportation areas such as parking lots, sidewalks, and driveways.

By evaluating the impervious area distribution within each individual sewershed and evaluating this in the context of a particular CSO, MSD can begin to target particular types of impervious surface and identify effective green infrastructure techniques to reduce the associated runoff.

Land Use

Land use is important in this process because the types of impervious surfaces are directly linked to land use types. Land use distribution was calculated for each sewershed based on identified categories. These categories included residential, commercial, industrial, parks and open space and public space.

This data helps determine which green infrastructure techniques may be most appropriate for a particular area. For example, in an area comprised predominantly of residential land use, most of the impervious surface is residential rooftops and roadways. Therefore, a recommended Green Infrastructure Program targeting this area would need to identify techniques that are suitable for these types of impervious surfaces and would likely not anticipate a large benefit from a control such as a green roof program.

Public Ownership

Using data provided by LOJIC, public properties within each basin were identified and included police stations, fire stations, post offices, schools, and other government buildings. The total roof area and parking lot area associated with publicly owned lands were calculated for each sewershed basin. This determined how much public property was contributing to the imperviousness of the sewershed. Public buildings were marked as a potential for a green roof and public parking lots were marked as a potential for permeable pavement or biofiltration techniques. In order for the MSD green initiative to be successful, major property owners within the CSS will need to become partners in the implementation of green infrastructure techniques. Large land-owning public agencies represent good candidates to fulfill this need.

Single Family Homes

Utilizing LOJIC data, the number of single-family homes and associated rooftop area, in each sewershed, was calculated based on the “Single Family” land use delineation. This determined the total single-family rooftop area that contributed to the imperviousness of the basin. Based on the size of the residential parcels, the density of the homes, the percentage of the impervious area, and the subsurface conditions of the area, a ranking of good, fair, or poor was given to each basin regarding the potential effectiveness of a downspout disconnection program.

Commercial/Industrial Property

The LOJIC database contains land use information that delineates commercial and industrial properties from other land use types. While MSD is actively working with this sector in new and redevelopment projects to educate and incentivize green practices, MSD has opted to be very conservative in its estimates of green benefits in the context of the Final LTCP and therefore has not projected CSO reductions from projects in this land use class.

3.2.5.7. NEIGHBORHOOD AND FOCUS AREA EVALUATIONS

An important outcome of the regional evaluation was the identification of seven focus areas recommended for further evaluation. While each site has unique characteristics, they all represent opportunities to:

- Offload or remove significant amounts of stormwater runoff from the CSS
- Partner with a public agency
- Establish connectivity of green spaces

The focus areas and the associated CSO reduction projects discussed below represent conceptual solutions only. Each area will require additional study to determine the feasibility of the proposed techniques. Most of the proposed concepts involve a combination of green and gray infrastructure technologies.

Focus Area 1 – Northwest Area

Focus Area 1, located in the northwest portion of the combined sewer service area is comprised of residential and industrial land uses with a significant amount of Right of Way (ROW). A total of 272 acres have been identified within this Focus Area 1.

Based on an analysis of existing surface drainage patterns, soil characteristics and available land area the following green infrastructure opportunities exist:

- Redirect stormwater runoff from the interstate system to biofiltration facilities and dry wells located in the I-264 ROW.
- Capture, treat, and redirect runoff from rail yard to facilities in I-264 ROW.
- Construct porous alleys in local neighborhoods.
- Separate storm sewers in local neighborhoods and redirect to the biofiltration facilities and dry wells located in the I-264 ROW.

Refer to Figure 3.2-12 for the features and conditions of the Northwest Focus Area.

Figure 3.2-12 Northwest Green Focus Area
Figure is located at the end of this chapter.

Focus Area 2 - Northeast Area

Focus Area 2, located in the northeast portion of the combined sewer area is comprised of residential, industrial, natural stream network and a significant amount of ROW. Based on an analysis of existing surface drainage patterns, soil characteristics and available land area the following green opportunities exist:

- Separate storm sewers in local neighborhoods and redirect to stream system or biofiltration, wetlands and/or sinkholes facilities along stream corridor.
- Enhance local greenway system and establish greater connectivity between neighborhoods.
- Incorporate green infrastructure controls into major planned State highway corridor reconfigurations adjacent to the Ohio River.
- Capitalize on existing neighborhood organizations and areas with public support for green infrastructure through targeted downspout disconnection programs, rain barrel distribution, and residential rain garden installations.

Refer to Figure 3.2-13 for the features and conditions of the Northeast Focus Area.

Figure 3.2-13 Northeast Green Focus Area
Figure is located at the end of this chapter.

Focus Area 3 – South Central West Area

Focus Area 3, located in the south-central west portion of the combined sewer area is primarily residential land use along with a number of schools and some ROW. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Separate storm sewers in local neighborhoods and redirect to adjacent stream networks.
- Create strategic partnerships with local schools to incorporate green infrastructure components on school properties that also provide educational opportunities.
- Implement green infrastructure techniques on Louisville Metro Municipal Housing Authority property.
- Retrofit existing detention facilities to incorporate water quality-based design elements and/or infiltration components.

Refer to Figure 3.2-14 for the features and conditions of the South-Central West Focus Area.

Figure 3.2-14 South Central West Green Focus Area
Figure is located at the end of this chapter.

Focus Area 4 - South Central East Area

Focus Area 4, located in the south-central east portion of the combined sewer area is comprised of residential, industrial and a significant amount of interstate ROW. This focus area has tremendous opportunity to forge valuable strategic partnerships. Key landowners in this area include Kentucky Exposition Center, Kentucky Transportation Cabinet, University of Louisville, Churchill Downs, and Louisville International Airport.

There are a relatively high percentage of pavements in this study area in the form of parking lots, roadways, and runways contributing large amounts of stormwater runoff to the CSS. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Redirect stormwater runoff from the interstate system to biofiltration facilities and dry wells located in the I-65 ROW.
- Install pervious pavements in large parking lot areas.
- Incorporate vegetated stormwater controls into existing large parking lot areas.
- Implement green street practices.
- Increase canopy cover.

Refer to Figure 3.2-15 for the features and conditions of the South-Central East Focus Area.

Figure 3.2-15 South Central East Focus Area
Figure is located at the end of this chapter.

Focus Area 5 – Southwestern Parkway Area

Focus Area 5, located in the southwestern parkway portion of the combined sewer area is comprised primarily of residential land use along with interstate ROW. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Strong potential for green street techniques at multiple scales of roadway systems ranging from local, to collector to state highways.
- Potential to utilize various techniques to control roadway runoff ranging from dry wells to biofiltration to rain gardens.
- Utilize interchange area in State ROW for infiltration of runoff.
- Separate storm sewers in two local neighborhoods and discharge directly to the Ohio River.
- Utilize green streets to provide connectivity to local parks.

Refer to Figure 3.2-16 for the features and conditions of the Southwestern Parkway Focus Area.

Figure 3.2-16 Southwestern Parkway Green Focus Area
Figure is located at the end of this chapter.

Focus Area 6 – Southwest Greenway and Parkway Area

Focus Area 6, located in the southwest greenway and parkway portion of the combined sewer area is comprised of residential, industrial, interstate ROW, and a utility corridor. This Focus Area includes an existing MSD detention basin and a natural stream. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Potential to develop a greenway connection
- Ability to enhance existing detention basins
- Opportunity to work with strategic partners
- Potential to infiltrate into glacial outwash

Refer to Figure 3.2-17 for the features and conditions of the Southwest Greenway and Parkway Focus Area.

Figure 3.2-17 Southwest Greenway & Parkway Green Focus Area
Figure is located at the end of this chapter.

Focus Area 7 – Central Business District Area

Focus Area 7, located in the Central Business District portion of the combined sewer area is comprised of mostly impervious surfaces including buildings, roadways, and large parking lots. This central downtown area provides a great opportunity to utilize green controls to capture runoff while connecting the community. The following green opportunities exist:

- Strong potential for green street techniques at multiple scales of roadway systems ranging from local to collector streets.
- Potential to retrofit existing buildings with vegetated roofs
- Opportunity to retrofit existing parking lots with biofiltration techniques or rain gardens. Refer to Figure 3.2-18 for the green street concept plan for the Central Business District Focus Area.

An initial test site was installed in 2007 at a parking lot for the Girl Scouts of Kentuckiana's new headquarters on Lexington Road.

Figure 3.2-18 Central Business District Green Focus Area
Figure is located at the end of this chapter.

As discussed, each Focus Areas will require additional evaluation to determine which, if any, of the proposed concepts are in fact feasible. Stormwater offloading, strategic partnerships and the use of natural systems are key elements to each area. Each proposed project has the potential to have a significant impact on both the green infrastructure initiative as well as MSD's overall CSO mitigation program, which may translate into the elimination and/or reduction of proposed gray controls.

Additional maps for each focus area can be found in Appendix 3.2.9.

Appendix 3.2.9 Seven Focus Areas
Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

3.2.5.8. SITE EVALUATIONS

As previously mentioned, MSD has worked intensely to develop effective partnerships, where multiple entities benefit from implementation of green infrastructure practices. A good example of this effort is the relationship MSD has developed with JCPS. MSD has worked with JCPS to develop green concept plans for two schools - Roosevelt Perry Elementary and Engelhard Elementary - both located within the CSS. These concept plans provide the schools with new site plans that incorporate green elements, enhance the functionality of the sites, improve aesthetics, and provide a reduction in stormwater runoff entering the CSS.

Roosevelt Perry Elementary is located on the west side of Downtown Louisville Metro. This site has approximately 2.5 acres of impervious surface. The existing site is somewhat disjointed with parking adjacent to and close to the building, while playground areas are located around the corner of an adjacent building next to a very busy road. Currently, the runoff from this site discharges directly to the CSS – approximately 2.3 MG per year. A revised site plan was developed that addresses the needs of JCPS and targets the reduction of runoff from the site. The proposed plan incorporates pervious pavements, bio-swales, a small vegetated roof, outdoor educational space, and a cistern and curbs extensions that result in an estimated 79 percent reduction (1.8 MG) of annual runoff to the CSS. Additionally, the parking was moved to the perimeter of the site, hard and soft playground areas were moved to the middle of the property, and outdoor classroom facilities were located just outside of the existing school.

The Roosevelt Perry concept plan also represents a great example of the benefits that a multi-scaled approach can achieve. Interviews with school officials determined that most of the students enrolled in this school live in the adjacent neighborhoods. The concept plan incorporates revised street designs that improve pedestrian safety through the use of vegetated curb bump outs at cross walks that serve as a traffic calming element and also infiltrate stormwater runoff from the roadways. Simple modifications to an adjacent, underutilized park create a more valuable community asset and a badly needed functional playground for an urban school. The multi-scale site plan should serve as the catalyst for a meaningful partnership between JCPS, Metro Parks, Public Works, and MSD that collectively achieves far more community benefit by targeting limited resources at an integrated, coordinated plan.

Engelhard Elementary, the second concept plan site, is located just south of Downtown Louisville Metro. The site is comprised of one building, a parking lot, and a grass play area. Approximately 1.8 acres of impervious surface discharge approximately 1.8 MG per year directly to the combined sewer. The green concept plan incorporates pervious concrete, a bio-retention swale, reinforced turf, and curb cuts resulting in an estimated reduction of 1.4 MG per year to the CSS. In addition to the green elements, the proposed concept plan relocated the play area closer to the school, dramatically improved traffic flow through the site and provided much needed parking facilities.

According to the 2007 JCPS Facility Needs Survey, there is $75,000 worth of site and pavement work planned for Engelhard in the next five years. Discussions are currently ongoing, between MSD and JCPS to determine the benefits and logistics of implementing the proposed plan or some version of it.

Each of these schools provided an opportunity to demonstrate the importance of evaluating individual sites from a variety of perspectives. While the specific conditions of each site were improved in terms of stormwater runoff, safety, traffic flow and parking, each proposed plan stepped beyond the parcel boundaries of the individual school site to identify opportunities to effectively integrate these school sites into a larger context of the neighborhood and the sewershed (refer to Appendix 3.2.10).

Appendix 3.2.10 Concept Plans

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

3.2.5.9. GREEN INFRASTRUCTURE DEMONSTRATION PROJECTS

Upon completion of the green CSO sewershed evaluations, workshops were conducted to review the results of each of the basin evaluations. The result of these workshops was the identification of a subset of basins that were deemed to be candidates for more detailed evaluations with the objective of selecting 19 green infrastructure demonstration projects. Site visits were performed at each of the candidate locations and an evaluation was performed that considered numerous factors including property ownership, public visibility, soils, geology, basin size, proximity to adjacent structures and age of those structures.

The result of this effort was the selection of 19 potential locations in the CSS for the construction of green infrastructure projects that generally can be categorized into five major component types. These types are biofiltration, green alleys, green streets, dry wells, sinkholes and wetlands creation or restoration. Greater detail of each of these component types is presented in the following pages. As further discussed below, the dry well demonstration projects were replaced as part of 2012 IOAP Update.

Biofiltration Techniques

Similar to most highly urbanized areas, downtown Louisville Metro contains a high percentage of impervious area. One of the primary objectives of the green infrastructure effort is to replace hard infrastructure with vegetation where practical. Biofiltration techniques provide a means to reduce stormwater runoff, promote groundwater recharge, maximize evapotranspiration, and reduce the total impervious surface in the CSS. While biofiltration is an important component of this program, the performance of infiltration techniques in downtown areas may be negatively impacted as a result of the compaction of native soils that typically occurs in urban settings. MSD will explore techniques such as soil aeration to enhance the ability of public green spaces to infiltrate stormwater runoff.

From a geologic standpoint, several types of alluvial deposits underlie downtown Louisville Metro. Some areas contain fine-grained layers near the ground surface, but silty sands and sands at depths of less than five to seven feet underlie many portions of central and south-central downtown. Such relatively permeable conditions are conducive to effective installation and function of bioswales.

Parking lots provide ample opportunity to cost effectively utilize biofiltration techniques. Based on the impervious area evaluation, parking lots represent a significant portion of the impervious area within the CSS. Retrofitting existing parking lots and redirecting runoff to vegetated perimeters and medians will effectively and efficiently reduce the volume of water entering the combined system. Five parking lots were identified as candidates for demonstration projects. These sites were selected based on the presence of relatively permeable stratigraphic conditions in the subsurface and the absence of any indication of leaking or malfunctioning infrastructure or sensitive building foundations in the immediate vicinities of the chosen sites. If properly designed these systems will reduce the runoff from the site and provide needed green space to these large impervious areas. Appendix 3.2.11 provides some cross-sectional details for this type of green infrastructure technique.

Appendix 3.2.11 Biofiltration Technique Cross Sections
Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Parking lots were identified as candidates for demonstration projects at the following locations:

- CSO053 – MSD Main Office Parking Lot Biofiltration Swale
- CSO053 – Seventh and Cedar Green Parking Lot
- CSO181 – Second and Broadway Green Parking Lot
- CSO198 – Third and West Ormsby Biofiltration Swales
- CSO022 – Sixth Street and Muhammad Ali Green Parking Lot

Rain Gardens

Rain gardens are vegetative systems used to intercept runoff from relatively small drainage areas. Runoff directed to rain gardens is reduced through infiltration and evapotranspiration practices. MSD has been implementing a residential rain garden program for many years. See Section 3.2.5.10.

In an effort to expand the application of this technique to the urban setting, MSD has identified one site downtown to construct a rain garden. The site is within the sewershed of CSO028 and located at Sixth Street and Broadway. Additionally, MSD is committed to identifying four additional sites within the first year of the program to more fully evaluate the applicability of rain gardens to reduce CSOs in the downtown area.

Green Alleys

The transportation network in downtown Louisville Metro includes a large number of alleys - over 500 in the CSS area. A partnership between MSD and Louisville Metro Public Works would facilitate the utilization of porous pavement technology during the alley renovation process and could prove to be a cost-effective technique for CSO control.

As stated previously, many portions of downtown Louisville Metro are underlain by silty sand and sand deposits that allow infiltration rates suitable for the installation of porous pavements. Many portions of west Louisville also include similar subsurface conditions, and alleys were included in almost all of the original road construction in that area. A limiting factor, however, is the widespread presence of old, leaking infrastructure under and in close proximity to many alleys. Increased infiltration into the subgrade around these compromised pipes and associated structures could lead to subsidence under the alleys and surrounding structures. Therefore, green alleys were chosen with special consideration of available information on the existing active and inactive infrastructure.

While there are numerous porous pavement technologies available including porous asphalt, porous pavers, bricks with spacers, etc., the technology selected for these demonstration projects is pervious concrete. Two types of alley configurations were selected for these demonstration projects. The first configuration assumes that the entire alley surface would be replaced with a pervious concrete surface. The other configuration assumes that only a 4-foot wide center strip of porous concrete will be constructed. Appendix 3.2.12 provides typical details for pervious concrete.

Pervious concrete contains less lime and finer particles than ordinary concrete.

Appendix 3.2.12 Porous Concrete Cross Sections

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

The following three alleys were identified as candidate demonstration projects:

- CSO015 – Seventeenth and W Hill Permeable Alley
- CSO053 – Seventh and Market Permeable Alley
- CSO121 – Campbell and Main Permeable Alley

Green Streets

A large percentage (27 percent) of the impervious surfaces in the CSS is associated with roadways. Green street techniques have the potential to play a significant role in MSD's Green Infrastructure Program. While numerous configurations ranging from street edge alternatives, to sidewalk planters, to porous pavements are all components of green streets, this evaluation did not identify the specific techniques to be used in the demonstration project, but rather recognized that each street will require a site-specific design.

Stratigraphy suitable for the green street application is similar to that of green alleys, so the same areas of downtown were evaluated for potential candidates. Some green street techniques allow a slightly deeper discharge depth, such as street edge solutions, but for the purposes of this part of the project, areas with relatively shallow (five feet to seven feet deep) silty sands and sands were considered. Many of the possible green street locations included open space on adjacent parcels to minimize the risk of destabilization of shallow, soil-bearing foundations by saturation of the bearing soils.

One location - Housing Authority Property: Beecher Terrace in CSO208 was identified for a green street demonstration project. This location includes shallow foundations at a distance of at least 40 feet from the nearest infiltration point. This distance was considered to be sufficient to minimize the chances of saturating the foundation bearing soils. General assumptions for cost and performance were utilized for the evaluation with the understanding that these values would need to be refined once a final concept plan was developed for the site.

Dry Wells

Dry well construction was considered to have a high potential for offloading surface water runoff from the CSS in the central and western portions of the CSS area. Dry wells can have a relatively high capacity compared to other green infrastructure techniques, and they typically are used in areas where surficial fine-grained clays and silts reduce shallow infiltration rates and prohibit the effective use of methods like bioswales and green streets.

A dry well typically consists of a concrete pipe section that is inserted into the ground and transports runoff from an existing stormwater sewer line to permeable layers in the subsurface. The dry well system can include any number of filtration devices to prevent contaminants from being discharged into the aquifer. The number and type of such devices depends on the origin of the runoff and the presence of other filters prior to the runoff entering the sewer system.

To develop a dry well properly, a soil test boring should be advanced at the location of the proposed dry well. The stratigraphy revealed by the boring should be evaluated to determine at what depth soil permeability will permit infiltration rates that will allow rapid discharge of surface water runoff into the subsurface. The boring information also should be used to characterize groundwater levels in order to define boundaries between saturated and unsaturated zones. After permeability and groundwater conditions have been established, the structure can be sized assuming an infiltration rate at a given discharge depth.

Dry wells proposed to be used in the MSD project likely will be constructed to discharge at depths of 15 to 25 feet below the ground surface into fine- to medium-grained sands. Groundwater levels in the target zones in the western and north central portions of the CSO area have been recorded to be between 30 feet and 65 feet below the ground surface causing the proposed dry wells to discharge in the unsaturated zone. As a result, infiltration rates will be required to be estimated, and conservative estimates will be used.

A number of potential dry well locations were identified on publicly owned parcels where soil test borings on nearby sites indicated sands and gravels at depths of 15 to 20 feet below the existing ground surface. Several public agencies, including the Louisville Metro Housing Authority and the JCPS expressed their willingness to allow dry well construction on their properties in order to further the green initiative. See Appendix 3.2.13 for a standard dry well cross-section.

Appendix 3.2.13 Dry Well Cross Sections

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

The construction of dry wells will most likely require obtaining an Underground Injection Control permit. In Kentucky, the Underground Injection Control permitting process is administered through EPA - Region 4 in Atlanta. The agency requires that a form be completed detailing the location of the proposed dry well, the type of construction and documentation on any known sources of contamination in the area, or any vicinity-wide plumes of contamination. The data is reviewed to determine if the feature will be introducing any new contaminants into the aquifer or will be attenuating any existing plumes of contamination. If the EPA does not believe the dry well poses a significant risk to the quality of the aquifer, a rule authorization is granted. See

Appendix 3.2.14 for a copy of the required form. Table 4.1-1 (in Volume 2, Chapter 4) lists the demonstration project alternatives that were constructed, including those that replaced the five dry well demonstration projects due to excessive time required for study and permitting for the dry well projects.

Appendix 3.2.14 Dry Well Rule Authorization Form

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Five candidate locations were selected for the construction of dry wells.

- CSO189 – I-264 Off-Ramp Dry Well
- CSO019 – I-264 On-Ramp Dry Well
- CSO191 – I-264 and Gibson Dry Well
- CSO191 – Russell Lee Drive Dry Well
- CSO191 – JFK Montessori Area Dry Well

Sinkholes and Wetlands

There is a possibility that sinkholes with well-defined throats could be used as dry wells. Dry well installation is common in the karst terrain in southern Indiana and central Kentucky. Solution features in the calcareous rock layers (usually limestone) were formed by groundwater flow, so a discharge capacity of some volume typically is present in the rock layers beneath a sinkhole of substantial size. The difficult part of developing a dry well in a sinkhole is evaluating the capacity and determining whether the solution features in the immediate zone beneath the upper rock surface are clogged with soil fines and may be flushed out with hydrostatic pressure. Specific geotechnical evaluations will be necessary before discharging any additional runoff to the subsurface in the eastern portion of the CSO area, due to the potential of causing karst-related subsidence.

A dry well in a sinkhole is constructed in much the same manner as a dry well in an alluvial stratigraphy. The most significant difference is that considerable work must be completed to identify the throat, which is the opening in the upper rock surface into the network of solution features.

Placement of dry wells in sinkholes is difficult because there is no order or regularity to the location of such features. The probability of a sinkhole with adequate capacity to receive runoff being located on accessible property near sewer structures with significant flow is low. However, several closed contour depressions were identified in areas where stormwater runoff could be offloaded from the CSO system. One such location is in close proximity to a delineated wetland adjacent to the Beargrass Creek. Preliminary plans have been discussed to separate nearby sewers and discharge the flow to the existing wetland area. The wetland would need to be expanded and enhanced and reconfigured to allow large flows to discharge directly to a very large existing sinkhole feature.

Exploration of the sinkhole for capacity should be performed by exposing the throat and doing a series of pump tests in which water is discharged into the feature in several manners. One test should include a large volume of water in a short flow duration, to simulate a brief, intense precipitation event. At least one other test should be conducted by discharging a steady flow into the feature for an extended time to explore constant flow capacity, intermediate storage, and possible silting in.

This project represents an opportunity to utilize a natural system for stormwater control, improve an existing resource, and potentially reduce and/or eliminate a gray control. Due to the unique nature of this project, a more detailed preliminary evaluation can be found in Appendix 3.2.15.

Appendix 3.2.15 Wetland/Sinkhole Preliminary Evaluation

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

The 19 proposed demonstration projects will cost approximately $1.5 million to implement and will remove an estimated 10 MG of stormwater from the CSS annually. But more importantly, these projects represent an opportunity to demonstrate various green techniques, develop more accurate and locally based cost information and monitor their performance.

3.2.5.10. GREEN PROGRAM DEVELOPMENT

In addition to the 19 demonstration projects, MSD's recommended green infrastructure plan includes six programs elements. These program elements are downspout disconnection, rain barrel program, residential rain gardens, green roof incentives, urban reforestation, and dry wells.

These programs were implemented on a regional level by MSD in an effort to reduce CSOs, as well as to raise public awareness of the responsibility that individuals have in protecting and enhancing our local water resources. Each of the green programs, and costs associated with their implementation, is described in more detail below.

It is important to note that for the purpose of evaluating the potential stormwater reductions achievable through the use of green infrastructure, the regional evaluation used a 15-year planning horizon. However, as will be discussed later in the document, MSD assessed the performance of green infrastructure demonstration projects and programs during the first six years of implementation with the goal of evaluating and adjusting financial allocations for particular programs based on a benefit-cost analysis. MSD finalized the details for a regional downspout disconnect and rain barrel programs. In addition, MSD will define a more formal strategy for developing programs, such as a vegetative roof incentive or urban reforestation program, that deal with public and private partners as the demand for such infrastructure increases and funding is available.

Concurrent with the development of the green programs, MSD completed all 19 demonstration projects. The completion of these demonstration projects could support development of more formal partnership arrangements with other local agencies such as Metro Housing Authority, Public Works, and JCPS. Successful implementation of the demonstration projects should provide a level of confidence in the community to more readily commit to widespread application of specific techniques on public property outside the control of MSD that can then be translated into formal green programs, including budgets and implementation levels, for elements such as green streets, permeable alleys, and green parking lots.

Special Note: Through December 2020, MSD has completed all green infrastructure demonstration projects as well the other green infrastructure program elements, totaling nearly $45 million for an incremental system benefit. MSD's plan to capture and treat or remove 95 percent of the systemwide CSO volume exceeds the 85% requirement of the CSO Policy Presumption Approach. Additional or future green infrastructure projects are not necessary to achieve the required percent capture. The approach presented throughout Chapter 3 to develop and implement the program remains accurate. Chapter 4 presents the work completed and performed relative to the Green Infrastructure Program.

Downspout Disconnection

Single-family rooftops account for 18 percent of the impervious area within the CSS area. By disconnecting roof downspouts, a significant portion of this impervious area can be removed from the combined system. MSD will develop an incentive-based Downspout Disconnection Program to target the stormwater entering the CSS from residential land use.

The proposed program will offer homeowners financial incentives per disconnected downspout. The financial incentive will motivate homeowners to participate in the program and should result in higher participation rates.

Utilizing LOJIC data the total square footage of single-family rooftops was calculated for each basin. Field surveys of approximately 30 basins were conducted in an effort to determine the percentage of single-family homes with downspouts that are directly connected to the CSS. The results of this effort indicated that, on average, approximately 65 percent of parcels have downspouts that were directly connected to the combined sewer. In estimating the potential benefits of the downspout disconnection program in basins that were not field surveyed, it was assumed that 65 percent of the total residential rooftop area was available for disconnection. For those sewersheds where field surveys were conducted the actual percent of downspouts connected was utilized in the evaluation.

In estimating the potential stormwater reduction from this program, each basin was given a rating of high, medium, or low for both effectiveness and participation. The "effectiveness" rating was based on criteria such as soil conditions, lot size and density of the homes. This variable is intended to provide an estimate of the percentage of the stormwater removed during the disconnection that somehow flows back into the CSS through either direct or indirect means. Even if a downspout is disconnected from the CSS, some of the redirected runoff still have the potential to re-enter the CSS.

The "participation" rating was based on local knowledge of the neighborhoods and types of residents within the area. A 10 percent participation rate implies that 10 percent of the homes will participate in the program. However, note that based on assumptions stated above, even if a homeowner agrees to participate, for the purposes of this evaluation, stormwater reduction estimates only assume that 50 percent of the roof is disconnected.

Furthermore, because of the potential for sinkhole creation, green components that require shallow infiltration will not be recommended on the eastside of the CSS area without further geotechnical investigation. Therefore, basins that were tagged as not suitable for infiltration, based on the regional soils evaluation, discussed in Section 3.2.6.4, were automatically given an implementation rate of zero. After further investigation, certain areas in this region will be eligible for a downspout disconnection program, thus increasing the benefit of the program.

Utilizing the matrix in Table 3.2-3, an estimate of the stormwater removal effectiveness was determined for each sewershed. For example, if for a particular sewershed the participation rate is estimated to be low, but the effectiveness of disconnected water remaining out of the CSS is medium, then the matrix indicates that the program will in effect, removing 10 percent of the roof area from the CSS.

The results of each sewershed evaluation were combined and totaled. Using conservative estimates for each program variable, it has been estimated that once fully implemented the downspout disconnection program will remove approximately seven percent of connected single-family roof area from the CSS that translates into the removal of 134 MG of stormwater annually. To see specific reductions for each basin and a program flowchart please see Appendix 3.2.16.

Table 3.2-3 Downspout Disconnection Stormwater Reduction Matrix

		Effectiveness: LOW	Effectiveness: MEDIUM	Effectiveness: HIGH
PARTICIPATION	HIGH	15%	35%	40%
PARTICIPATION	MEDIUM	10%	25%	35%
PARTICIPATION	LOW	5%	10%	15%

Utilizing the matrix in Table 3.2-3, an estimate of the stormwater removal effectiveness was determined for each sewershed. For example, if for a particular sewershed the participation rate is estimated to be low, but the effectiveness of disconnected water remaining out of the CSS is medium, then the matrix indicates that the program will in effect, removing 10 percent of the roof area from the CSS.

The results of each sewershed evaluation were combined and totaled. Using conservative estimates for each program variable, it has been estimated that once fully implemented the downspout disconnection program will remove approximately seven percent of connected single-family roof area from the CSS that translates into the removal of 134 MG of stormwater annually. To see specific reductions for each basin and a program flowchart please see Appendix 3.2.16.

Appendix 3.2.16 Downspout Disconnection Reductions and Program Flow Chart

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Based on an evaluation of anticipated administrative and reimbursement costs, $250 per downspout was used to establish a program budget. The cost for program management and marketing costs was derived from data provided by the City of Portland, Oregon Stormwater Retrofit Program Manager.

Table 3.2-4 Downspout Disconnection Program Costs

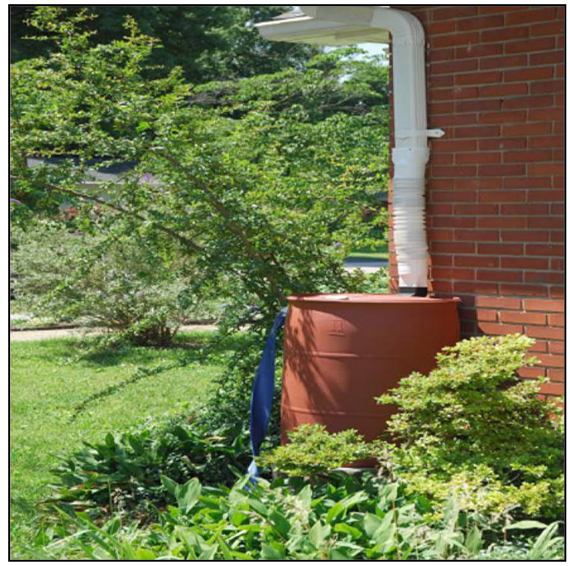
DOWNSPOUT DISCONNECTION PROGRAM COSTS	
Estimated Program Cost per Downspout	$250
Estimated Downspouts Disconnected	1,545
TOTAL	$386,000

The program participation estimates assume that 1,545 downspouts will be disconnected annually, which equates to approximately $0.05 per gallon removed. MSD will strategically perform geotechnical evaluations for basins originally marked as unsuitable for downspout disconnection in order to increase the overall effectiveness of this program.

As stated earlier, the 15-year timeframe is used for planning purposes only to estimate potential long-term reductions in stormwater runoff to the CSS. Many assumptions have been made regarding the performance of this program that will need to be evaluated during the first six years of implementation. Therefore, while downspout disconnection is envisioned to be an important component to the Final LTCP, MSD's long-range commitment to this program will be based on the cost effectiveness of this technique in comparison to more traditional gray solutions.

Rain Barrel Program

Rain barrels are an effective way to educate the public about CSOs and provide an opportunity for homeowners to actively participate in the reduction of overflows. MSD currently has a rain barrel program in place and has distributed rain barrels to over 350 residents within the MSD service area. The current program is being performed in partnership with Youth Build and the Louisville Nature Center. However, MSD will continue to explore other opportunities to increase overall distribution and use of rain barrels throughout the CSS area.



Rain barrels collect and store rainwater from the roof to use later for watering. Each barrel provides storage for 58 gallons of water.

Table 3.2-5 Rain Barrel Program Costs

ANNUAL RAIN BARREL PROGRAM COSTS	
Estimated Program Cost per Rain Barrel	$165
Estimated Rain Barrel Target	1,000
TOTAL	**$165,000**

Because MSD cannot control rain barrel use and maintenance, the potential reductions of stormwater runoff provided by rain barrels will not be included in the Final LTCP, in terms of downsizing proposed gray controls. As the number of rain barrel installations increase, MSD may begin to realize volume reduction benefits of this program. If monitoring suggests a measurable decrease in the stormwater entering the CSS as a result of this program, MSD will re-evaluate how this program can be incorporated into the Final LTCP. See Appendix 3.2.17 for a program flowchart.

Appendix 3.2.17 Rain Barrel Program Flow Chart

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

MSD's program will develop and distribute annual brochures to homeowners with rain barrel tips and information on proper operation and maintenance. In addition, MSD will continue to distribute marketing information and pamphlets, make presentations at public meetings, and use other techniques to encourage and educate homeowners throughout the community to participate in the rain barrel program.

For budgeting purposes, MSD assumes 1,000 rain barrels will be distributed annually. This will result in an annual program cost of approximately $165,000. See Table 3.2-5 for a more detailed breakdown of annual costs.

Private Property Rain Garden Program

A residential rain garden program provides MSD with an opportunity to enhance the downspout disconnection program. By assisting homeowners with the proper redirection of downspouts to an appropriately sized rain garden, both MSD and homeowner's benefit.

Table 3.2-6 Private Property Rain Garden Program Cost

ANNUAL RAIN GARDEN PROGRAM COSTS	
Estimated Program Cost per Rain Garden	$1,300
Estimated Rain Garden Installation Target	24
TOTAL	**$31,000**

MSD has developed an educational manual, *A How-To Guide for Building Your Own Rain Garden*, to assist homeowners with the design and implementation of a residential rain garden. Interested homeowners are encouraged to contact MSD for information about installing a rain garden on their property. The residential rain garden program requires that homeowners actively participate in the planning and construction phases. If desired by the homeowner, MSD staff will assist with plant selection, design calculations, and construction. Appendix 3.2.18 shows the MSD flowchart for program implementation.

Rain Garden on Harvard Street

Appendix 3.2.18 Residential Rain Garden Program Flow Chart

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Based on MSD's experience, the costs to construct residential rain gardens, including plants, range from $1,000 to $2,500. The actual costs are affected by the size of the garden and level of participation by the homeowner with construction and plant selection activities. For budgeting purposes, MSD assumes design and construction of 24 rain gardens per year.

Green Roof Incentive Program

Vegetated roofs, or green roofs, are vegetated areas that are designed as part of a roof system. While this technology has been used in Europe for many years, it is only in recent years that vegetated roof systems have become an accepted practice in the U. S. These systems can be utilized on commercial, industrial, or residential roofs. Data from monitored vegetated roof systems indicate a significant reduction in annual runoff from these systems when compared to more traditional metal or asphalt roofs.

The following information, taken from the EPA fact sheet on green roofs (See Appendix 3.2.4 presents the results of a green roof performance study:

> *Penn State Green Roof Research Center has also noted a decrease in both total stormwater runoff and peak flow discharge. […] In this 1+ inch storm event, the green roofs captured approximately 25% of total runoff compared to the conventional roofs. Over the period from May 23, 2003 to June 1, 2003, 2.21 inches of rain fell, of which the green roof detained 1.05 inches (~47 %). The center noted that the spring of 2003 was wet and cool.*

A number of both public and private entities involved in new development and re-development activities in the MSD service area have been considering the installation of vegetated roofs. MSD has performed evaluations at a number of MSD owned buildings regarding the structural suitability of existing facilities to be retrofitted with vegetated roofs. MSD is committed to demonstrating this technology and an appropriate site will be identified to install a vegetated roof.

However, MSD recognizes the potential benefits that green roofs represent in terms of stormwater reductions to the CSS and has evaluated approaches to encourage or incentivize more widespread application of this technique throughout Louisville Metro. An evaluation of the potential benefits that MSD would realize from the installation of a green roof indicated that a square foot of a typical vegetated green roof ranges from $3.00 - $5.00 in equivalent “gray” CSO control.

A number of details associated with this program still need to be finalized. Issues such as design and performance standards, reimbursement levels for different types of vegetated systems, stormwater credits, plan review and approvals, inspections and maintenance issues still need to be finalized. However, MSD is committed to this program and has developed a budget for implementation.

Table 3.2-7 Green Roof Program Costs

ANNUAL GREEN ROOF PROGRAM COSTS	
Estimated Program Cost per Square Foot of Green Roof	$4.00
Estimated Square Foot of Green Roof Installed	222,900
TOTAL	**$892,000**

MSD estimates that the average stormwater benefit for installation of a vegetated roof is $4 per square foot. For budgeting purposes, the following assumptions have been made:

- Ten percent of public buildings will install vegetated roofs (1.8 million sq ft)
- Two percent of commercial buildings will install vegetated roofs (504,000 sq ft)
- Two percent of industrial buildings will install vegetated roofs (753,000 sq ft)

Based on these assumptions, over three million sq. ft. of vegetated roofs will be constructed in Louisville Metro over the next 15 years. At an average of $4 per square foot, this equates to $13.4 Million.

As stated earlier, the 15-year timeframe is used for planning purposes only to estimate potential long-term reductions in stormwater runoff to the CSS. Many assumptions have been made regarding the performance of this program that will need to be evaluated during the first six years of implementation. Therefore, while a green roof incentive program is envisioned to be an important component to the Final LTCP, MSD’s long-range commitment to this program will be based on the cost effectiveness of this technique in comparison to more traditional gray solutions.

Urban Reforestation Program

Urban reforestation is the practice of enhancing and restoring vegetative cover in urban areas. Trees provide natural control of stormwater runoff as well as other benefits such as improved air quality, increased wildlife habitat, and cooler temperatures.

A number of studies have been completed to evaluate the annual stormwater runoff reductions that a single urban tree can achieve. According to an article from *Stormwater: The Journal for Surface Water Quality Professionals:*

> *“Horticulturists note that trees' weekly water needs equal 5 gal. plus 5 gal. per caliper inch. For example, a 2-caliper-inch tree needs 15 gal. (5 + [5 x 2] = 15) weekly. This calculation, of course, is for minimum needs; many trees can take in more water.”*

Based on this information, a 2-inch caliper tree would require at a minimum 780 gallons per year. According to the New York City (NYC) Department of Parks and Recreation, the average NYC tree captures 1,432 gallons of stormwater each year. Research published in June 2005 and conducted in the city of Minneapolis by the Center for Urban Forest Research indicated that a tree could soak up to 2,000 gallons annually.

An evaluation of the system-wide unit cost ($/gallon) of gray solutions determined the marginal unit cost of gray controls (based on the unit cost per gallon to go from eight to four overflows per year) is approximately $0.30 per gallon. Using $0.30 per gallon as a basis, MSD could justify spending up to $240/tree (medium sized) based on the reduction in stormwater entering the CSS. However, MSD is committed to this program and has developed a preliminary budget for implementation.

The cost of trees varies substantially depending on the size and type of tree and the location for the proposed planting. Section 3.2.5.5 suggested that existing canopy cover in the CSS be increased by approximately 2,000 acres. Assuming that a medium sized tree has a 20-foot canopy, approximately 139 trees would be required to provide an acre of canopy cover and 278,000 trees to achieve the recommended goal. MSD can play a subordinate yet important role in this effort.

Based on the estimated benefits that trees provide to MSD and the community, the Green Infrastructure Program recommends that MSD allocate funds annually to promote and enhance tree planting programs throughout the City. The program will include financial assistance to a variety of programs including sapling giveaways and cost sharing in urban streetscape programs.

Based on the results of this evaluation, MSD will explore opportunities to work with other public and private entities within the Louisville Metro area to increase the current tree canopy by at eight percent over the duration of the Consent Decree. See Table 3.2-8 for program costs.

Table 3.2-8 Urban Reforestation Program Cost

ANNUAL URBAN REFORESTATION PROGRAM COSTS	
Estimated Program Cost per Tree	$240
Estimated Trees Planted	933
TOTAL	**$224,000**

Dry Wells

The geology of the west side of Louisville Metro – Zone 5 on the soil map (Appendix 3.2.6) – is suitable for deep infiltration techniques. The recommended green program suggests evaluating the feasibility of utilizing dry wells throughout this area as a mechanism to off load flow from street inlets into the subsurface. This approach has been successfully employed in other CSO communities, most notably in Portland, Oregon.

MSD owns approximately 18,000 inlets in Zone 5. For the purpose of estimating potential benefits from this program, assume that 50 percent of these street inlets will be directed to a dry well system. The estimation also assumes that each inlet has a drainage area of approximately 7,500 sq. ft. and that each dry well will receive flow from two existing inlet structures. If fully implemented, this program could remove 1.4 BG of stormwater from the CSS annually.

The most significant concern regarding dry wells is the potential challenge the permitting of these facilities presents. EPA Region 4 administers the Underground Injection Control Program in Kentucky. A dialogue needs to occur between EPA Region 4 and MSD to gain a better understanding of the extent of these requirements.

Because of the highly permeable soils present in the CSS area, MSD has elected to pursue the use of dry well technologies as part of the Final LTCP. The purpose of the demonstration project is to evaluate the feasibility of permitting dry wells as a stormwater control technique and to obtain a better understanding of the cost implications of complying with the permitting requirements. Based on the results of the demonstration projects, MSD will determine if it is appropriate to include dry wells as a component of its regional green infrastructure Programs.

Dry well costs vary significantly based on type of construction, size, and depth. Dry wells installed in other communities with average diameters of four feet to six feet and average depths ranging from 15 feet – 25 feet have had costs of $15,000 to $40,000, including exploratory costs and engineering evaluation.

Because of the significant impact on stormwater flows that this program represents, MSD is committed to exploring the feasibility of this technique for LTCP compliance. However, until the permitting issues are resolved, MSD will not assume any benefits from this program in the context of the LTCP and has not established program budget for dry wells.

3.2.5.11. GREEN COST TOOL

To ensure that the proposed Green Infrastructure Program is in fact cost effective, a green infrastructure cost/performance tool was developed. The two primary components of the MSD green plan include both programs and projects. Programmatic elements include such items as downspout disconnection and rain barrel distribution while the project components include items such as green streets and green alleys.

The differentiating factor between the two components is that programs will be implemented across large portions of the CSS area, while projects will be more localized and site specific. The green infrastructure cost/performance tool is a spreadsheet that computes costs and benefits (in terms of stormwater reduction) for both elements - programs and projects. This planning level tool integrates assumptions ranging from implementation levels, to costs, and stormwater reductions.

The purpose of the demonstration projects is to evaluate many of the assumptions that were used in the development of the cost tool. However, it is important to note that while MSD is committed to implementing an aggressive Green Infrastructure Program, MSD will direct appropriate resources toward those green components that are demonstrating the most benefit for the money invested. Therefore, the cost tool will likely be frequently updated to reflect actual cost and performance data and provide MSD with a mechanism to readily adjust program and project allocations in an effort to maximize the benefits achieved through implementation of the Green Infrastructure Program.

The components evaluated in the green cost tool include:

- Programs
  - downspout disconnection
  - rain barrels
  - vegetated roof
  - urban reforestation
- Projects
  - green parking lots
  - dry wells
  - green streets
  - green alleys
  - biofiltration

For each component, the costing model considers a projected implementation rate and an estimated effectiveness. In some instances, for example downspout disconnection, these values are derived on a sewershed-specific basis and then summarized to produce an overall result.

For other components such as green alleys, benefits are derived by taking a standard performance value (gallons removed per year) and typical unit costs and applying these values to an estimated number of green alley projects expected to be constructed. This results in projected benefits of the program in terms of cost per gallon of stormwater removed on an annual basis.

This green cost tool allows MSD to compare proposed green infrastructure components to alternative gray controls by sewershed, or on a regional level. In situations where gray controls are relatively expensive, it may make sense to pursue more aggressively green controls. In other instances, green techniques may not be part of the recommended solution.

The results of the regional evaluation indicate that when implemented, the recommended green plan may remove nearly one BG of stormwater from the CSS at a cost of approximately $0.09/gallon to MSD. Preliminary assumed reductions in stormwater volume based on the use of green infrastructure were developed using the green costing tool developed as part of the business case evaluation, as previously discussed. This is different from the CSS hydraulic model which provides a more conservative estimate of the benefit of green because the model represents a continuous simulation and accounts for antecedent moisture conditions, infiltration limitations, and pervious connectivity to storm drains. Additionally, the CSS model is utilized to predict the effects of green infrastructure implementation on the AAOV for each CSO. This AAOV reduction does not match the stormwater reductions into the CSS due to attenuation and peak flow timing. This evaluation, which is intentionally conservative in terms of estimating green performance, reveals that green infrastructure can be a very cost competitive solution, with successful partnerships and cost sharing, when compared to more traditional gray controls. For a more detailed breakdown of the green plan, see Chapter 4, Section 4.1.2.1.

3.2.5.12. INTEGRATING GREEN WITH GRAY

2021 Update: Prior to constructing gray projects, MSD used the procedure below to evaluate the impact of reducing gray project sizes or eliminating gray projects entirely. This process is further described in Chapter 4 As the gray projects are either completed or substantially under construction, the tasks below are no longer needed. Furthermore, the Waterway Protection Tunnel has provided a higher level of control than initially envisioned with several of the original LTCP projects. Additional green infrastructure projects are not necessary to meet the Presumption Approach 85 percent system-wide control. MSD will consider future green infrastructure projects on a case-by-case basis. If sufficient localized CSO benefit is realized and funds are available, MSD may elect to support or expand green infrastructure.

The integration of the green infrastructure efforts and the gray infrastructure controls is a critical component of the successful implementation of Final LTCP. Planned green controls were translated into an estimated reduction in impervious surface for each basin. Inputs to the collection system model were revised to reflect these changes and the models were run to determine the potential decrease in CSO activity and the corresponding reduction of proposed gray controls that may result from the implementation of green components. See Appendix 3.2.19 for details of the modeling approach used to estimate the overflow volume and frequency reduction. As the first sets of green infrastructure demonstration projects were built, the controls were monitored and data on the effectiveness in reducing stormwater runoff were generated and analyzed. Based on the results of the post construction monitoring of the green controls, MSD will re-evaluate and adjust the size of planned gray projects to provide the target level of CSO control.

Appendix 3.2.19 Green Infrastructure AAOV Impact Assessment and Modeling
Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Once MSD has selected a location for a green best management practice (BMP) and has identified and worked with potential partners, MSD will begin the design phase of the project. During the design phase, MSD and the project partner will establish an O&M agreement for the specific green control. After the project has been constructed, the location will be entered in MSD's Hansen tracking system. This will allow for data on the location, size, construction cost, and inspection results to be readily available in a GIS format.

Each green control will be inspected on a regular basis to gather information on performance and maintenance routines. System monitoring will be evaluated, and the performance information will be used within the collection system model to perform Typical Year model simulations. The impacts of green infrastructure on AAOV and peak flow rates will be used to adjust the size of the planned gray projects. Figure 3.2-19 is an implementation diagram of the Green Infrastructure Program, inclusive of the process for constructing, inspecting, and monitoring a green project in order to assess impact on the size a gray control.

Figure 3.2-19 Green Infrastructure Program Implementation Flow Diagram

Figure is located at the end of this chapter.

Additionally, MSD will use the schedule developed for the design and construction of gray projects to assist in targeting green demonstration projects. At this time MSD estimates that green demonstration projects will be constructed by December 2011. MSD will conduct performance monitoring and/or CSS modeling before any modification to the gray projects are recommended. Therefore, gray projects scheduled for implementation after this timeframe will be targeted as priority areas to implement green components in order to evaluate the possibility of resizing gray controls due to the impact of the green infrastructure.

Appendix 3.2.20 MFWTP Wet Weather Standard Operating Procedure

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

Appendix 3.2.21 MFWTP Expansion TM

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

3.2.6. DEFINITION OF WATER QUALITY AND CSO CONTROLS

2021 Update: The information presented in this section remains relevant. Under the Presumption Approach MSD is not required to perform water quality sampling or to update the 2009 water quality model. Given the Final LTCP projects being implemented, the water quality benefits noted herein remain anticipated. Progress made with respect to local water quality improvements as documented over the past several years is summarized in the Executive Summary of this volume. MSD is encouraged that water quality trends are moving in a favorable direction as compared to the start of the Consent Decree.

The ultimate goal of the CSO Policy is to bring CSO communities into compliance with requirements of the Clean Water Act (CWA) (59 CFR 18688). This includes meeting the technology-based requirements (through NMC) and the water quality-based requirements through development of the Final LTCP. MSD established initial CSO control goals based on a review of the recreational and aquatic life use impairments in Beargrass Creek and the Ohio River. The initial water quality and CSO control goals were established by evaluating the relative impact of CSOs on fecal coliform bacteria and dissolved oxygen with water quality models.

Beargrass Creek and the Ohio River are highly urbanized systems, which have been affected by hydromodifications such as construction of channels for flood control and locks and dams for navigation. MSD programmatically decided to evaluate the Green Infrastructure Program and therefore evaluated a range of gray CSO control alternatives as defined in the CSO Policy (specifically zero, two, four, and eight overflows per

Typical Year). These alternatives were then simulated with the water quality models to generate a knee of the curve for locations along the Ohio River and Beargrass Creek. The knee of the curve was used to determine where the increment of water quality benefit gained (in terms of compliance with the water quality criteria) diminishes compared to the increased costs, in accordance with the CSO Policy (59 CFR 18688). A description of knee of the curve is provided in Chapter 4.

3.2.7. APPROACHES TO STRUCTURING COST CONTROL ALTERNATIVES

2021 Update: The general process used to develop initial CSO alternatives is described in this section. Information provided is from the 2009 LTCP development. Each project has been modified since the 2009 LTCP. Minor modification letters for each new project were prepared, summarizing the alternatives evaluated. A summary of the final projects can be found in Chapter 4, and the modification letters can be found in Appendix 4.0-1.

The initial step in deriving gray infrastructure CSO control alternatives was to list location of CSOs (See Figure 3.2-20); identify viable technologies; determine single versus multiple CSO solutions; and assess siting issues.

Figure 3.2-20 CSO Distribution by Region

Figure is located at the end of this chapter.

MSD's CSS contains 106 CSOs discharging to four receiving waters:

- Ohio River
- Beargrass Creek Muddy Fork
- Beargrass Creek Middle Fork
- Beargrass Creek South Fork

Five CSO control technologies were initially considered, consisting of the following:

- Sewer Separation
- In-line Storage
- Off-line Storage (Figure 3.2-21 and Figure 3.2-22)
- Treatment (two processes, Figure 3.2-23 and Figure 3.2-24)
- Hybrid Technologies (RTC with storage; RTC with treatment, Figure 3.2-25, Figure 3.2-26, and Figure 3.2-27)

Figure 3.2-21 Off-Line Storage Pumped Effluent Flow Diagram

Figure 3.2-22 Off-Line Storage Gravity Effluent Flow Diagram

Figure 3.2-23 Retention Treatment Basin Process Flow Diagram

Figure 3.2-24 Ballasted Flocculation Process Flow Diagram

Figure 3.2-25 Off-Line Storage with RTC Pumped Effluent Flow Diagram

Figure 3.2-26 Off-Line Storage with RTC Gravity Effluent Flow Diagram

Figure 3.2-27 Retention Treatment Basin with RTC Process Flow Diagram

Figures 3.2-21 through 3.2-27 are located at the end of this chapter.

During the development of project alternatives, a sixth technology, Pump Station Expansion, was added. As discussed in Section 3.1.2, initial CSO control alternatives were identified jointly by MSD and IOAP program consultants, taking under consideration factors such as regulatory compliance, implementability, operations and maintenance, public acceptance, etc. Typically using geographic criteria, CSO control projects were established either as individual or as groups, with numerous permutations of groupings, with multiple technologies to provide a broad array of projects for evaluation of the best CSO control solution for a given CSO/location.

The original project list provided 198 initial project alternatives. Due to an initial screening, the original list was reduced to 136 projects, distributed as shown in Table 3.2-9 across the various technologies.

Table 3.2-9 CSO Control Technology Alternatives (2009 LTCP Development)

PROJECT TYPE	PROJECT IDENTIFICATION CODE (USED IN THE PROJECT TRACKING DATABASE)	NUMBER OF PROJECTS EVALUATED
Pump Station Expansion	03	1
Sewer Separation	08	49
Off-line Storage	09B	49
Treatment	10	17
Hybrid Technologies	13	20

The criteria for the initial screening included technology viability and performance, neighborhood impact, professional assessment of groupings, etc. An example of the initial project screening is in-line storage technology; this was deleted as a stand-alone solution as previous CSS capacity studies indicated this technology, alone, would not achieve goals set for CSS performance.

Appendix 3.2.22 through Appendix 3.2.26 list details of the following data associated with initial solutions:

Appendix 3.2.22 Initial Project Fact Sheets
Appendix 3.2.23 Initial Project Location Maps
Appendix 3.2.24 Initial Project Cost Summary
Appendix 3.2.25 Initial Project Benefit Summary
Appendix 3.2.26 Initial Project Ground Truthing Documents
Appendix are the same as 2012 IOAP Modification and are provided on external USB storage drive.

3.2.7.1. PROJECTS COMMON TO ALL ALTERNATIVES

Projects that are termed, "Common to All Alternatives" are those that have a system-wide impact. These include projects implemented under NMC, the Green Infrastructure Program, which provides source control/reduction (reducing CSO frequency and volume), the RTC Program, which is designed to maximize system storage, and Pump Station Expansion, which re-directs flow within the CSS to different watersheds. NMC and the Green Infrastructure Program are described extensively in other sections of the IOAP; RTC and the Pump Station projects will be discussed in following sections.

3.2.7.2. OUTFALL-SPECIFIC SOLUTIONS

Outfall-specific solutions are considered where multiple CSOs share a common outfall; where a CSO is remote and cost-prohibitive to convey to a CSO control group; or where the disruption caused by constructing conveyance (such as dense urbanization, heavy traffic corridor, etc.) is deemed too significant.

The MSD CSS includes several CSOs that fall under these categories. Several common outfalls convey discharge to the receiving stream from two-to-three individual CSOs. However, two major collectors/outfalls convey a significant number of CSOs: Sneads Branch Relief Drain, which collects discharge from 11 CSOs with a single discharge point to Beargrass Creek South Fork, and Central Relief Drain, which collects discharge from 22 CSOs into a common outfall to the Ohio River. Of the 136 projects evaluated, 83 were outfall-specific solutions.

3.2.7.3. LOCALIZED CONSOLIDATION OF OUTFALLS

The geographic distribution of MSD CSOs provides excellent opportunity for consolidation of CSO controls, primarily in the Central Business District and the three Beargrass Creek Forks. Unfortunately, these regions are highly urbanized, limiting the number of available facility locations. Fifty-seven consolidated projects were evaluated during development of the Final LTCP. The localized consolidations grouped from as few as three to as many as 32 CSOs into a single control location.

3.2.7.4. REGIONAL CONSOLIDATION

The localized consolidation concept was expanded to an evaluation of two regional consolidation configurations. Both of these involved the use of a single CSO control technology, specifically large diameter off-line tunnels with an appropriately sized dewatering pump station, to capture CSO for storage and subsequent conveyance to and treatment at the Morris Forman WQTC. The facilities included 35 CSOs in one configuration and the 106 CSOs in the second configuration.

3.2.7.5. UTILIZATION OF MORRIS FORMAN WQTC CAPACITY

The Final LTCP evaluates off-line system storage with pump-back into the CSS as interceptor and treatment capacity becomes available following a wet weather event. As such, evaluation of the sustained wet weather treatment capacity of the CSS receiving treatment facility, Morris Forman WQTC, was warranted. Note that the Morris Forman WQTC is the only treatment facility in the MSD system that receives combined sewage.

MSD prepared a hydraulic model of the Morris Forman process train and conducted process stress tests in October 2002. These tests are documented in a report from CH2M HILL dated March 23, 2003. The results of the hydraulic modeling and stress testing were used to prepare the “MFWTP - Wet Weather Standard Operating Procedure” dated May 25, 2004 and included in Appendix 3.2.20. This document includes the first version of a “capacity calculator” that is still used today, with minor modifications.

The calculator considers the number of process units available for use, from bar screens through chlorine contact basins. It also considers the depth of the sludge blankets in the primary sedimentation basins and the secondary clarifiers, since sludge blanket depth impacts the amount of flow that can be treated through the units without washing out solids.

With all process units on-line, and primary sedimentation basin and secondary clarifier sludge blankets at optimum levels, the peak flow capacity of the Morris Forman WQTC is 350 MGD. Attempting to take more than 350 MGD through the primary sedimentation basins will flood the effluent weirs and wash out solids regardless of blanket depth. If some treatment units are out of service, the peak capacity will be less, proportional to the capacity of the treatment units not in service.

Operating experience shows that the peak capacity of 350 MGD cannot be sustained for long periods of time without loss of process efficiency or washing out of solids. The maximum sustained capacity of the Morris Forman WQTC has been determined to be 325 MGD if all process units are in service and sludge blankets are at optimal levels. A firm capacity, the capacity of the plant with the largest unit of the most critical component out of service, was established as 240 MGD.

While the peak hydraulic capacity of the plant is 350 MGD not all of that flow can pass through the secondary treatment process. With all units in service, and secondary clarifier sludge blankets at optimal level, the maximum capacity of the secondary treatment system is 140 MGD. The portions of the flow that do not receive secondary treatment do receive screening, grit removal, primary sedimentation, and disinfection.

In addition to evaluating the current capacity of the Morris Forman WQTC, MSD also conducted a study to evaluate the potential for plant expansion on the current site. This evaluation is documented in the "Morris Forman WWTP Expansion" Technical Memo, Appendix 3.2.21. The conclusion of this evaluation was that the existing site was fully developed and constrained from expanding due to topography. The study evaluated satellite treatment at two nearby sites and using two different treatment technologies. These evaluations are also included in the technical memorandum.

The result of these evaluations was the establishment of standard operating procedures (SOP) to maximize treatment at the Morris Forman WQTC, and confirmation that expansion of the treatment plant on the existing site may not be practical. If additional treatment capacity is needed to achieve the objectives of the Final LTCP, off-site satellite treatment will be necessary. A further discussion of treatment alternatives and evaluation is provided in Section 3.3.

3.2.7.6. CONSIDERATION OF SENSITIVE AND PRIORITY AREAS

EPA's "Combined Sewer Overflows Guidance for Long-Term Control Plan" expects that a LTCP will give the highest priority to controlling overflows to sensitive areas, defined in other Chapters of Volume 2.

As described in Chapter 1, Section 1.3.7.1 and Chapter 2, Section 2.8, a study was completed within the three Forks of Beargrass Creek to segment and rank stream reaches based on their ecological sensitivity. These results determined which reaches would realize greater benefit from water quality improvements and should be given higher priority consideration during the CSO control and implementation decision process. The results of this prioritization process and ecological reach ranking are not the sole determining factor; however, it is one of several variables integrated into the Final LTCP CSO control projects selection process and implementation schedule discussed in detail in Chapter 4.

Individual stream segments have an ecological rating derived from the sum of its weighted parameter points, discussed in detail in Chapter 2, Section 2.8. Stream segment scores and their priority rankings are shown in Table 3.2-10.

For a preferred control alternative, ratings for the individual CSO reaches involved in the project were summed and averaged. This numerical average score was assigned a priority level using the priority delineations discussed in Chapter 2, Section 2.8 to give the project an appropriate ecological rating. Averaging reach scores versus summing reach scores reduces the bias that would be created by assuming ecological improvement potential is higher for projects that group a large number of CSOs into a single control. In the case of the MSD CSS, the highest priority projects, per summing ecological reach ratings, would be those overflowing into the concrete-lined improved channel of Beargrass Creek South Fork, shown in Figure 3.2-28. Of the 42 CSOs discharging into Beargrass Creek South Fork, 32 discharge to the concrete-lined improved channel. The ratings calculated by summing reach scores, would imply that there is potential for significant improvement in the concrete-lined channel, which is not the case.

Figure 3.2-28 Low Priority Reach (South Fork Beargrass Creek CSO081 and CSO118)

This resulting rating was used in conjunction with other selection criteria to determine the order of implementation of recommended projects. Other factors that affect the schedule include, but are not limited to, benefit-cost ratio, coordination with proposed development projects, site availability, costs, and cash flow.

Table 3.2-10 Stream Segment Priority Scores And Ratings

REACH NAME	ACCESSIBILITY	THREATENED / ENDANGERED SPECIES OR THEIR HABIT	STREAM RAPID BIOASSESSMENT PROTOCOL	BANK EROSION HAZARD INDEX	INDEX OF BIOTIC INTEGRITY	CSO AVERAGE ANNUAL OVERFLOW VOLUME (AAOV)	LANDUSE	LAND COVER	RESTORATION POTENTIAL	REACH LENGTH	SCORE	PRIORITY RATING CATEGORY
MI206	10	9	9	5	10	2	10	7	10	10	110	Highest
S109	4	4	9	7	10	7	10	10	8	10	102	Highest
S108	7	5	9	8	10	2	10	10	7	9	101	Highest
S018	5	4	9	6	10	8	10	10	7	8	100	Highest
S137	4	4	8	9	10	8	10	10	8	1	94	High/ Medium
S097	7	5	8	10	10	2	7	7	8	6	93	High/ Medium
S106	4	4	5	9	10	9	10	10	8	1	89	High/ Medium
S081/088	6	4	10	7	1	10	8	8	8	10	87	High/ Medium
MI126	9	5	3	4	5	9	10	10	10	4	82	High/ Medium
MI144	6	5	7	4	5	8	5	5	9	9	80	High/ Medium
MI127	9	5	7	3	5	3	5	8	10	7	79	Medium
MI166	9	5	3	7	5	3	10	7	10	7	79	Medium
MI125	9	5	4	4	5	3	10	9	10	3	76	Medium
S093	3	3	9	7	1	10	3	7	8	6	70	Medium
S130	3	3	10	7	1	5	1	7	8	5	64	Medium
S087/131	1	2	9	7	1	9	2	5	8	5	61	Medium
MI140	2	3	4	5	5	5	1	6	5	9	57	Medium
MI086	1	2	2	6	5	10	1	4	5	2	47	Medium
MU132/154/ 167	2	1	1	7	1	1	8	8	8	4	44	Medium/ Low
S091	1	1	1	1	5	10	4	5	1	7	43	Medium/ Low
S092	1	1	1	1	5	10	4	5	1	5	41	Medium/ Low
S111/148	1	1	1	1	5	3	5	6	1	8	39	Medium/ Low
S113	1	1	1	1	5	4	5	6	1	5	37	Medium/ Low

Table 3.2-10 Stream Segment Priority Scores And Ratings

REACH NAME	ACCESSIBILITY	THREATENED / ENDANGERED SPECIES OR THEIR HABIT	STREAM RAPID BIOASSESSMENT PROTOCOL	BANK EROSION HAZARD INDEX	INDEX OF BIOTIC INTEGRITY	CSO AVERAGE ANNUAL OVERFLOW VOLUME (AAOV)	LANDUSE	LAND COVER	RESTORATION POTENTIAL	REACH LENGTH	SCORE	PRIORITY RATING CATEGORY
S151	1	1	1	1	5	1	5	8	1	6	37	Medium/ Low
S152	4	1	1	1	5	3	3	6	1	4	36	Lowest
S110	4	1	1	1	5	6	5	4	1	1	36	Lowest
S142	1	1	1	1	5	10	2	2	1	2	33	Lowest
S119	1	1	1	1	5	7	1	1	1	7	33	Lowest
S082	2	1	1	1	1	9	1	4	1	8	32	Lowest
S153	1	1	1	1	5	4	1	5	1	5	32	Lowest
S141	1	1	1	1	5	10	1	3	1	1	32	Lowest
S121	1	1	1	1	5	6	1	5	1	2	31	Lowest
S117/149/179	1	1	1	1	5	2	1	1	1	9	30	Lowest
S084	1	1	1	1	5	7	1	1	1	1	27	Lowest
S120	1	1	1	1	5	5	1	1	1	2	26	Lowest
S146/147	1	1	1	1	5	1	1	2	1	2	23	Lowest
S083/118	1	1	1	1	5	1	1	1	1	1	21	Lowest

Range:	95-130	Highest Priority
	80-94	High / Medium Priority
	46-79	Medium Priority
	37-45	Medium / Low Priority
	13-36	Lowest Priority

3.3. EVALUATION OF CSO CONTROL ALTERNATIVES

In this section, the process of designing and estimating costs for the initial CSO control is discussed. Furthermore, the methodology for selecting and optimizing control alternatives, including the preferred solutions, is presented. Figure 3.3-1 summarizes the CSO controls alternative process.

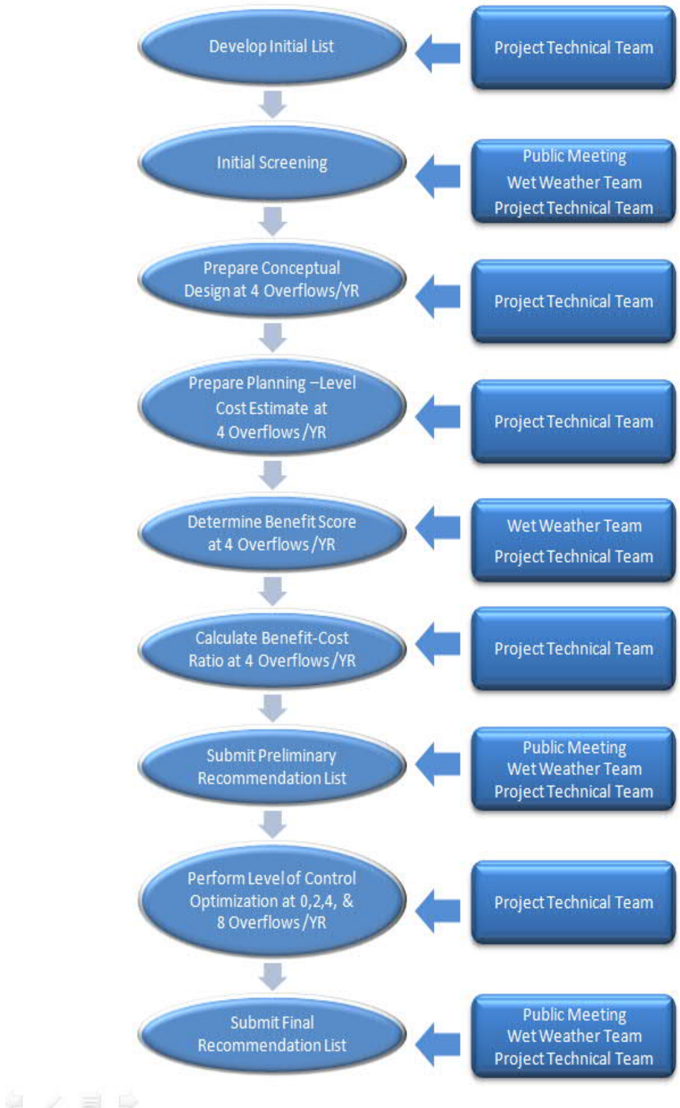


Figure 3.3-1 CSO Control Alternative Process

3.3.1. CSO CONTROLS SIZING AND CONCEPTUAL DESIGN

The initial step in developing CSO control projects was determination of CSO frequency, flow rate, and volume. As discussed in Chapter 2, Section 2.4.3, Jefferson County, Kentucky 2001 rainfall data was established as the yearly rainfall data to be used for sizing. A series of InfoWorks CS model runs were performed under varying CSS configurations, applying the 2001 rainfall data modes. The eventual CSS model conditions for sizing gray infrastructure alternatives were defined to include the following:

- Green Infrastructure Program build-out
- RTC program implementation
- Flow re-direction from Beargrass Creek South Fork watershed to the Ohio River watershed

- Reduced inflow contribution from the separate sewer system based on flow re-direction projects planned for the sanitary sewer system

The CSS hydraulic model output produced a list that included the number of overflows predicted for each CSO in the CSS for the 2001 annual rainfall. Each overflow or event was defined by volume, flow rate, and duration. This data was then used to size conveyance and volume required to achieve a performance goal. The performance goal or target for the initial suite of 136 projects was set at a level of four overflows per year, per the presumptive approach. Per this goal, the conveyance rate design basis was set at the fifth highest flow rate, providing that only the four higher flows would exceed the hydraulic capacity of the collection system and associated overflow control. Likewise, the volumetric design basis was set at the fifth highest overflow volume, providing capture of overflows that are lesser in volume than the largest four events. Note that the conveyance rate and volumetric design parameters are independent since model results indicated different storms produced overflow volumes and rates that are precipitation simulation-driven, not event-driven. Thus, the fifth highest overflow may not necessarily occur at the fifth highest conveyance rate.

For conceptual design of sewer separation projects, pipe diameters were set equal to the diameter of the existing combined conveyance pipe. For nearly all separation projects, a new stormwater system, or modifications to the existing system for conversion to stormwater only, was considered. Of 49 sewer separation projects evaluated, 44 were storm sewers only, two were sanitary only, and three were a mix of systems.

In executing conceptual design of the storage and treatment projects, the Project Cost Estimating Document, MSD's Design Manual, MSD Record Drawings, LOJIC and GIS data were the primary guides and data sources. Conveyance piping was sized using the minimum pipe slope set by MSD guidelines. Basin storage depths were set at 15 feet, with an additional two feet freeboard, in an effort to minimize excavation costs. However, to offset the cost of large pump stations required by the high flow rates predicted by the model, basins were typically set at a depth that allowed gravity in – pump out operation (24-hour return for conceptual sizing), resulting in some basins to be up to 40~50 feet below grade. It is expected that pump station sizing and basin depth will be optimized as part of the final design process.

In regard to the regional storage facilities (tunnels) considered, two configurations, the Ohio River drainage basin, as depicted in Figure 3.3-2 and the entire CSS as depicted in Figure 3.3-3, are inclusive of the Ohio River and Beargrass Creek drainage basins, were conceptually laid out. The Ohio River facility encompassed 35 CSOs and the CSS facility encompassed all 106 CSOs. Both configurations envisioned storage per the CSO controls sizing parameters discussed above and included 48-hour pump-back stations. The average depth of each facility was assumed to be 100 feet. As such, a "mixed face" was assumed, versus a rock face, based on anecdotal information as to subsurface soil conditions along the proposed alignment.

Figure 3.3-2 Regional Consolidation Alternative 1
Figure 3.3-3 Regional Consolidation Alternative 2

Figures are located at the end of this chapter.

As discussed in Section 3.2.7, satellite treatment considered two treatment processes: ballasted flocculation and retention treatment basin. The criterion for selection of treatment was the modeled treatment rate; five MGD for ballasted flocculation and 0.5 MGD for retention treatment basin. Of the 17 treatment plants evaluated, seven were ballasted flocculation and 10 were retention treatment basin.

The RTC program has been under consideration by MSD since 1999. Several inflatable dams are in operation to maximize storage in the Southwest Outfall and Sneads Branch Relief Drain. However, no RTC project alone is predicted by the model to provide sufficient storage to achieve the CSO target of four overflows per year. Hybrid projects are RTC projects paired with either storage or treatment, to take advantage of maximum in-line storage, thus reducing the size of the CSO control. Of the 20 hybrid technology projects evaluated, 19 were RTC-storage and one was RTC-treatment.

Also inclusive of the design process was identification of potential sites for construction of control alternatives. Most alternatives considered more than one location. In order to evaluate the feasibility of a site, a ground-truthing exercise was performed. This exercise reviewed the following parameters:

- Property Use Classification
- Utility Conflicts
- Site Constructability
- Adjacent Transportation Corridors
- Adjacent Property Use Classification

3.3.2. PROJECT COSTS

The Project Cost Estimating Document was utilized to determine estimated costs for CSO control alternatives. The tool served to generate consistent conceptual/planning level costs for technology solutions being analyzed for each respective scenario. The costing platform (data workbook) utilized by the tool to generate these planning level costs was built from a database of costing and construction data compiled from a variety of sources associated with similar construction projects. The tool also institutes planning level contingencies for the uncertainties encountered with each respective project. The planning level costs generated by the tool may vary +50 percent to -30 percent from a detailed cost for a specific project. As such, the main focus of the tool is to compare (not develop) planning level estimates for the projects being evaluated while taking into account each site's individual constraints.

The tool is used to evaluate a multitude of project approaches/technologies that could be utilized for addressing CSO controls. Specific to this Final LTCP, these approaches/technologies are as follows:

- Flow Redirection
- RTC Flow Control
- Sewer Separation
- Storage
- Satellite Treatment

The tool is populated with individual construction costing modules/worksheets that correspond to the construction aspects that are relative to each of the above overflow reduction approaches/technologies. The costing modules/worksheets incorporated with the tool cover:

- **Conveyance/In-line Storage** – planning level cost development for open-cut, auger bored, micro-tunneled, or open-faced tunnel-boring machine sewers.
- **Pump Stations** – planning level cost development for pump stations with below ground wet wells, bar screens, a super structure, submersible pumps, piping, controls, and a backup generator.
- **Force Mains** – planning level cost development for the trench installation of ductile iron force mains utilizing the same costing methodology as open-cut sewers.

- **Flow Control** – planning level cost development for the installation of either inflatable dams (in pipeline or channels) or an RTC adjustable sluice gate.
- **Off-line Storage** – planning level cost development either covered or uncovered storage, concrete, or earthen structure, with facilities consisting of a diversion structure, grit pit, coarse screening, flushing, instrumentation, standby generator, sump pumps and tankage.
- **Satellite Treatment** – planning level cost development for either ballasted flocculation or retention treatment basin facilities, including screening and disinfection.

These modules also have parameters associated with them that consider the constraints and conditions of the respective project site / tract being evaluated.

In addition, the tool also possesses ancillary costing modules that generate additional non-construction costs that include: program management costs, administration costs, real estate costs, contingency costs, engineering and inspection costs, planning and preliminary design costs, design services costs, interest costs, and costs for performance bonds.

3.3.3. PERFORMANCE

The performance of CSO controls is difficult to predict precisely. As noted in earlier sections of this chapter, the target for the preliminary control alternatives evaluation was four overflows per year, which established the sizing of control projects. Different technologies provide different water quality outcomes even as they eliminate or reduce CSO overflow volume and frequency. Future conditions or regulations may require a higher level of CSO control than is provided for in this Final CSO LTCP. Higher levels of control may be obtained through expansion of existing controls (where space allows), addition of facilities such as supplemental storage in other locations, or retrofitting modifications to existing facilities (such as making process additions, for example, coagulant addition and disinfection to convert storage basins to discharging equivalent primary treatment under some flow conditions). Other opportunities to modify the level of CSO controls may include enhancement or expansion of the Green Infrastructure Program should monitoring indicate cost-effective source runoff reduction.

The five technologies evaluated, listed in Section 3.2.7, include the following:

- Pump Station Expansion
- Sewer Separation
- Off-line Storage
- Treatment
- Hybrid Technologies

Sewer separation, which separates sanitary sewage and stormwater into distinct, respective piping systems, can potentially result in continued discharge of poor water quality to a receiving stream (depending on pollutant load). In applying the benefit tool described in Section 3.1.2.2, this potential is factored into project scoring by assigning no improvement to the public health value, although technically the CSO overflow/volume is eliminated by sewer separation.

Reduction of CSO to a receiving stream by utilizing off-line storage can have a wide range of volumetric performance based on the hydraulic characteristics of the CSS. The percent capture is dependent on the distribution of the overflow event volumes; the remaining overflows of the preferred performance level (zero-12 overflows per year) could comprise a significant portion of the annual overflow volume generated by a respective CSO or group of CSOs. The project technologies and associated level of CSO control recommended, discussed in Chapter 4, are eventually input into the CSS model to determine system wide CSO capture.

The two high rate physical-chemical treatment equivalent primary technologies evaluated, retention treatment basin (and ballasted flocculation produce different levels of effluent water quality. Retention treatment facilities are essentially settling basins with enhanced settling created by chemical (coagulant) addition. Settling is followed by addition of disinfectant, typically chlorine, followed by a de-chlorination agent. Overflow rates are typically several thousand gallons per day per square foot (gpd/sq ft), allowing the facility footprint to be minimal compared to conventional treatment. Treatment is only initiated once the volume of the basin is exceeded; otherwise the stored sewer overflow is pumped back to the CSS once capacity is available following the wet weather event.

Ballasted flocculation is a higher level of treatment than retention treatment basin, primarily resulting from higher clarification performance. Higher mixing energies, coupled with a ballasted settling material (for example, Microsand) and significantly higher surface overflow rates (several orders of magnitude higher) result in higher quality effluent. Similar to retention treatment basin, chlorination-dechlorination is applied to reduce pathogen counts to within regulatory limits. UV or oxidants may also be used for pathogen inactivation. Due to operating requirements, and unlike retention treatment basin, a storage basin is added at the head of the plant to allow operator travel time and plant start-up. Also similar to retention treatment basin, treatment is only initiated once the volume of the tank is exceeded; otherwise the stored overflow is pumped back to the CSS.

Capital costs for construction of the treatment facilities (excluding pump stations and tanks) vary significantly: approximately $0.13 - $0.15 per gallon of treatment rate for retention treatment basin vs. approximately $0.45 - $0.50 per gallon for ballasted flocculation treatment rate. Ballasted flocculation costs would actually be higher because a storage tank is required at the head of the facility. Operating costs, such as chemicals, power, maintenance, etc., are similarly higher for retention treatment basin vs. ballasted flocculation: $0.007 per gallon vs. $0.019 per gallon.

The treatment facility surface overflow design rates of 6,000 gpd/sq ft and 60 gpm/sq ft for retention treatment basin and ballasted flocculation respectively (per the Project Cost Estimating Document) will reduce pollutants and pathogen counts to the levels found in Table 3.3-1.

Table 3.3-1 Satellite Treatment Performance

PARAMETER/TREATMENT PROCESS	BALLASTED FLOCCULATION	RETENTION TREATMENT BASIN
Total Suspended Solids (TSS)	80%-95% removal	50% removal
Biochemical Oxygen Demand (BOD)	60%-80% removal	30% removal
Pathogen Count	126 E. Coli/100 ml	126 E. Coli/100 ml

It is important to note that the CSO Control Policy permits treatment of CSO discharge to the following minimum levels of treatment:

- Primary clarification
- Solids and floatable removal and disposal
- Disinfection and removal of disinfectant residuals

The conceptual design elements and criteria of both processes listed above comply with these requirements. Whereas ballasted flocculation treatment exceeds the requirements dictated by the CSO Control Policy (hence the higher costs), retention treatment complies with the stated minimum requirements.

Performances of hybrid technologies are dependent on the types of systems merged into the control facility(s). The majority of hybrid projects evaluated were RTC with off-line storage, therefore performance of these controls would mirror that of off-line storage: determined by hydraulics of the respective CSOs. Where RTC is paired with treatment, the effluent quality of the treatment selected would determine the impact to the receiving stream.

The Pump Station Expansion project is utilized to re-direct flow within the CSS; the controls installed in the receiving sewershed will determine the performance of CSO control applied to that diverted volume of combined sewage.

3.3.4. COST/PERFORMANCE EVALUATIONS

The benefit-cost ratio data generated by the benefit scoring and conceptual/planning-level cost estimates of the initial project list of 136 control alternatives was ultimately screened to a group of 19 preferred CSO control projects that were modeled to achieve the initial target overflow goal of four per year. While benefit-cost evaluations were the primary method to determine alternative selection, it was not the only factor considered in the decision process. Operational considerations, primarily the conveyance and treatment capacity available to empty the in-line and off-line storage basins, plus ecological reach ratings, described in Section 3.2.7.6, were also taken into consideration. As a result, two projects that were not the best-ranked benefit-cost ratio were recommended for the next step in the process (level of control optimization): one satellite treatment project, and one pump station expansion project.

Following the preliminary recommendation preferred of CSO control projects to MSD and the WWT, the preferred CSO control projects were subject to an optimization process level of control performance of zero, two, and eight overflows per year, to complement the initial performance sizing of four overflows per year. The benefit-cost calculations were also developed for the zero, two, and eight overflows per year, with the optimal benefit-cost ratio level of control recommended in the Final LTCP.

This set of data for the various level of control projects was then plotted against performance targets to develop knee of the curve graphs. The graphs presented to the WWT included the following:

- Cost versus wet weather capture percentage
- Wet weather capture versus fecal coliform model predictions for both Ohio River and Beargrass Creek watersheds

The outcome of these CSO control project recommendations are presented in Chapter 4.

3.3.5. RATING AND RANKING OF ALTERNATIVES

At the completion of this evaluation process, the CSO projects were ranked by benefit-cost ratio. Outfall-specific solutions with one technology were compared technology versus technology. Localized consolidation projects grouped different combinations of CSOs in different geographic locations with competing control technologies. Typically, projects were selected by the highest benefit-cost ratio. Exceptions were made on ease of implementation per geographic requirements (available land area). In addition, CSS operation improvement opportunities, (basically reduction in pumping, or the need to add wet weather treatment capacity to the system) were included in the decision process.

In 2012, the hydraulic model was updated and re-calibrated, resulting in significant changes to the overflow frequencies and occurrences at various CSOs. Based on the new models, projects were re-analyzed using the 2009 projects as a basis, and using the process described in this chapter. As further, more detailed recalibrations were performed and as system characteristics were updated, additional modifications were made after the 2012 IOAP update. A summary of the modifications can be found in Chapter 4, and the description and justification, including additional alternatives analyzed, can be found in the minor modification letter for each project (Appendix 4.0-1).

Green Infrastructure Strategy

FIGURE 3.2.1
GRAPHICAL DEPICTION OF
GREEN INFRASTRUCTURE STRATEGY

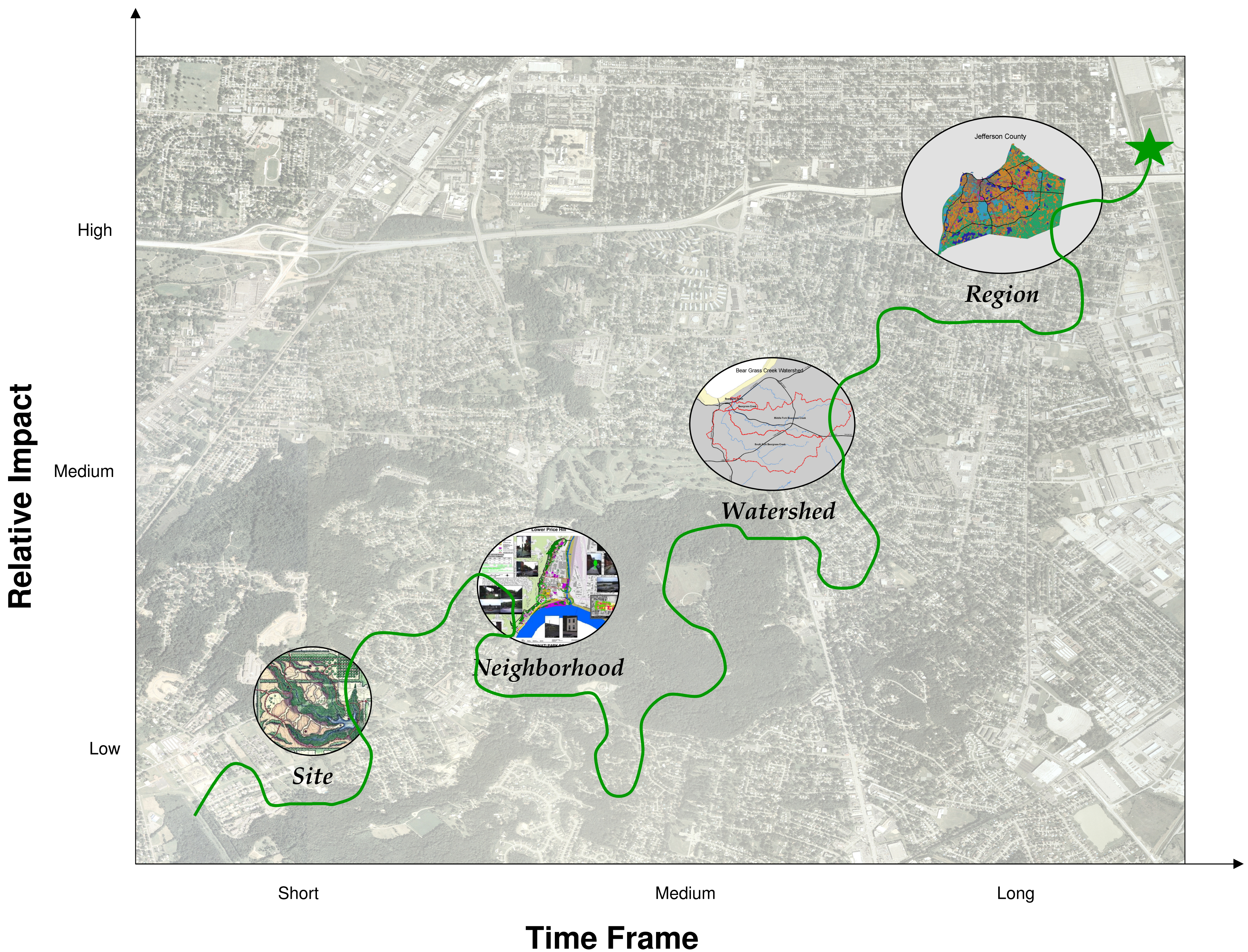


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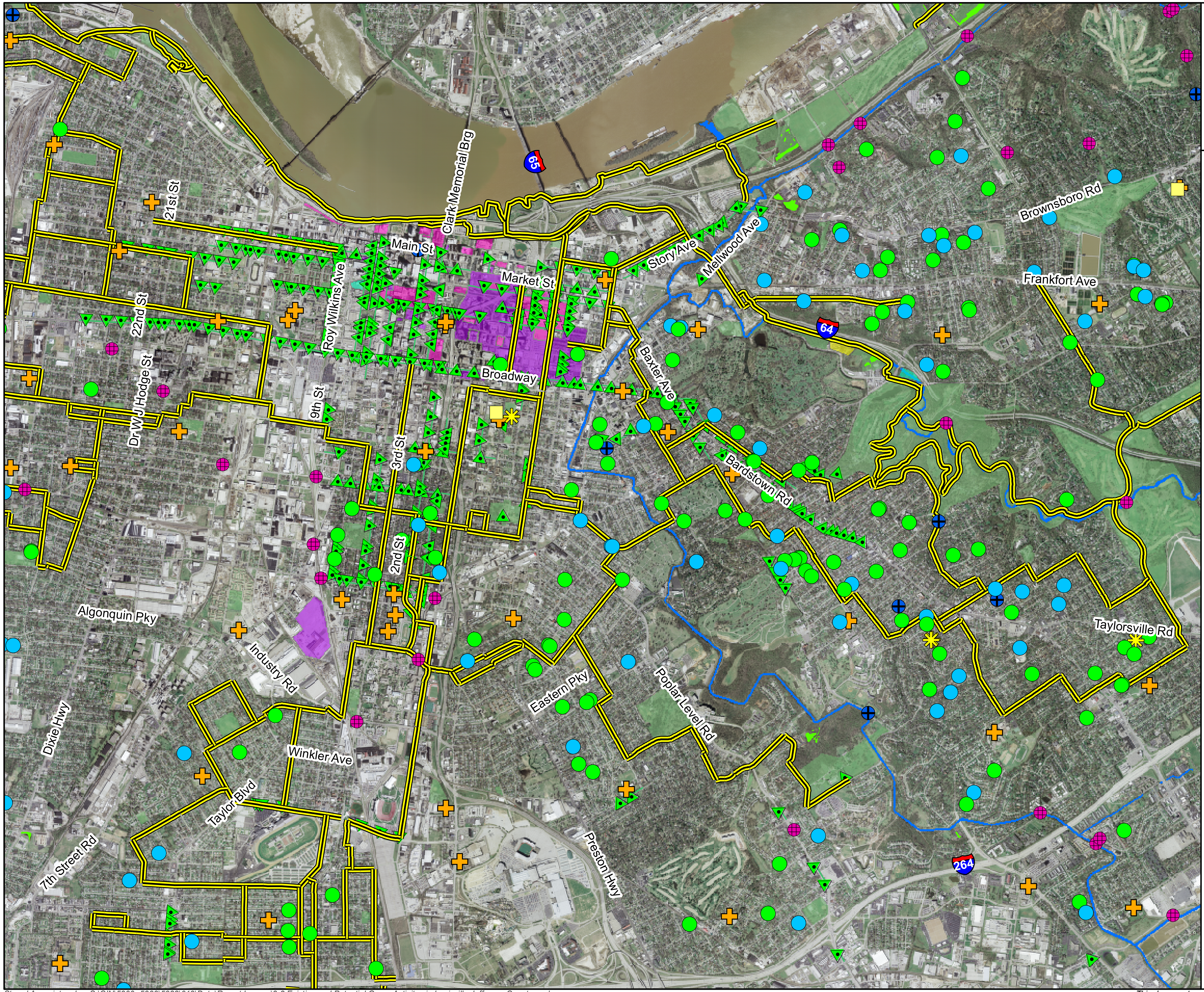
FIGURE 3.2.2
EXISTING AND POTENTIAL GREEN ACTIVITIES IN LOUISVILLE AND JEFFERSON COUNTY AS OF AUGUST 2008



LEGEND

- Outdoor Classroom
- Rain Barrel
- Rain Garden
- Rain Barrel Request
- Drainage Hot Spots
- Consent Decree Projects
- Public Schools
- Bikeway
- Community of Trees
- Mosquito Pretreatment Zones
- Existing Green Projects
- Proposed Green Projects
- Proposed New Construction
- Proposed Renovation
- Stream
- Metro Parks

LOJIC MSD Metropolitan Sewer District PROJECT WIN

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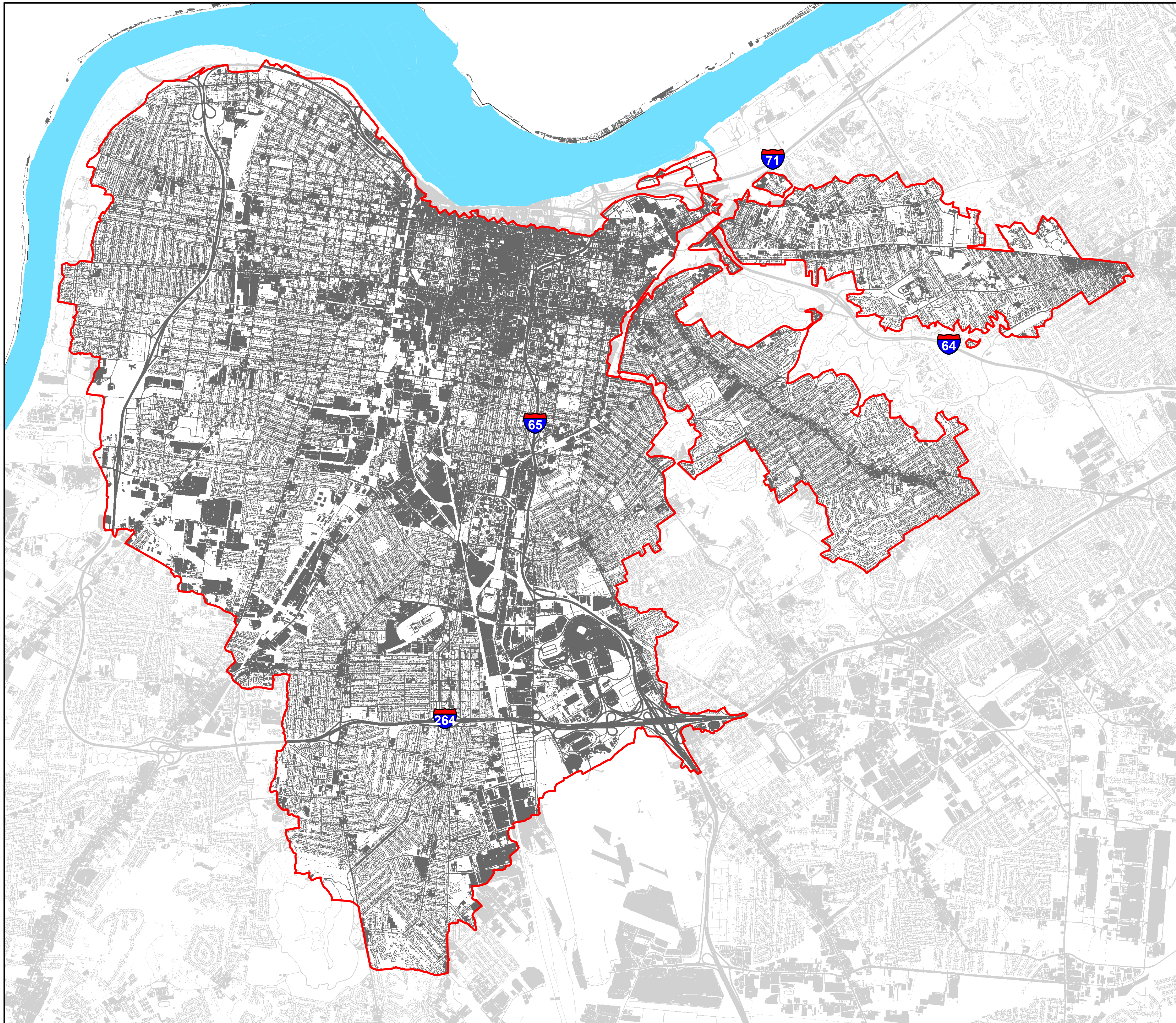
FIGURE 3.2.3
IMPERVIOUS SURFACES
WITHIN THE COMBINED SYSTEM



LEGEND

- CSO Boundary
- Ohio River
- Storm Water Impervious Area

FIGURE 3.2.4
HISTORIC CIVIL WAR MAP

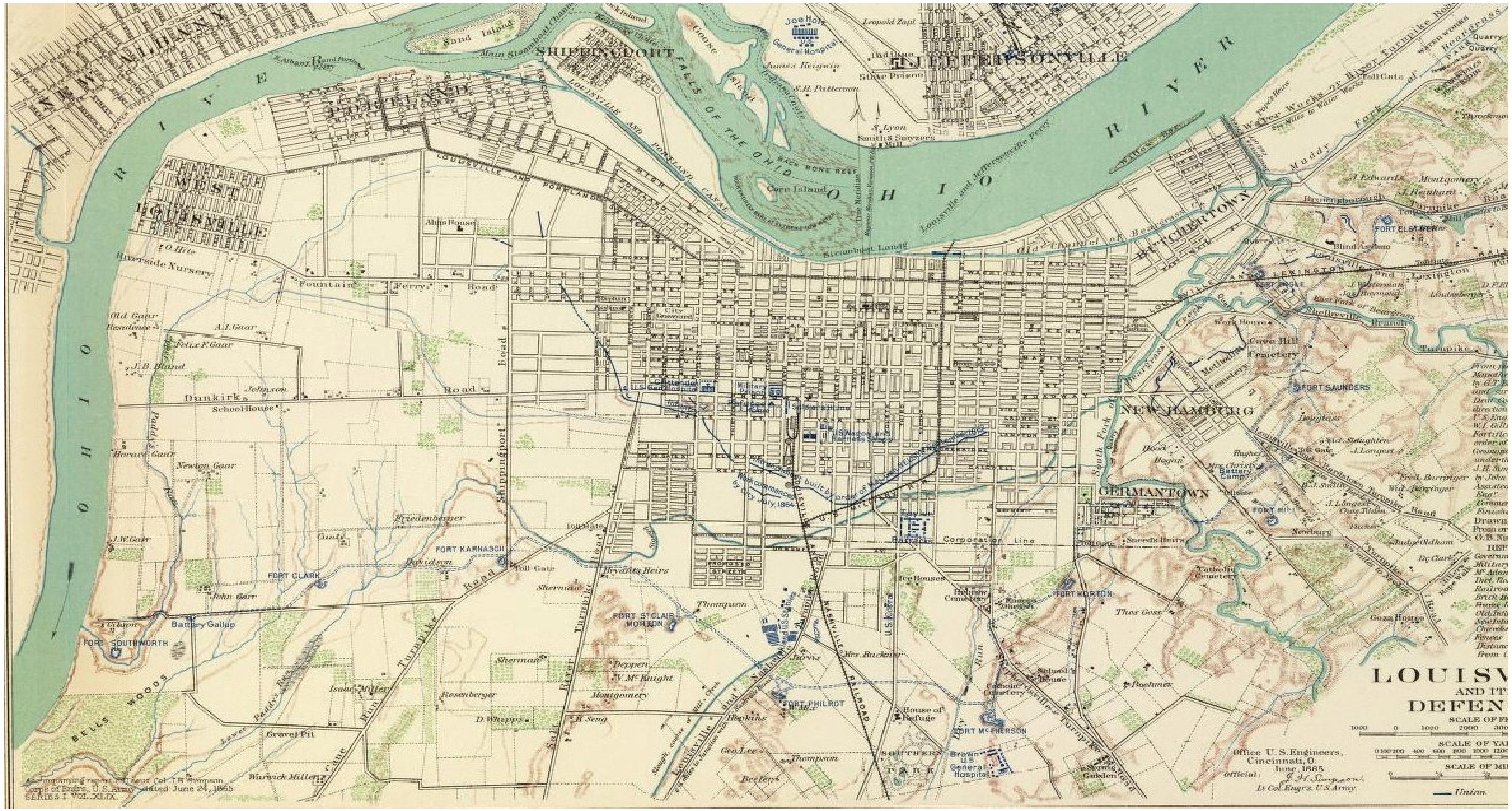
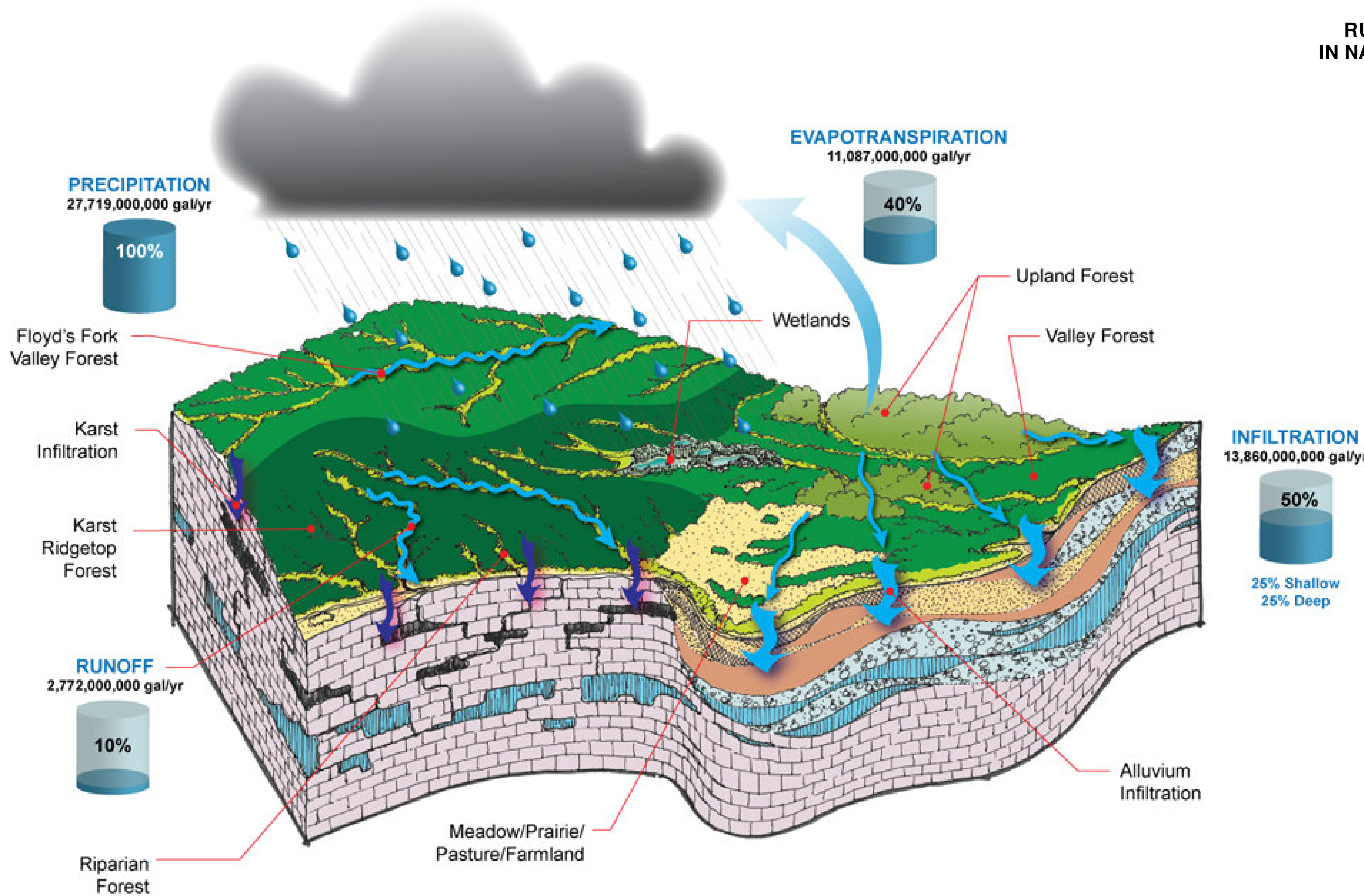


FIGURE 3.2.5
RUNOFF SCENARIO
IN NATURAL CONDITIONS



NOTE: Water quantities are for CSO areas only.

FIGURE 3.2.6
TREE CANOPY
EVALUATION RESULTS

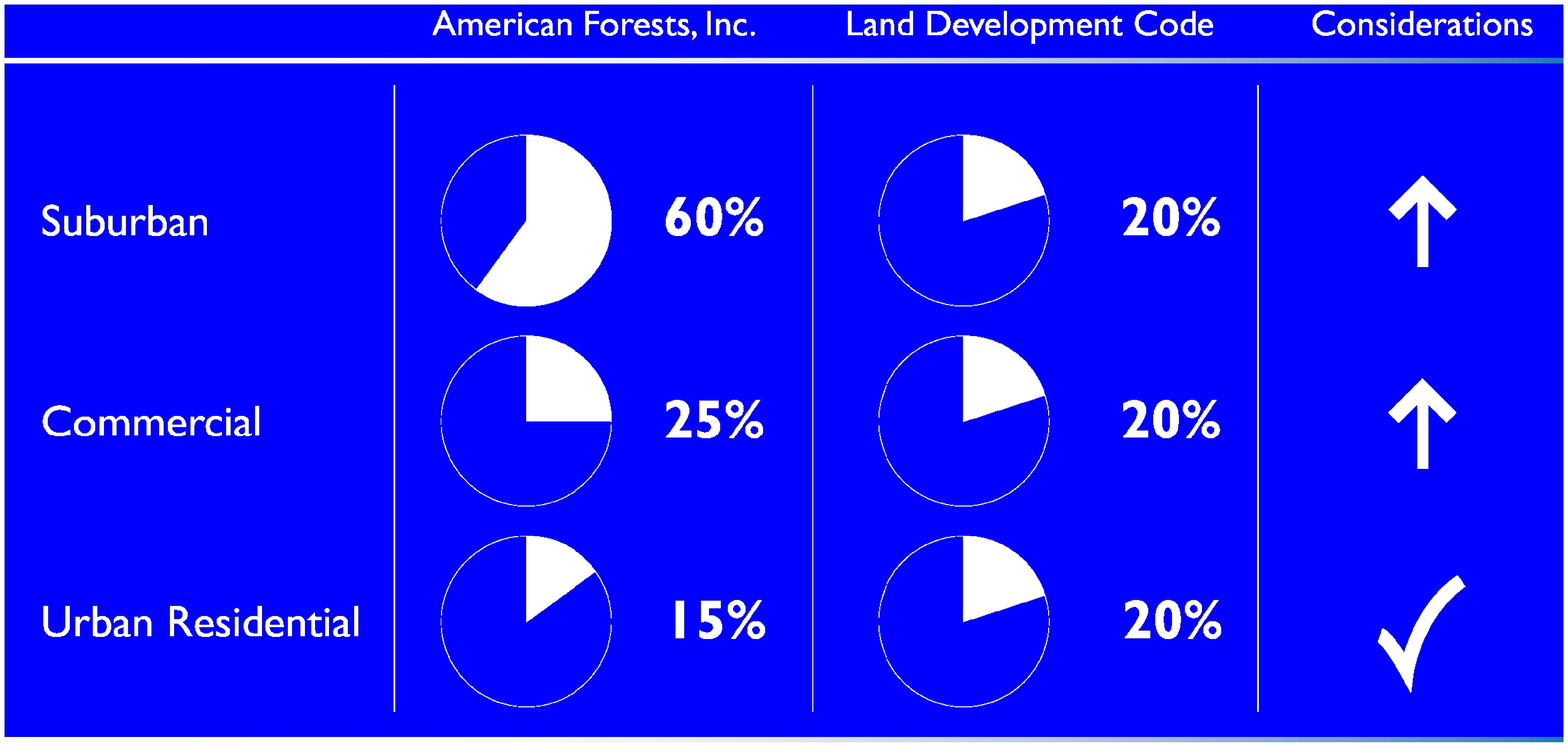


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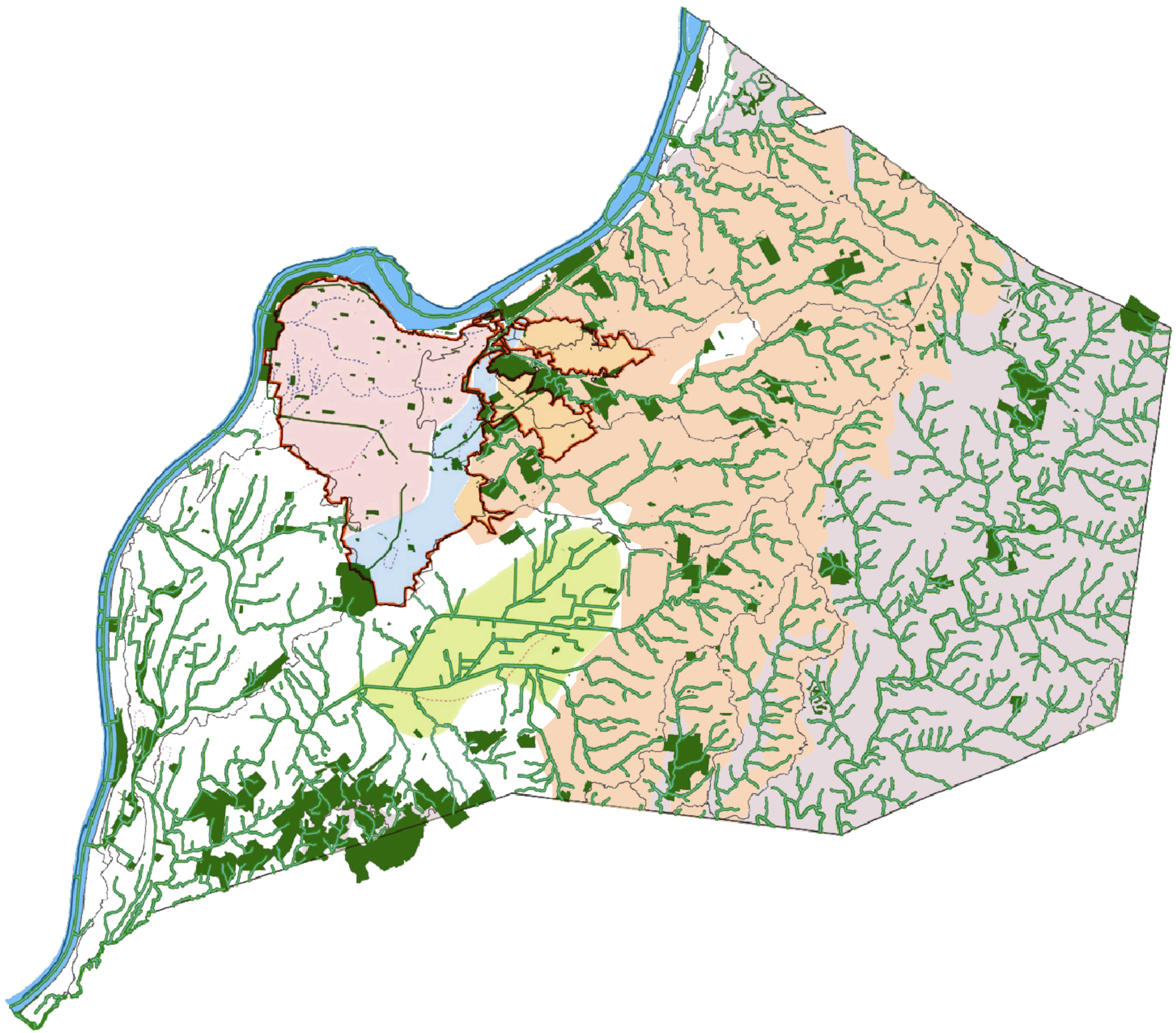
FIGURE 3.2.7
CSS SYSTEM AND THE LOCAL STREAM NETWORKS



LEGEND

- Streams with LDC-Recommended Buffers
- Historic Streams
- Loess Terrace Geology with Moderate Infiltration Potential
- Karst Geology with Strategic Infiltration Potential
- Alluvial Geology with High Infiltration Potential
- Karst (Major)
- Karst (Moderate)
- Low Land
- Watershed
- Metro Parks & Open Space

Human Nature: X:\20710 (Louisville MSD w Strand)\GIS projects\LTCP\LTCP_StreamNet_327.ai

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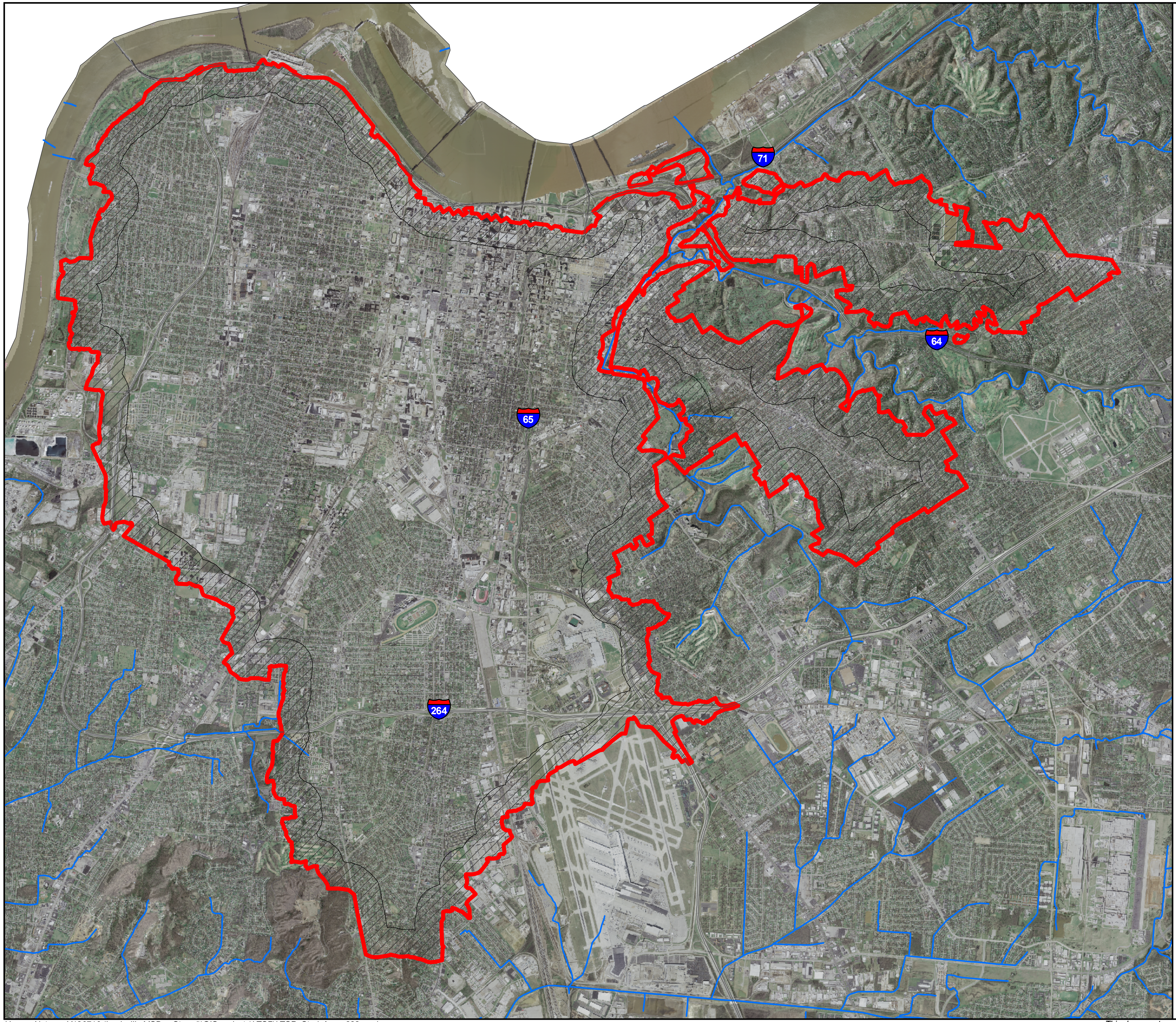
Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 3.2.8
STUDY AREA PARALLEL TO THE CSS
1/4 MILE INSIDE EXISTING BOUNDARY
FOR STORMWATER REDIRECTION



LEGEND

- Major Roads
- Streams
- CSO Boundary
- 1/4Mile CSO Buffer (8,000 Acres)

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FIGURE 3.2.9
KENTUCKY GEOLOGIC MAP

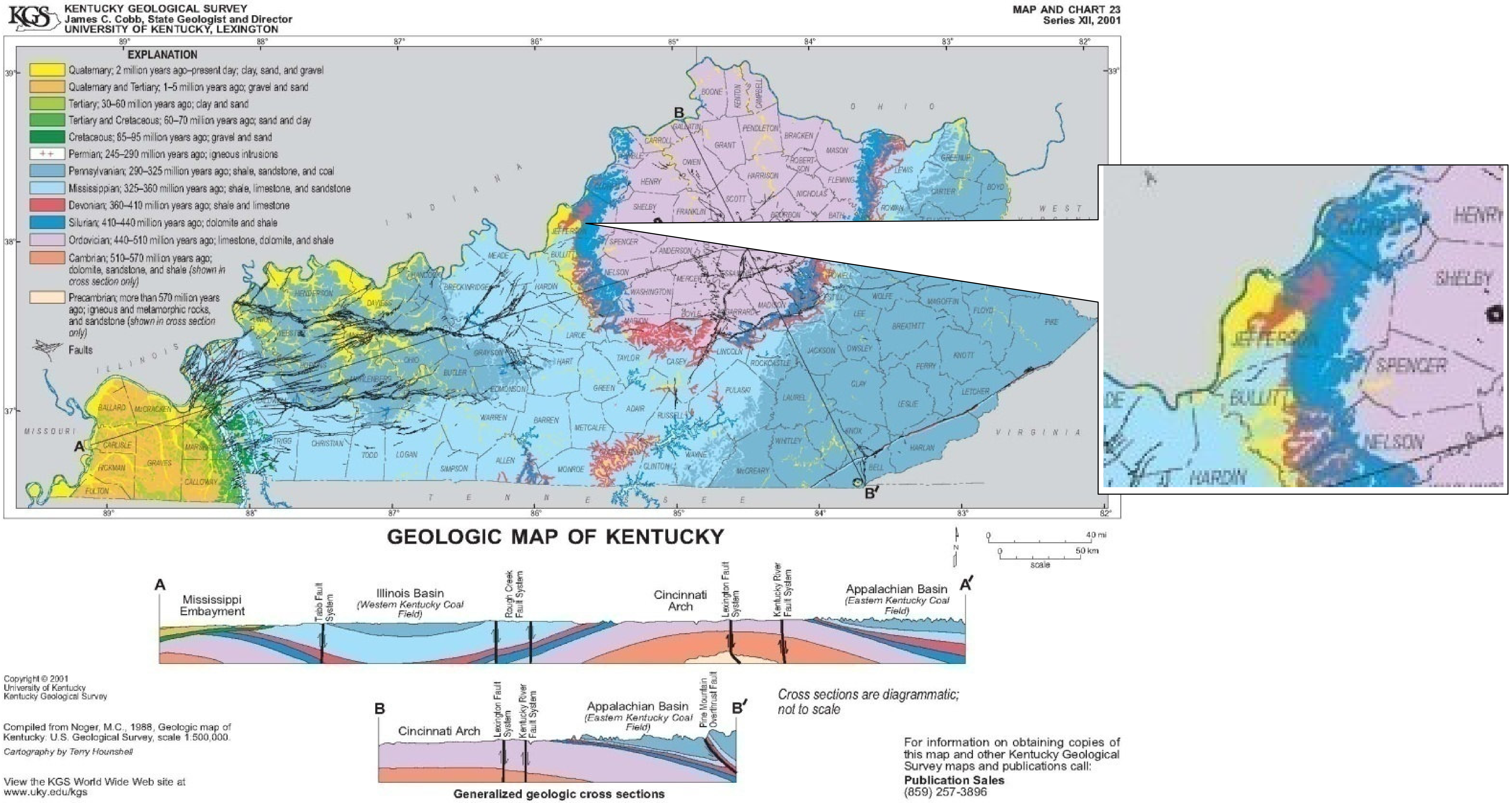

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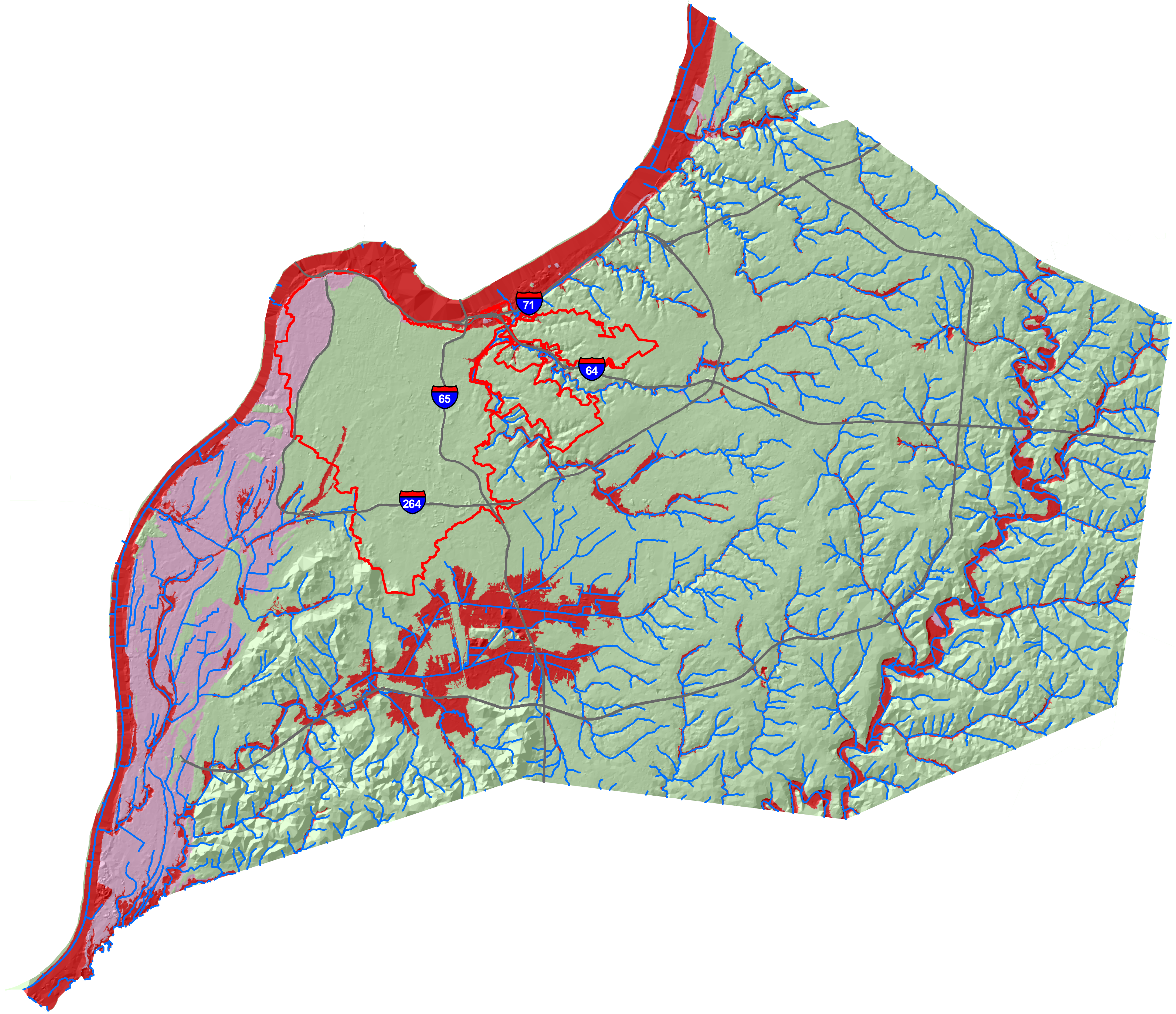
FIGURE 3.2.10
Flood Zones



LEGEND

- Major Roads
- Streams
- CSO Boundary

Flood Zones

- Outside Floodplain
- 100 Yr Floodplain
- 500 Yr Floodplain

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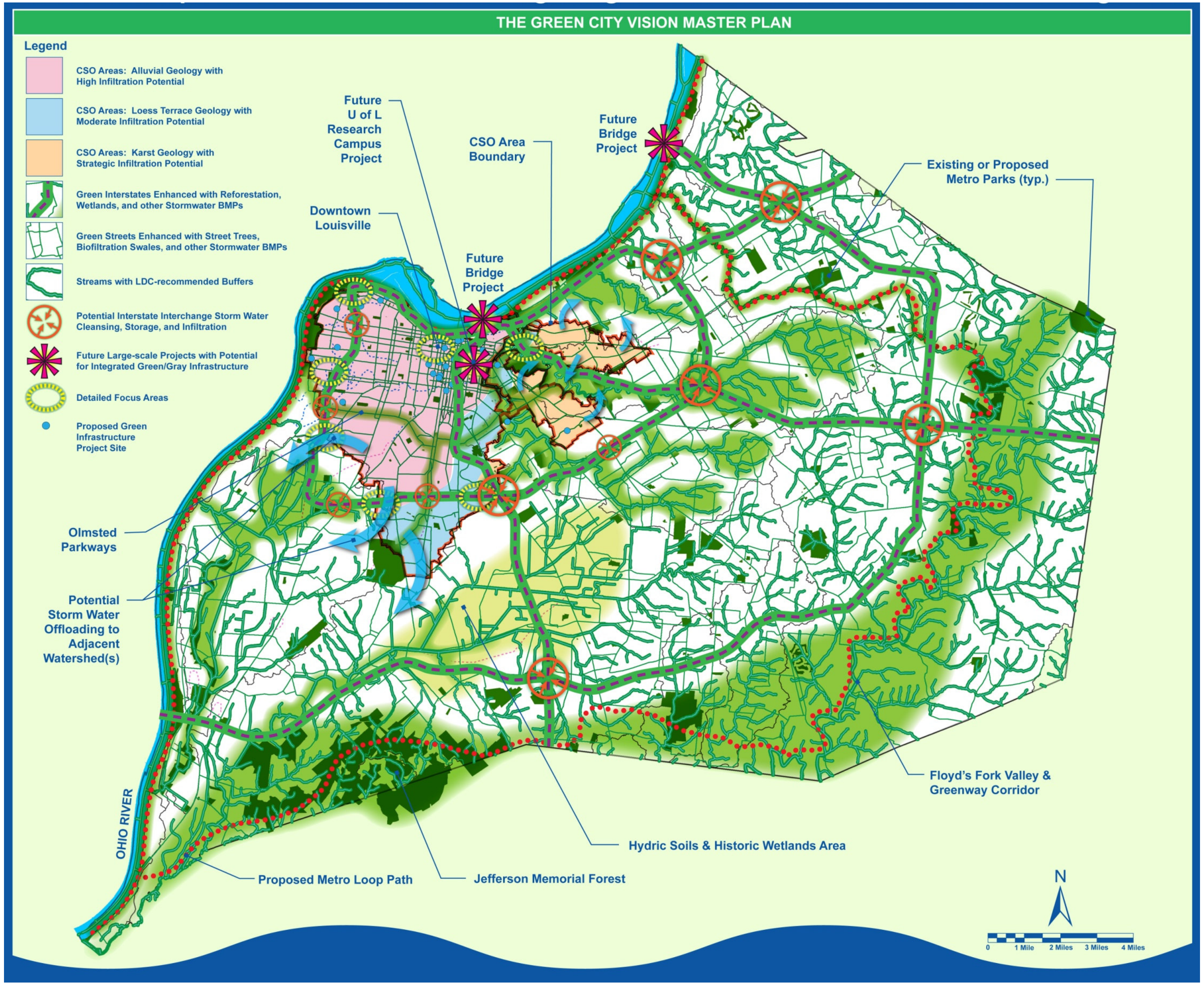
Vol. 2 – Final CSO Long Term Control Plan

FIGURE 3.2.11
GRAPHICAL DEPICTION OF REGIONAL EVALUATION



Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 3.2.12
NORTHWEST GREEN FOCUS AREA

LEGEND

- Flow Direction
- Proposed Pipe Solution
- CSO Boundary
- Drainage Area
- Potential Infiltration Area
- Impervious Area
- Right of Way
- Ohio River
- Alluvium
- Glacial outwash (Wisconsinan)
- Artificial fill

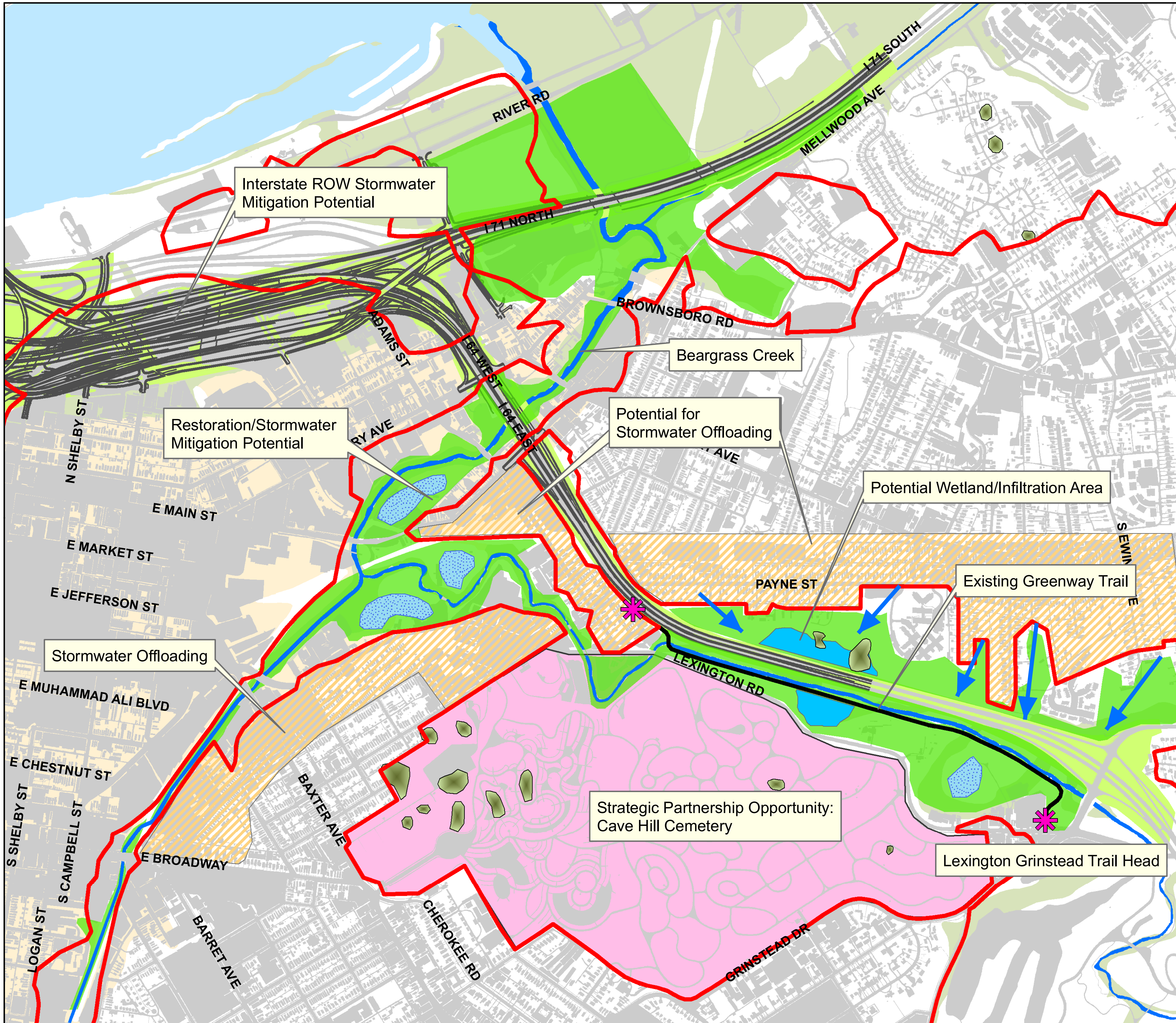
Soils
Outwash; Silts and clays in upper 15 to 20 feet, sands below, grading into gravel. Limestone 70 to 100 feet deep

Features	Area (Acres)
Drainage Basin NW	272
Interstate	
Road Right of Way	50
Impervious	17
Metro	
Road Right of Way	22
Impervious	15
Other	
Impervious	72

Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 3.2.13
NORTHEAST GREEN FOCUS AREA



LEGEND

- Trailhead
- Kennedy Interchange
- Trail
- CSO Boundary
- Stormwater Mitigation Sites
- Sinkholes
- Potential Infiltration Area
- Stream Restoration
- Stormwater Offloading
- Ohio River
- Impervious Surfaces
- Right of Way
- Stream
- Strategic Partnership Opportunity
- Glacial outwash (Wisconsinan)
- Alluvium

Features	Area (Acres)
Stream Restoration	289
Stormwater Offloading Area	216
Strategic Partner Opportunity	324
Potential Wetland/Infiltration Area	9
Stormwater Mitigation Sites	12
Interstate ROW Mitigation Potential	167

LOJIC MSD Metropolitan Sewer District PROJECT WIN

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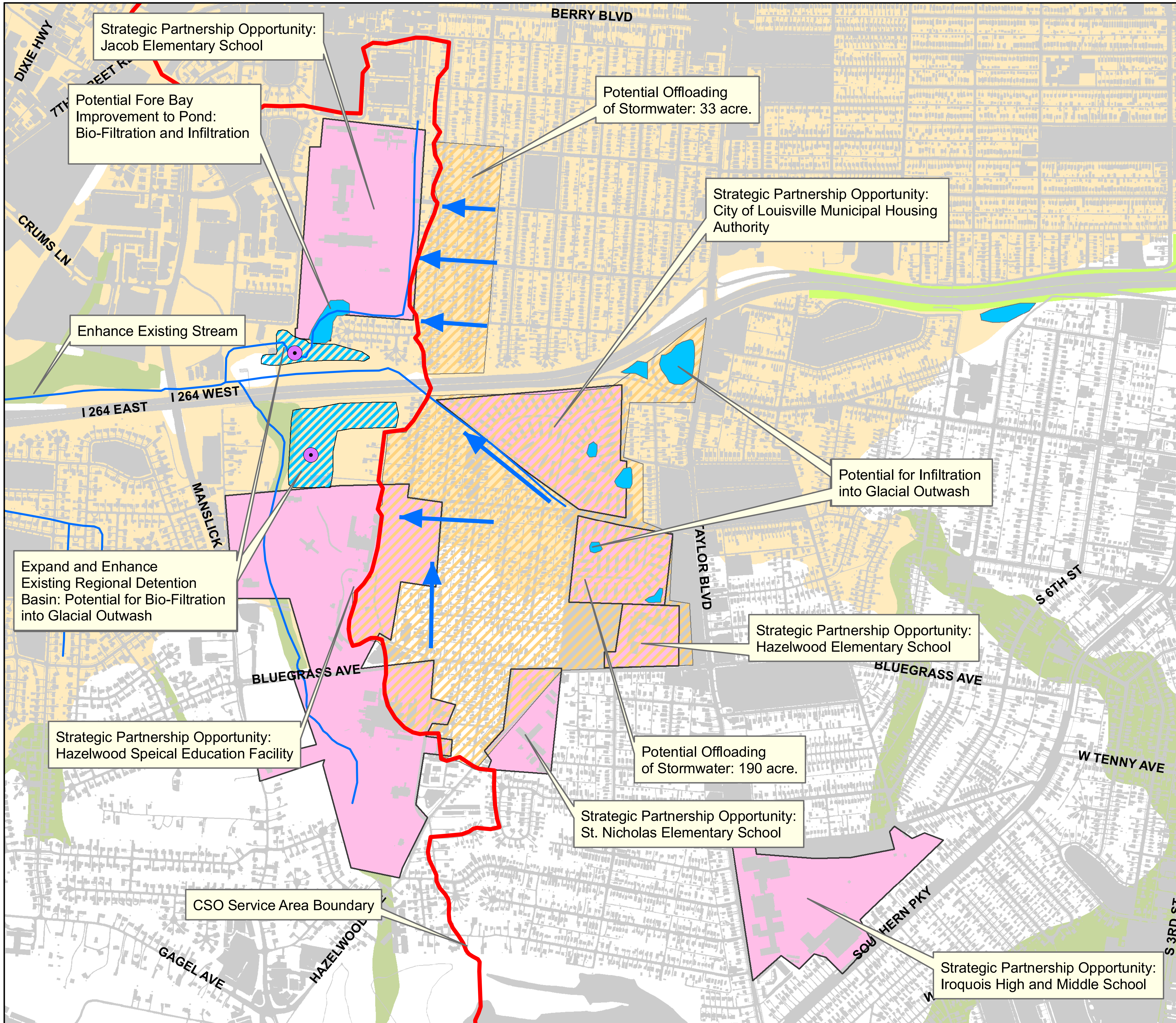
FIGURE 3.2.14
SOUTH CENTRAL WEST GREEN FOCUS AREA



LEGEND

- MSD Detention Basins
- Streams
- CSO Boundary
- Existing Detention Basins
- Potential Infiltration Area
- Stormwater Offloading
- Strategic Partnership Opportunity
- Impervious Surfaces
- Glacial outwash (Wisconsinan)
- Alluvium

Features	Area (Acres)
Stormwater Offloading Area	223
Strategic Partner Opportunity	254
Potential Infiltration Area	6
Existing Detention Basins	15

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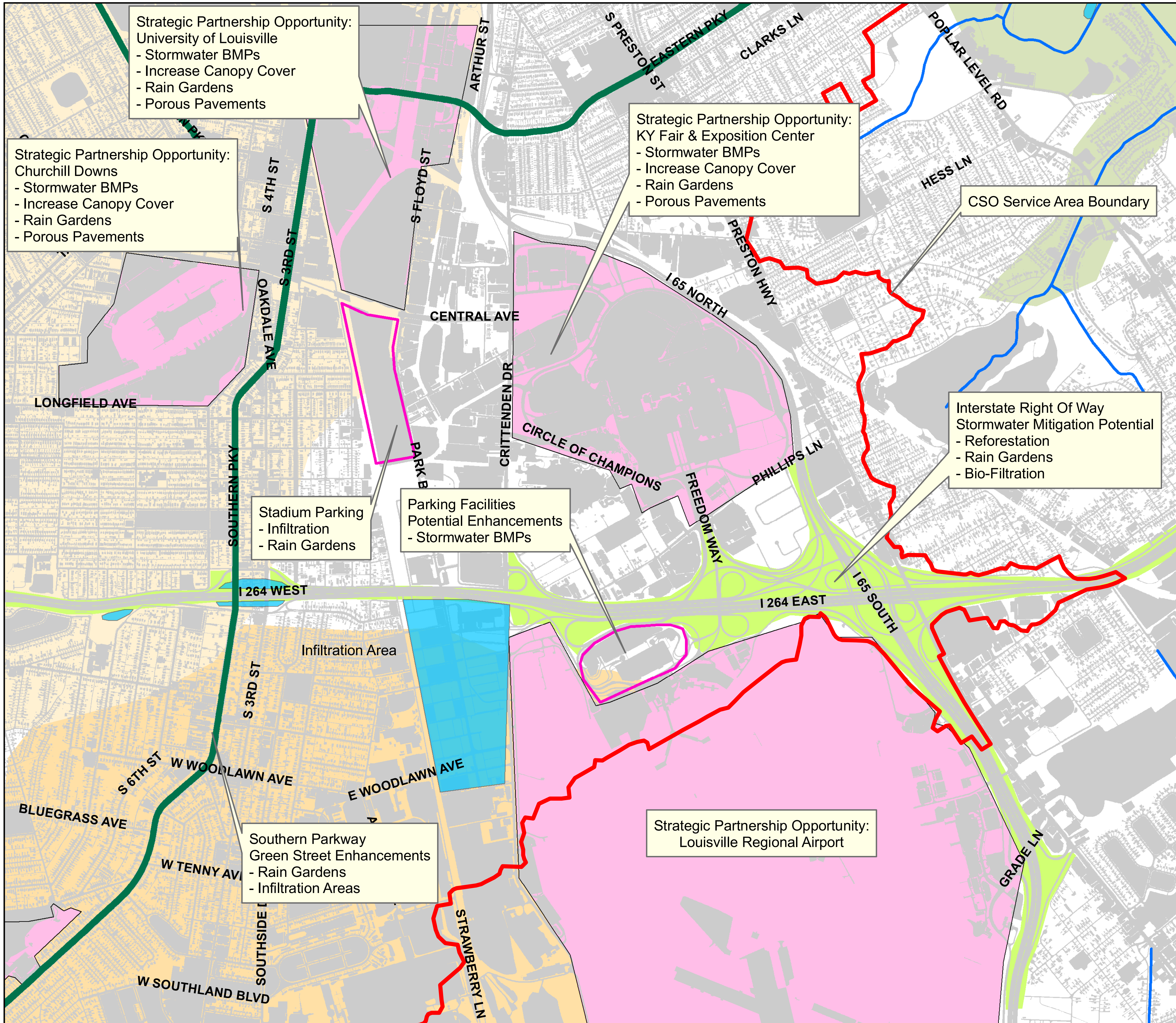

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FIGURE 3.2.15
SOUTH CENTRAL EAST
GREEN FOCUS AREA

LEGEND

- Streams
- CSO Boundary
- Parking Enhancement Opportunity
- Olmsted Parkway System
- Potential Infiltration Area
- Strategic Partnership Opportunity
- Impervious Surfaces
- Right of Way
- Alluvium
- Outwash
- Terrace

Features	Area (Acres)
Strategic Partner Opportunity	2540
Potential Wetland/Infiltration Area	113
Parking Enhancement Potential	75
Interstate ROW Mitigation Potential	172

LOJIC MSD Metropolitan Sewer District PROJECT WIN

Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 3.2.16
SOUTHWESTERN PARKWAY
GREEN FOCUS AREA

LEGEND

- MSD Detention Basins
- Streams
- Green Alley
- Green Street
- CSO Boundary
- Olmsted Parkway System
- Stormwater Offloading
- Potential Infiltration Area
- Existing Detention Basins
- Metro Parks & Open Space
- Ohio River
- Impervious Surfaces
- Strategic Partnership Opportunity
- Right of Way
- Alluvium
- Glacial outwash (Wisconsinan)
- Artificial fill

Features	Area (Acres)
Strategic Partnership Opportunity	68
Potential Infiltration Area	13
Green Streets Right of Way	45
Storm Water Off Loading	56
Existing Detention Basins	6
Interstate Right of Way *	121

* Including Insterstate ROW in both Southwestern Area and Southwest Greenway & Parkway Area

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Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 3.2.17
SOUTHWEST GREENWAY AND PARKWAY GREEN FOCUS AREA

LEGEND

- MSD Detention Basins
- Streams
- Bike Route
- Olmsted Parkway System
- Potential Infiltration Area
- Existing Detention Basins
- Metro Parks & Open Space
- Ohio River
- Strategic Partnership Opportunity
- Impervious Surfaces
- Right of Way
- Greenway Connection
- Alluvium
- Glacial outwash (Wisconsinan)
- Artificial fill

Features	Area (Acres)
Potential Infiltration Area	13
Greenway Connection	331
Existing Detention Basins	1.5

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FIGURE 3.2.18
CENTRAL BUSINESS DISTRICT GREEN FOCUS AREA GREEN STREET CONCEPT PLAN

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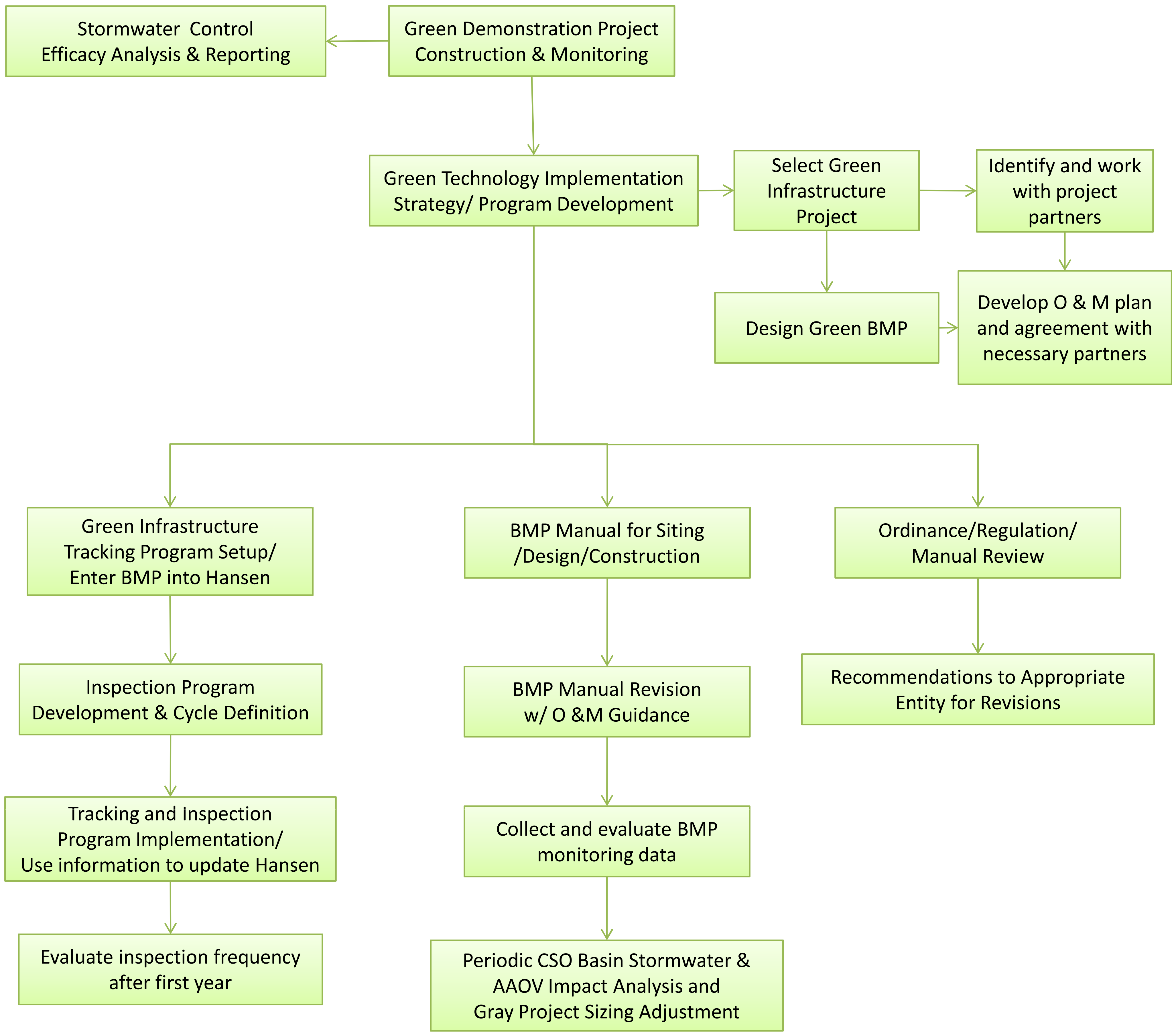
Vol. 2 – Final CSO Long-Term Control Plan

FIGURE 3.2.19
Green Infrastructure Program Implementation Preliminary Flow Diagram



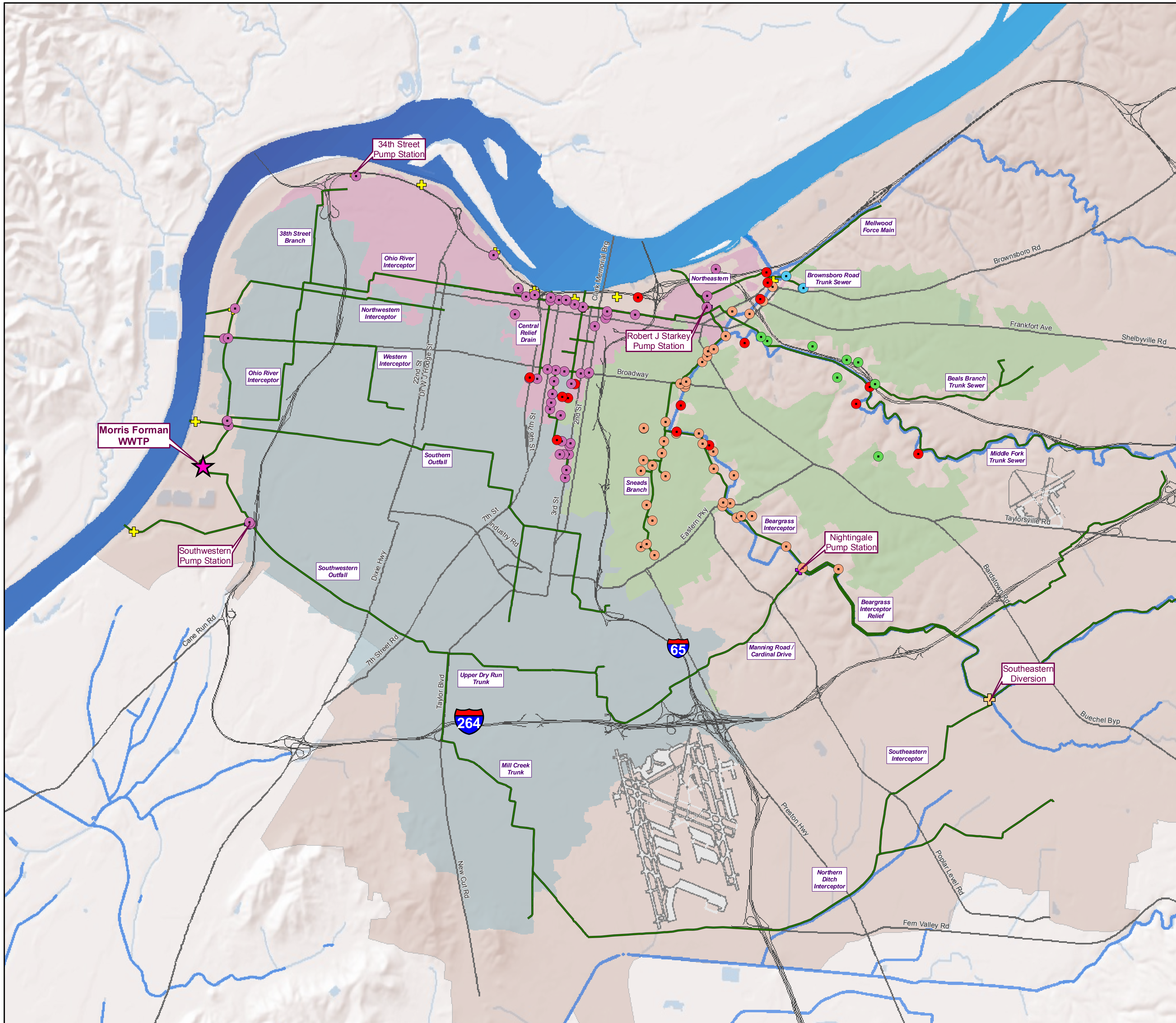


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FIGURE 3.2.20
CSO DISTRIBUTION BY REGION

LEGEND

CSO by Region

- Ohio River
- Middle Fork Beargrass Creek
- Muddy Fork Beargrass Creek
- South Fork Beargrass Creek
- Eliminated CSO
- Flood Pump Station
- Sanitary Pump Station
- Southeastern Diversion
- Wastewater Treatment Plant
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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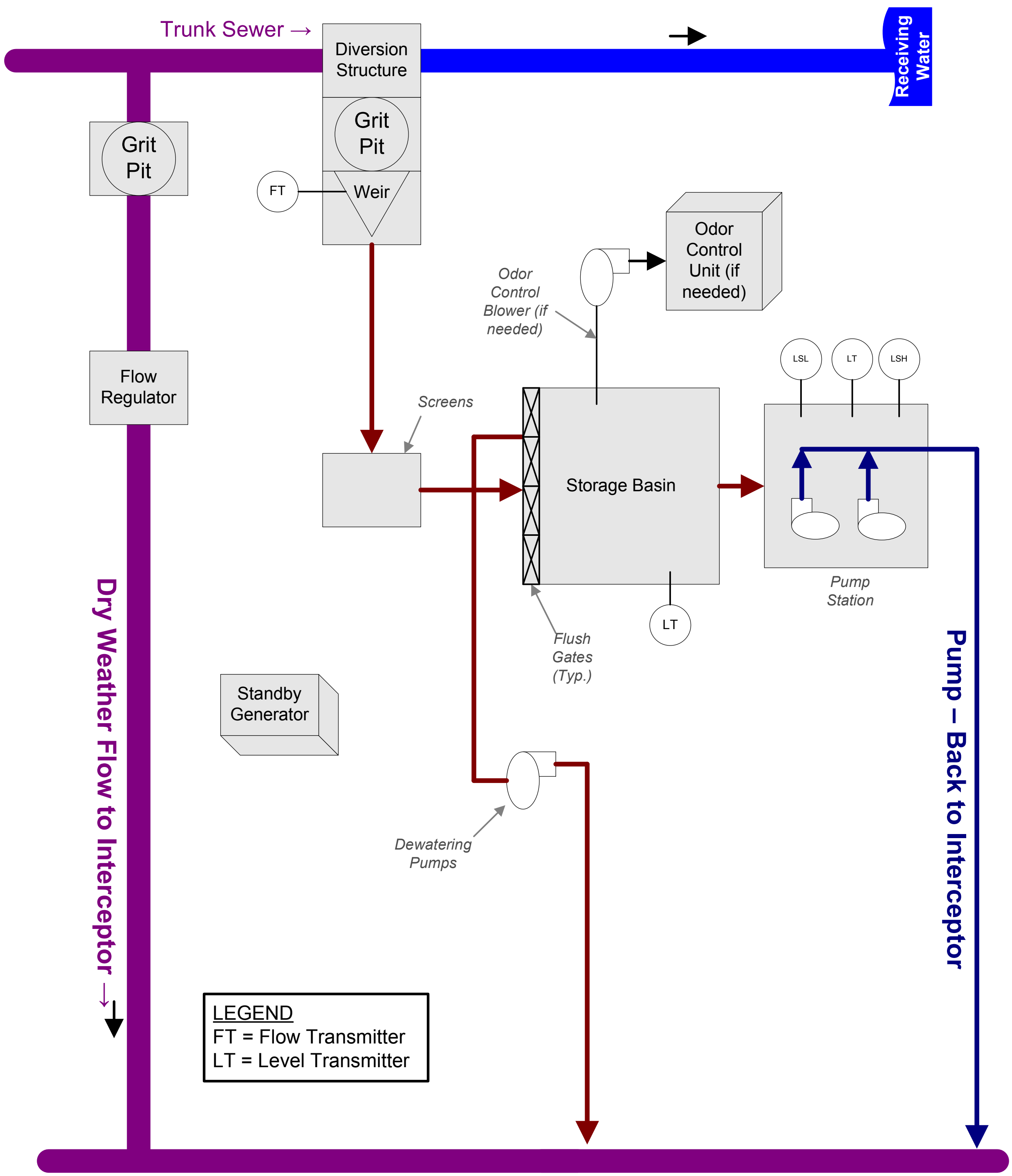
Figure 3.2.21
Off-Line Storage Pumped Effluent Flow Diagram



PROJECT WIN Waterway Improvements Now

MSD Metropolitan Sewer District

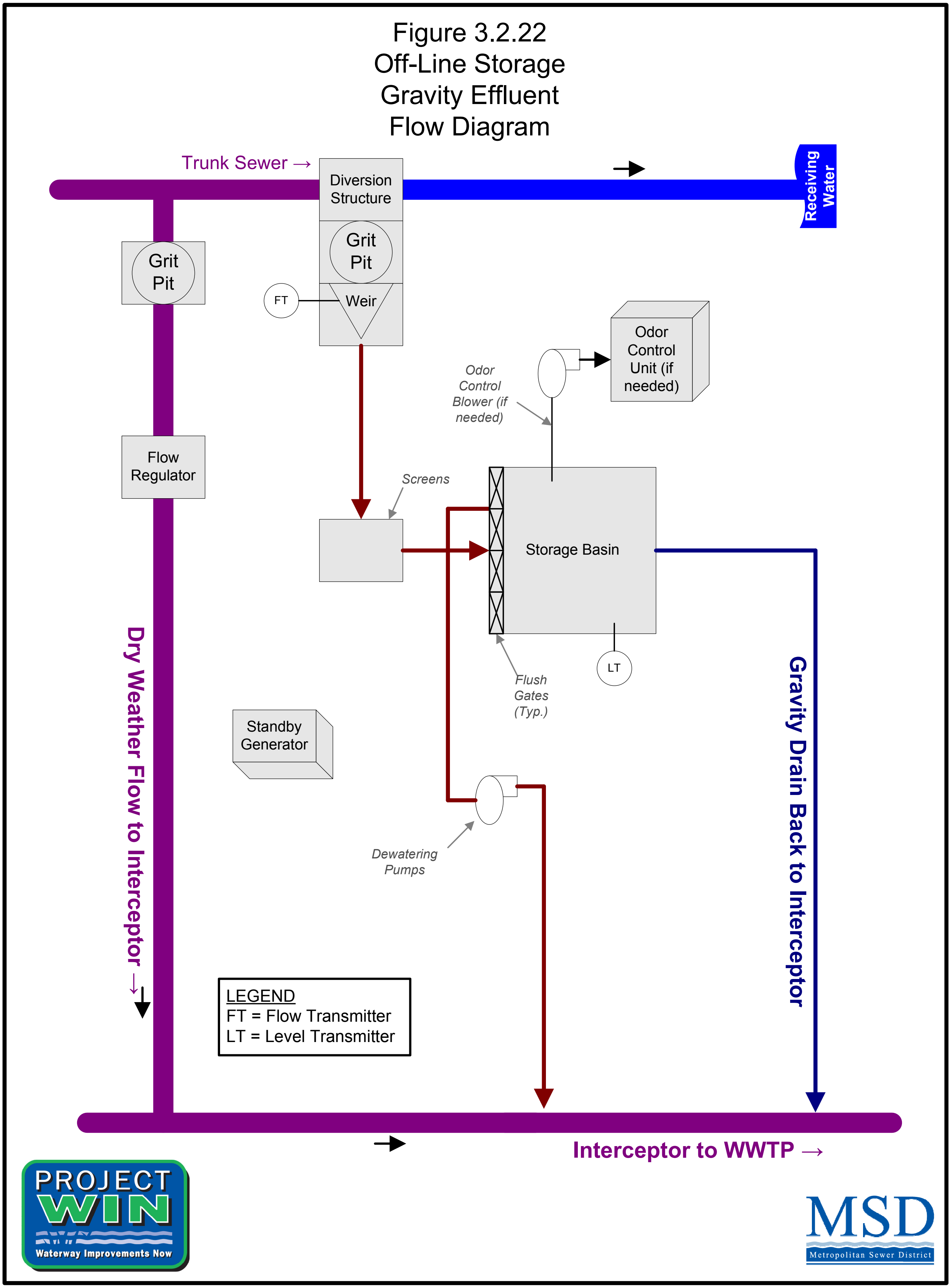


Figure 3.2.22
Off-Line Storage
Gravity Effluent
Flow Diagram
Trunk Sewer →
Diversion Structure
Receiving Water
Grit Pit
Grit Pit
FT
Weir
Odor Control Unit (if needed)
Odor Control Blower (if needed)
Flow Regulator
Screens
Storage Basin
LT
Flush Gates (Typ.)
Standby Generator
Dewatering Pumps
Dry Weather Flow to Interceptor →
Gravity Drain Back to Interceptor
LEGEND
FT = Flow Transmitter
LT = Level Transmitter
Interceptor to WWTP →
PROJECT WIN
Waterway Improvements Now
MSD
Metropolitan Sewer District

Figure 3.2.23
Retention Treatment Basin
Process Flow Diagram

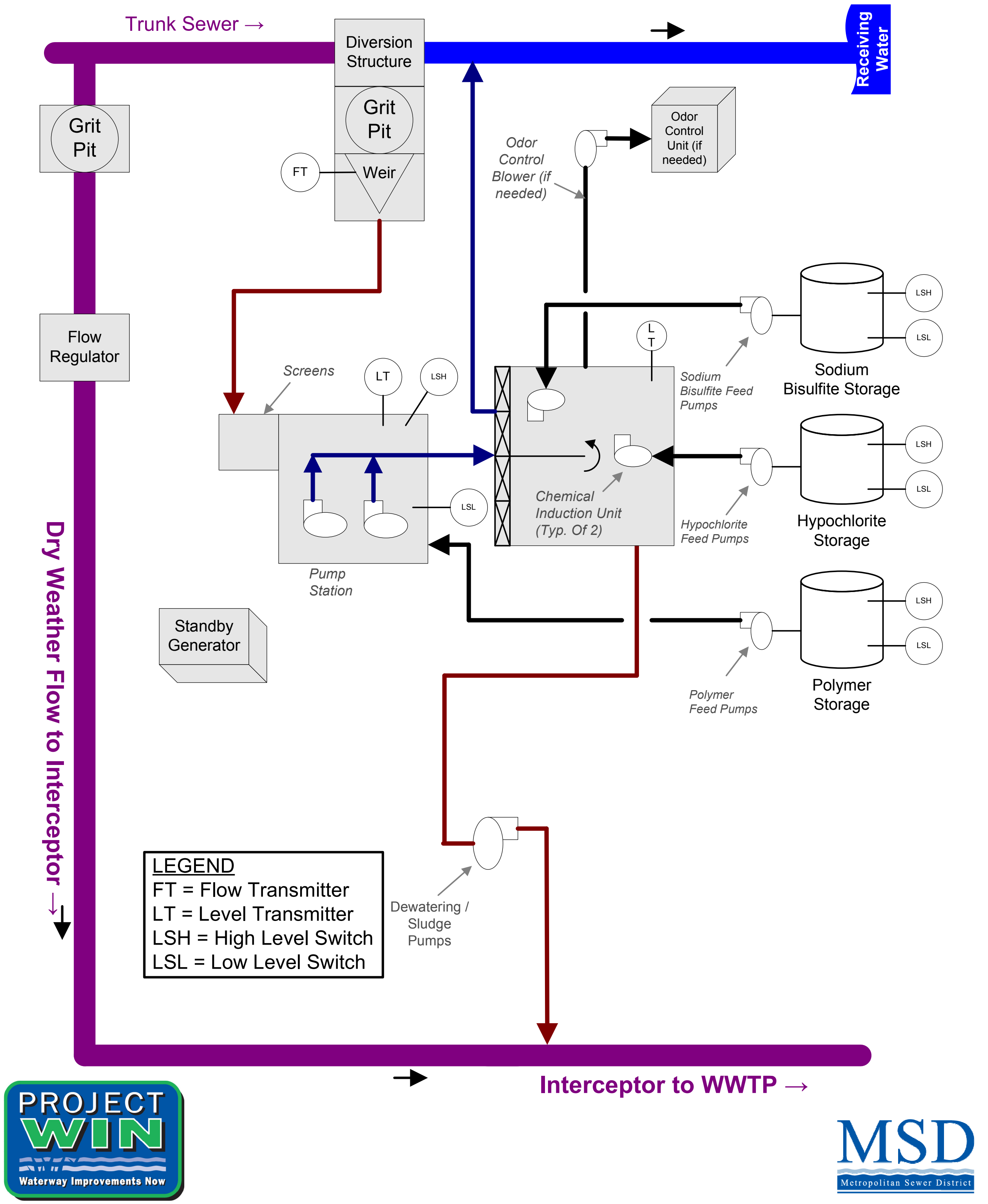


Figure 3.2.24
Ballasted Flocculation
Process Flow Diagram

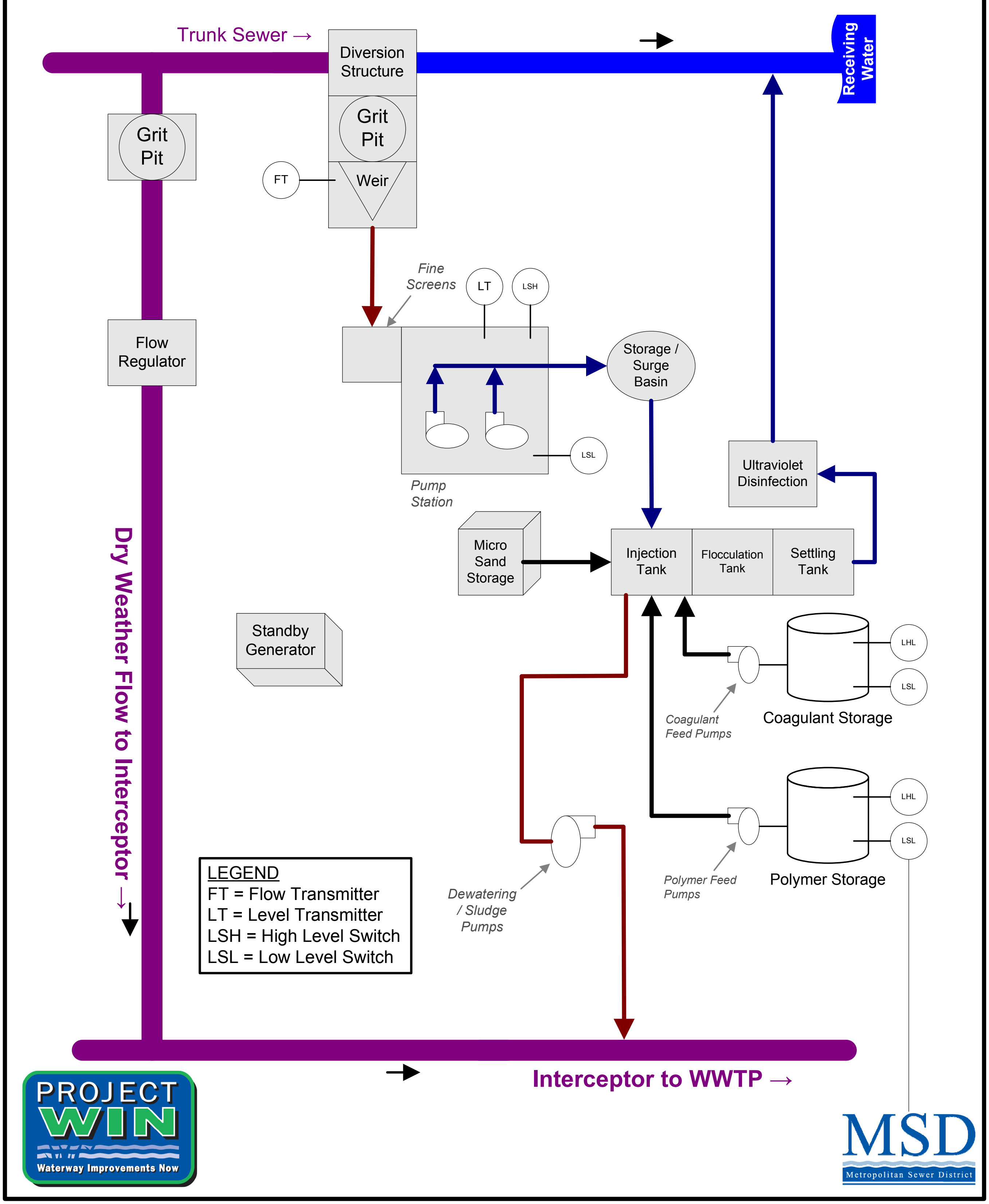


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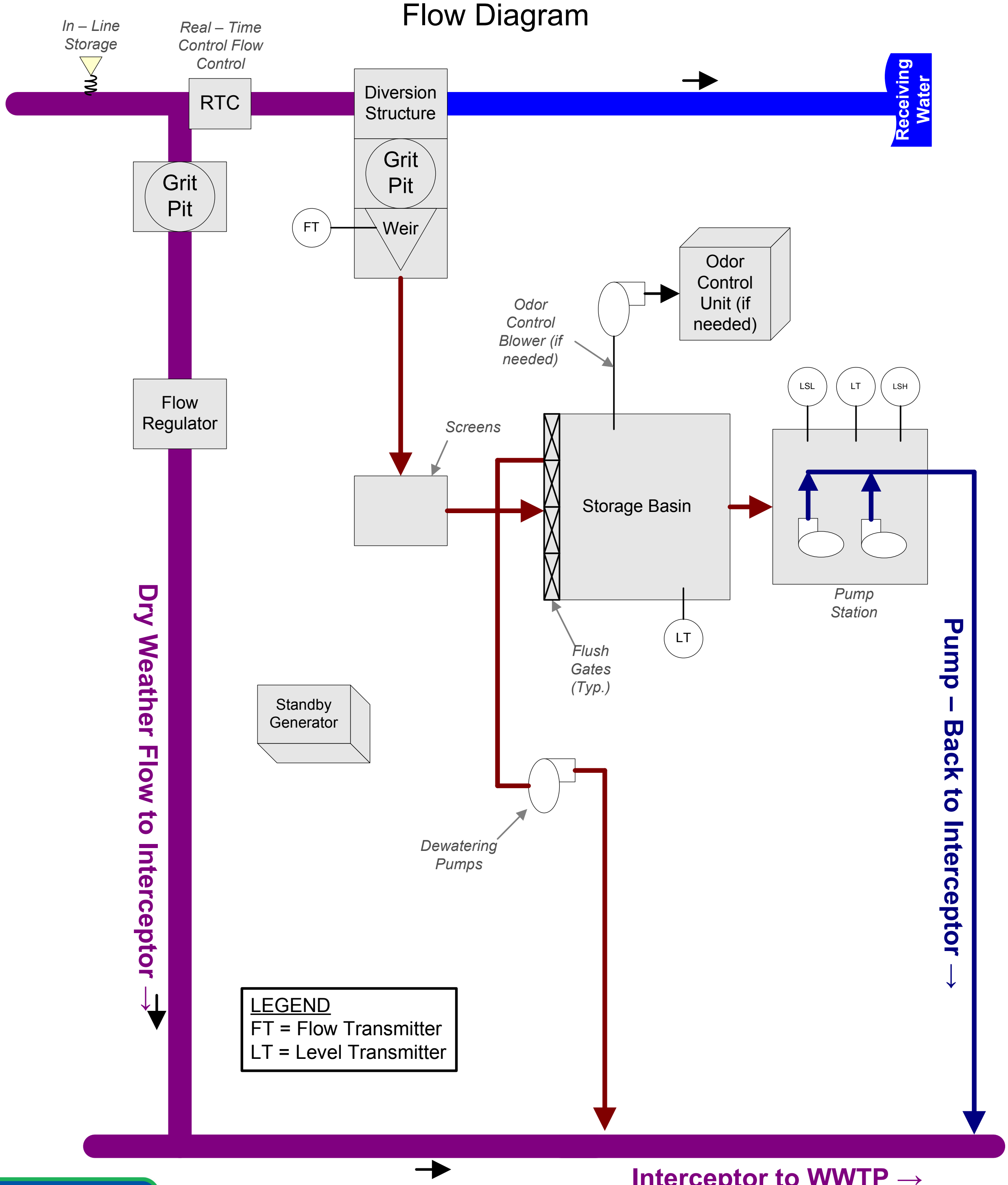
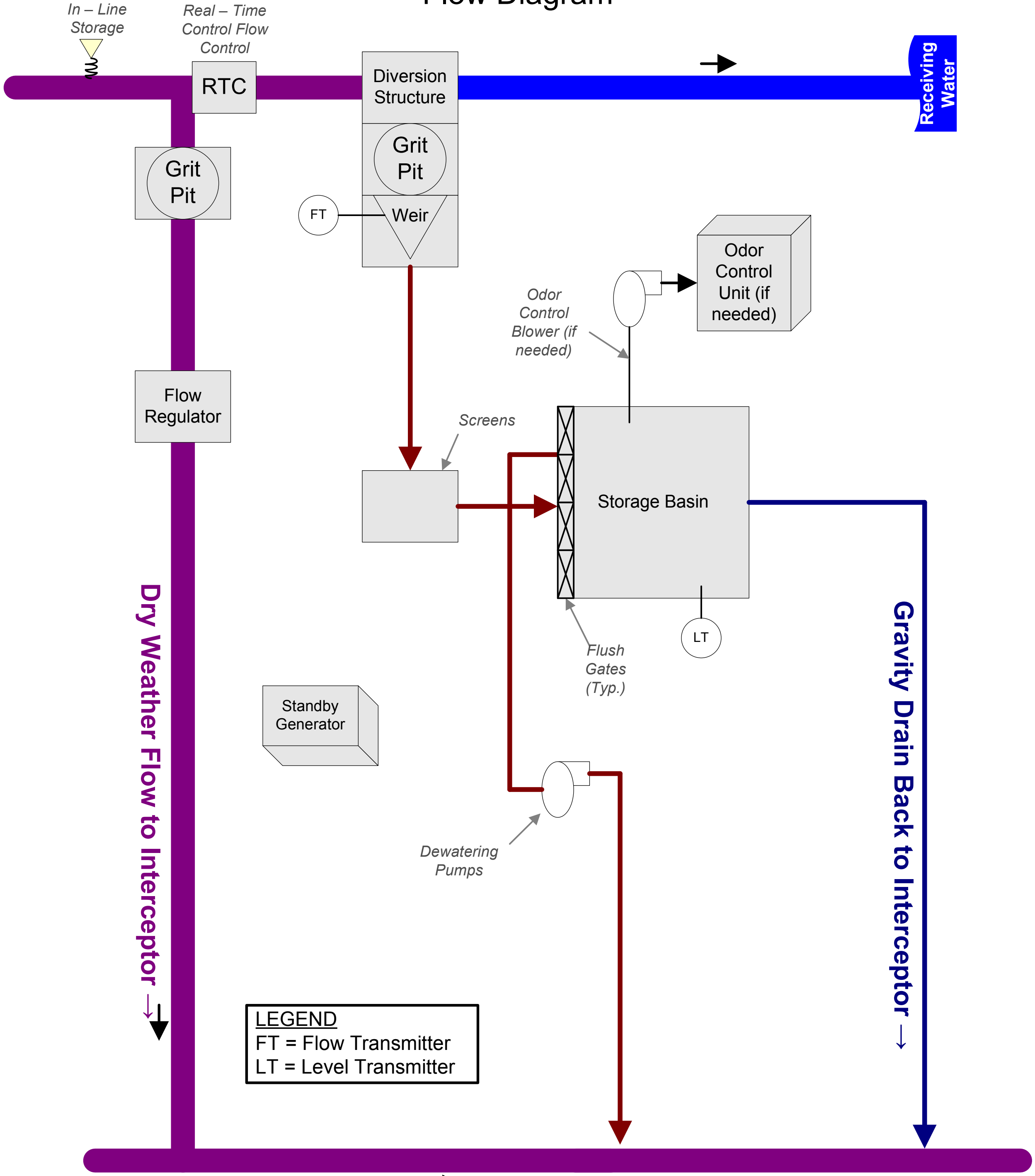
Figure 3.2.25
Hybrid Technology:
Off-Line Storage with Real Time Control
Pumped Effluent
Flow Diagram



PROJECT WIN Waterway Improvements Now

MSD Metropolitan Sewer District

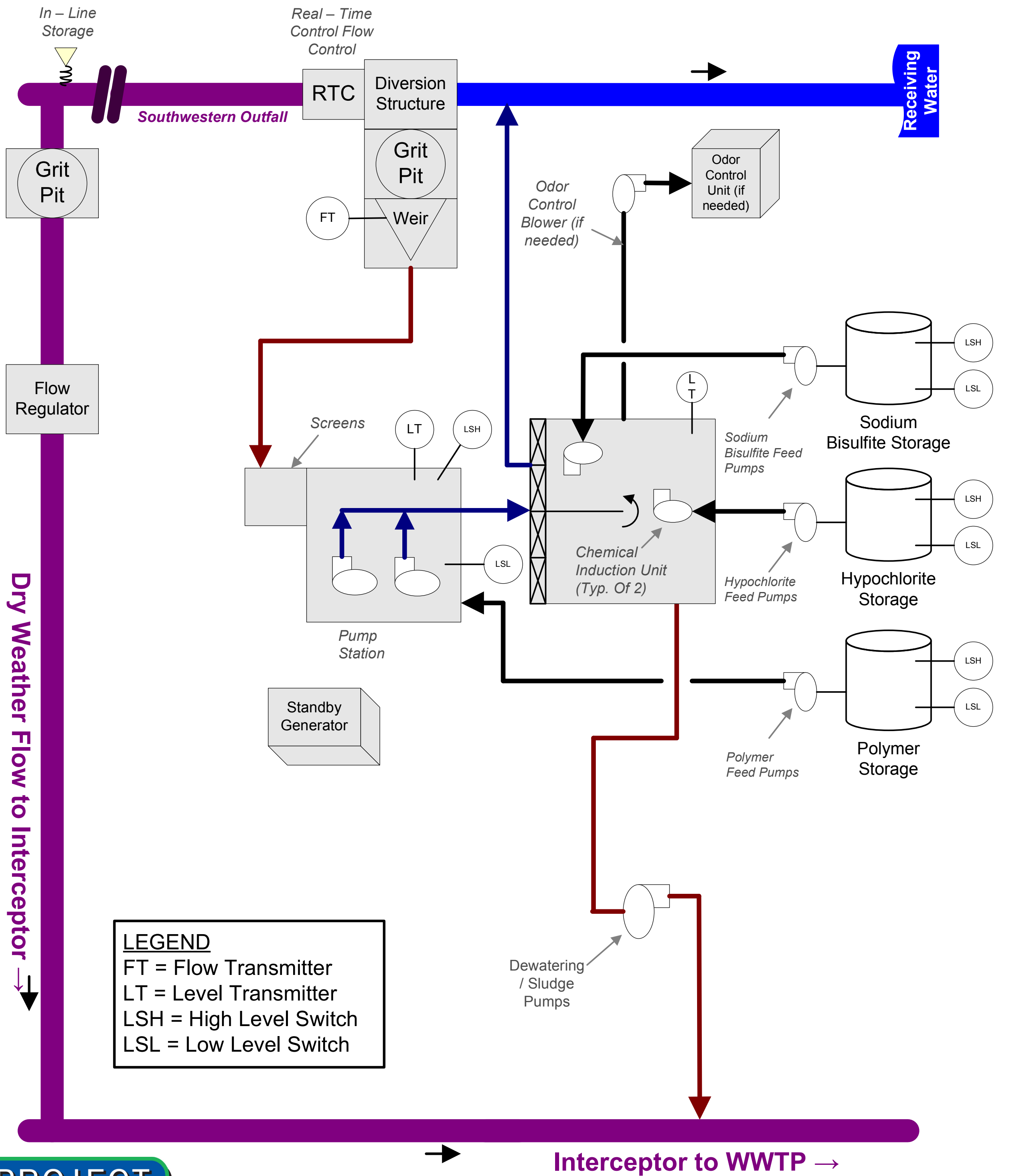
Figure 3.2.26
Hybrid Technology:
Off-Line Storage with Real Time Control
Gravity Effluent
Flow Diagram



PROJECT WIN Waterway Improvements Now

MSD Metropolitan Sewer District

Figure 3.2.27
Hybrid Technology:
Retention Treatment Basin with Real-Time Control
Process Flow Diagram



PROJECT WIN Waterway Improvements Now

MSD Metropolitan Sewer District

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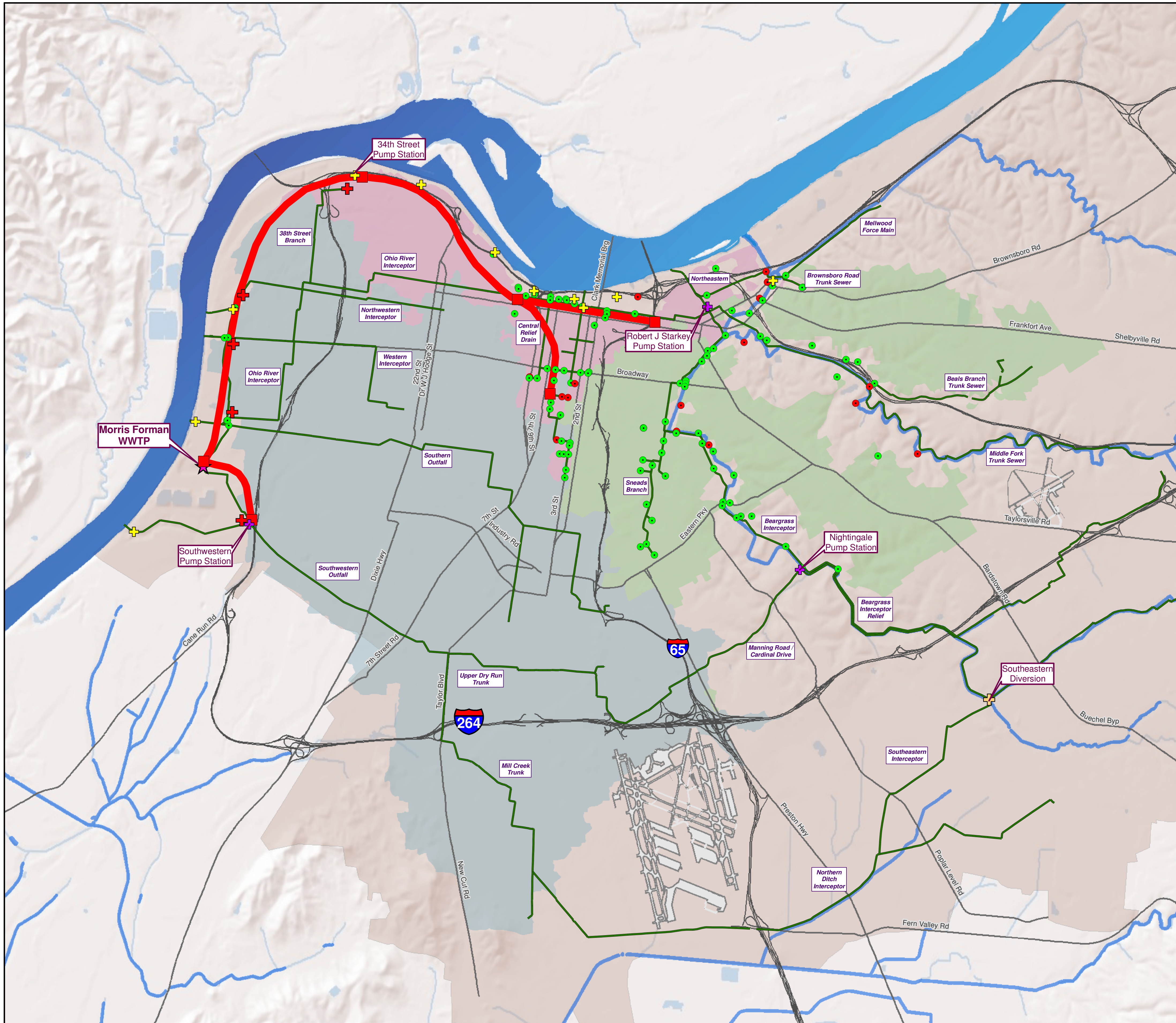
Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 3.3.2
REGIONAL CONSOLIDATION ALTERNATIVE 1



LEGEND

- Construction Access Shaft
- Drop Shaft >= 12 MGD
- Active CSO Location
- Eliminated CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Wastewater Treatment Plant
- Regional Consolidation Alternative
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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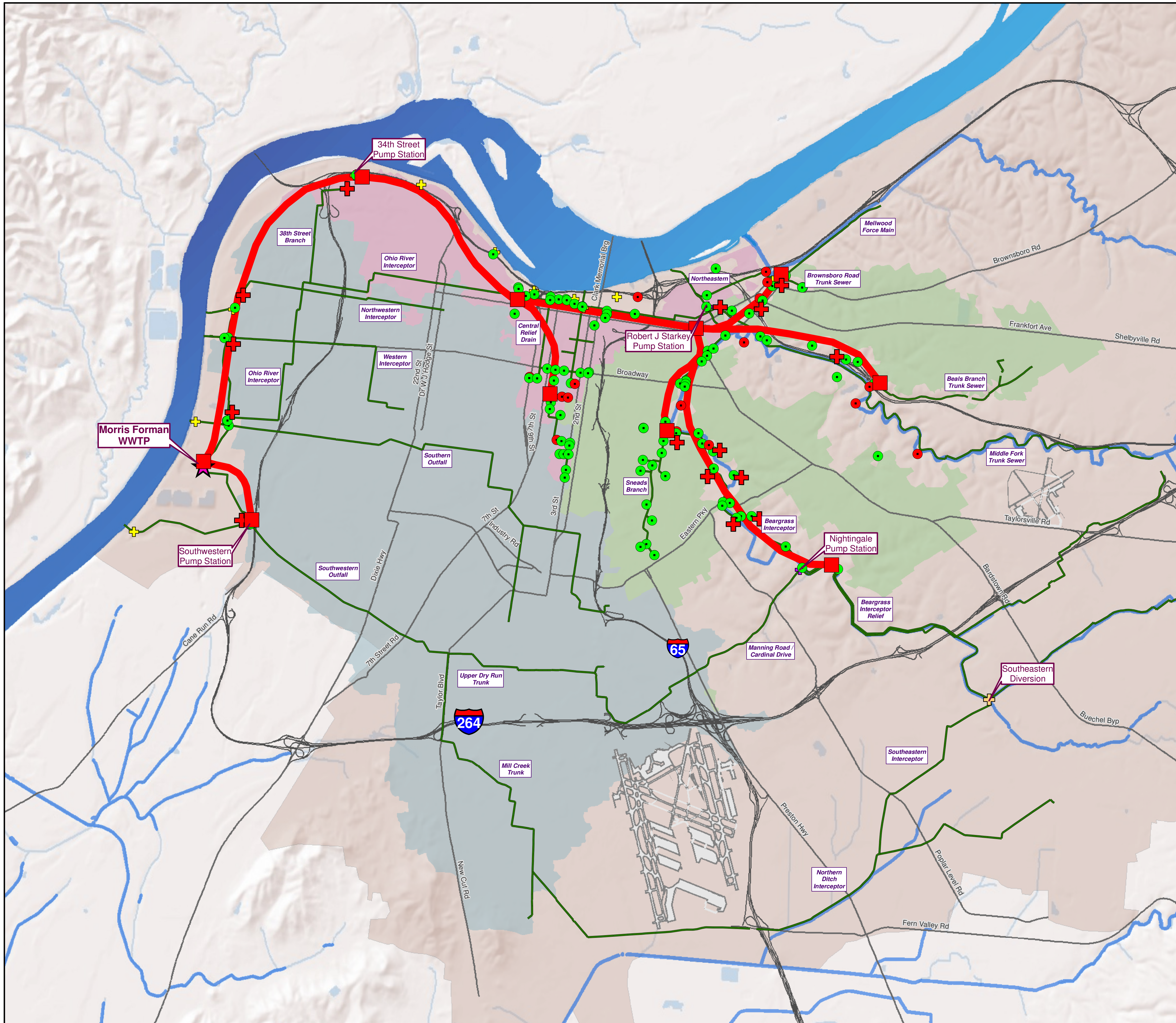
Integrated Overflow Abatement Plan

Vol. 2 - Final CSO Long-Term Control Plan

FIGURE 3.3.3
REGIONAL CONSOLIDATION ALTERNATIVE 2



LEGEND

- Construction Access Shaft
- Drop Shaft >= 12 MGD
- Active CSO Location
- Eliminated CSO Location
- Flood Pump Station
- Sanitary Pump Station
- Wastewater Treatment Plant
- Regional Consolidation Alternative
- Major Sewer Line
- Interstate
- Major Road

Regional Boundaries

- Beargrass Creek
- Ohio River North
- Ohio River West
- Morris Forman Service Area
- Water Feature

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O'Brien & Gere: I:\Lville-Jeff-Msd.10777\40109.Cso-Ltcp-Develo\LTCP PROJECT\GIS\MXDs\for LTCP Document\3.3.3 Regional Consolidation - Alternative 2.mxd

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APRIL 30, 2021

2021 IOAP MODIFICATION

VOLUME 2 FINAL LTCP, CHAPTER 4

METROPOLITAN SEWER DISTRICT

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

Note: Appendices shown in italic text were not revised for the 2021 IOAP and remain the same as the 2012 IOAP Modification. All appendices have been provided on a separate USB flash drive and are not included in this report.

Chapter 4: SELECTION OF A FINAL CSO LONG-TERM CONTROL PLAN

Special Note – 2021 IOAP Modification: This chapter was initially developed in 2009. This chapter generally describes the procedures used to select the level of control, prioritize projects, and develop the Final LTCP. An overview describing LTCP progress to-date and modifications made is provided at the beginning of this chapter. Items discussing procedure are unchanged, as is overall statistical information developed from the 2009 LTCP. Other items throughout this chapter related to project modifications are revised where relevant. One of the Volume 2, Chapter 4 appendices has been updated from the information provided with the 2012 IOAP and two new appendices were added for the 2021 IOAP.

The development of the Final Long-Term Control Plan (Final LTCP), as presented in the Volume 2 chapters, is the result of applying a well-documented and highly structured decision analysis process. This process considers a wide range of factors, resulting in a comprehensive program that significantly reduces Louisville and Jefferson County Metropolitan Sewer District (MSD) CSOs. The evolution of the Final LTCP program includes an integration of both green infrastructure and conventional gray infrastructure solutions. In total, the recommended suite of projects in the Final LTCP in conjunction with the application of the programmatic elements, is expected to capture and treats or eliminate 95 percent of the volume of combined sewage collected in the combined sewer system (CSS) for the Typical Year precipitation events on a system-wide annual average basis.

Chapter 4 presents the final list of elements that comprise the Final LTCP. The process to develop final gray infrastructure projects, followed by summaries of the final recommended green, gray, and flood pump station programs and projects is presented. Chapter 4 concludes with a discussion of the benefits and successes resulting from implementation of the Final LTCP.

In the 2009 Final LTCP there were 28 total gray infrastructure projects and 19 green infrastructure demonstration projects. Since the 2009 Final LTCP, 27 of the 28 gray projects have been modified. Four of the gray projects were consolidated into the Waterway Protection Tunnel Project, two projects were incorporated into the Logan & Breckenridge Street Storage Basin Project, the Algonquin Parkway Storage Basin Project was divided into two new projects, and the Central Relief Drain Project was split from the 13th & Rowan CSO Project; resulting in a total of 25 Final LTCP gray infrastructure projects. The green infrastructure projects and overall green infrastructure program are presented in Section 4.1.2.1

As part of the adaptive management methodology, projects can be modified based on improved calibration, changed conditions, or the evaluation of other alternatives. The modification of projects provides an improved final project better aligned with previously determined community values. As of December 31, 2020, 24 projects have been certified completed and the Waterway Protection Tunnel remains under construction. Table 4.0-1 summarizes the 25 Final LTCP projects, listing any changes to each project, the date if the project has been completed, and the revised schedule if the project is remaining. Table 4.0-2 summarizes the Waterway Protection Tunnel. A copy of minor modification letters can be found in Appendix 4.0-1 and a copy of certification letters can be found in Appendix 4.0.2

Appendix 4.0.1 LTCP Project Minor Modification Letters
Appendix 4.0.2 LTCP Project Certification Letters
These Appendices are new to the 2021 IOAP and are provided on an external USB drive.

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Table 4.0-1 Summary of Final LTCP Project Modifications

	FINAL LTCP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 CSO(S) CONTROLLED & LEVEL OF CONTROL	2009 TECHNOLOGY AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 CSO(S) CONTROLLED & LEVEL OF CONTROL	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 CSO(S) CONTROLLED & APPROVED LEVEL OF CONTROL	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
1	CSO108 Dam Modification, *L_SO_MF_108_S_09A_B_A_4*	Beargrass Creek South Fork	4 overflows per TY for CSO 108	CSO Structure Improvements	$150,000	2010	4 overflows per TY for CSO 108	CSO Structure Improvements	No Change	No Change	2018. Project remains the same, based on additional calibration of the hydraulic model, the level of control was changed from 4 to 8 overflows per Typical Year.	8 overflows per TY for CSO 108	CSO Structure Improvements	$107,600	2010
2	Adams Street Sewer Separation (*formerly Storage Basin*), *L_OR_MF_172_S_09B_B_A_0*	Ohio River	0 overflows per TY for CSO 172	0.12 MG Storage Basin	$983,000	2012	0 overflows per TY for CSO 172	Sewer Separation	$20,000	2012	2012. Sewer separation replaced 0.12 MG storage basin. Upon inspection of the sewer system, all but two catch basins were separated already during recent redevelopment. MSD completed remaining separations.	0 overflows per TY for CSO 172	Sewer Separation	$92,300	2012
3	CSO 123 Downspout Disconnection, *L_MI_MF_123_S_08*	Beargrass Creek Middle Fork	CSO 123	Downspout Disconnection	$315,000	2012	No Change	Downspout Disconnection	No Change	No Change	No Change	CSO 123	Downspout Disconnection	Costs included under Green Program	2012
4	34th Street Flood Pump Station DWO Elimination, *L_OR_MF_019_S_03_A_B*	Ohio River	CSO019	Flow Control	$541,000	2012	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$646,000	2012
5	4th Street Flood Pump Station DWO Elimination, *L_OR_MF_022_M_03_A_A*	Ohio River	CSOs 022, 023	Flow Control	$944,000	2012	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$986,400	2012
6	27th Street Flood Pump Station DWO Elimination, *L_OR_MF_019_S_03_A_A*	Ohio River	CSO019	Flow Control	$476,000	2013	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$726,700	2013
7	Shawnee Flood Pump Station DWO Elimination, *L_OR_MF_189_M_03_A_A*	Ohio River	CSOs 104, 105, 189	Flow Control	$411,000	2013	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$1,065,100	2013
8	CSO 206 Sewer Separation, *L_MI_MF_206_S_08_A_A_0*	Beargrass Creek Middle Fork	CSO 206	Sewer Separation	$3,842,000	2013	No Change	Sewer Separation	No Change	No Change	No Change	0 overflows per TY for CSO 206	Sewer Separation	$577,300	2013
9	CSO058 In-Line Storage & Green Infrastructure, *L_OR_MF_058_S_08_A_A_0*	Ohio River	0 overflows per TY for CSO 058	Sewer Separation	$1,361,000	2014	8 overflows per TY for CSO 058	Sewer Separation	No Change	No Change	2014, 2020. In 2014 project changed to weir modifications to address surcharging in lieu of ineffectual sewer separation. In 2020 project incorporated into 13th & Rowan remedy.	8 overflows per TY for CSO 058	Sewer Separation	Costs included in Waterway Protection Tunnel LTCP Project #25	2014
10	17th Street Flood Pump Station DWO Elimination, *L_OR_MF_190_S_03_A_A*	Ohio River	CSO 190	Flow Control	$625,000	2014	No Change	Flow Control	No Change	No Change	No Change	LOC and CSOs Controlled Not Relevant	Flow Control	$756,500	2014
11	CSO140 In-Line Storage & Green Infrastructure Controls, *L_MI_MF_140_S_08_A_A_0*	Beargrass Creek Middle Fork	0 overflows per TY for CSO 140	Sewer Separation	$3,150,000	2015	0 overflows per TY for CSO 140	CSO Structure Improvements	$574,000	2015	2012. Reconstructed the CSO structure to increase the low flow line to a 42-inch diameter opening which increased the conveyance capacity in lieu of sewer separation.	0 overflows per TY for CSO 140	CSO Structure Improvements	$54,700	2015

Table 4.0-1 Summary of Final LTCP Project Modifications

	FINAL LTCP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 CSO(S) CONTROLLED & LEVEL OF CONTROL	2009 TECHNOLOGY AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 CSO(S) CONTROLLED & LEVEL OF CONTROL	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 CSO(S) CONTROLLED & APPROVED LEVEL OF CONTROL	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
12	CSO160 In-Line Storage & Green Infrastructure, *L_OR_MF_160_S_08_A_A_0*	Ohio River	0 overflows per TY for CSO 160	Sewer Separation	$237,000	2015	0 overflows per TY for CSO 160	In-Line Storage and Sewer Separation	$231,000	2015	2012. In-line storage provided by a combination of raising the existing overflow weir and installing 88 feet of 72-inch diameter pipe.	0 overflows per TY for CSO 160	In-Line Storage and Sewer Separation	$248,200	2015
13	CSO093 Structural Modifications & Green Infrastructure, *L_SO_MF_093_S_08_A_A_0*	Beargrass Creek South Fork	0 overflows per TY for CSO 093	Sewer Separation	$952,000	2015	0 overflows per TY for CSO 093	CSO Structure Improvements	$488,000	2015	2012. Reconstruction of the CSO structure replaced the existing leaping weir with a more conventional overflow weir in lieu of sewer separation.	0 overflows per TY for CSO 093	CSO Structure Improvements	$1,693,200	2015
14	Story Avenue & Spring Street Green Infrastructure (*formerly Storage Basin*), *L_SO_MF_130_S_09B_B_A_8*	Beargrass Creek South Fork	8 overflows per TY for CSO 130	0.01 MG Storage Basin	$1,077,000	2016	8 overflows per TY for CSO 130	Green Projects	$896,000	2016	2012. Construction of a suite of green infrastructure projects in lieu of the storage basin.	8 overflows per TY for CSO 130	Green Projects	$1,070,000	2016
15	CSO190 Green Infrastructure Solution *(formerly 18th & Northwestern Pkwy Storage Basin)*, *L_SO_MF_190_S_09B_B_A_8*	Ohio River	8 overflows per TY for CSO 190	1.31 MG Storage Basin	$4,514,000	2017	8 overflows per TY for CSO 190	1.24 MG Storage Basin	$5,039,000	2017	2015. Green infrastructure solutions for CSO 190 replaced the storage basin at 18th and Northwestern Parkway.	8 overflows per TY for CSO 190	Green Infrastructure	$6,418,200	2017
16	Bells Lane Wet Weather Treatment Facility *(formerly Paddy's Run)*, *L_OR_MF_015_M_13_B_B_8*	Ohio River	8 overflows per TY for CSO 015, 191	50 MGD Treatment Facility	$24,940,000	2014	8 overflows per TY for CSO 015, 191	50 MGD Treatment Facility, 25 MG Storage via Real Time Control Optimization of Main Diversion Structure	$68,472,000	2016	2012, 2016. Optimization of flow through Morris Forman's Main Diversion Structure and MSD's Real Time Control strategy added storage volume. Additional time for construction was requested due to size increase, moving the site, offline storage, and integration of Southwestern Pump Station. Changed completion deadline from December 31, 2016 to September 30, 2017.	8 overflows per TY for CSOs 015 and 191	50 MGD Treatment Facility, 25 MG Storage via Real Time Control Optimization of Main Diversion Structure	$51,761,000	2017
17	Nightingale Pump Station Replacement & Storage, *L_SO_MF_018_S_03_A_A*	Beargrass Creek South Fork	0 overflows per TY for CSO 018	60 MGD Pump Station, 0 MG Storage	$15,710,000	2016	0 overflows per TY for CSO 0180 overflows per TY for CSO 018	33 MGD Pump Station with 7.7 MG Storage	$22,123,000	2016	2012, 2016. In 2012 reduced pumping capacity from 60 MGD to 33 MGD and added a 7.7 MG Storage Basin. In 2016, changed completion deadline from December 31, 2016 to June 30, 2017.	0 overflows per TY for CSO 018	33 MGD Pump Station with 7.7 MG Storage	$38,032,000	2017
18	Logan & Breckenridge Street Storage Basin, *L_SO_MF_092_M_09B_B_D_8* *(includes former Beargrass Creek Parallel Interceptor Project)* *(includes former Calvary - Creekside Storage Basin Project)*	Beargrass Creek South Fork	8 overflows per TY for CSOs 091, 113, 117, 146, 149, 152	Logan 11.83 MG Basin Calvary 3.46 MG Basin Combined 15.29 MG	Logan $30,320,000 Calvary $13,720,000 Combined $44,040,000	2017	8 overflows per TY for CSOs 091, 097, 106, 110, 111, 113, 117, 137, 146, 148, 149, 151, 152	Calvary Creekside Basin & Beargrass Parallel Interceptor eliminated and consolidated with 16.6 MG storage at the Logan Street Basin	$48,243,000	2018	2016. Technical functionality of project remained the same. Modified project to bury the basin and allow community-accessible open space above it.	8 overflows per TY for CSOs 091, 097, 106, 110, 111, 113, 117, 137, 146, 148, 149, 151, 152	16.6 MG Storage Basin	$92,821,600	2017

Table 4.0-1 Summary of Final LTCP Project Modifications

	FINAL LTCP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 CSO(S) CONTROLLED & LEVEL OF CONTROL	2009 TECHNOLOGY AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 CSO(S) CONTROLLED & LEVEL OF CONTROL	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 CSO(S) CONTROLLED & APPROVED LEVEL OF CONTROL	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
19	Southern Outfall In-Line Storage at 43rd Street (SOR1) *(formerly Algonquin Parkway Storage Basin)*, *L_OR_MF_211_M_13_B_A_8*	Ohio River	*former project subsequently eliminated and replaced in 2012: 8 overflows per TY for CSO 016, 210, 211*	*former project subsequently eliminated and replaced in 2012: 4.84 MG Storage Basin*	*former project subsequently eliminated and replaced in 2012: $17,300,000*	*former project subsequently eliminated and replaced in 2012: 2018*	8 overflows per TY for CSO 016, 210, 211	11.4 MG In-Line Storage	$3,544,000	2018	2012. Optimized operating rules between the Bells Lane Wet Weather Treatment Facility and the Morris Forman WQTC's Main Diversion Structure demonstrated that only inline storage was needed at SOR1 and SOR2. Eliminated the Algonquin storage basin portion of the project.	8 overflows per TY for CSOs 016, 210. 211	11.4 MG In-Line Storage	$2,999,500	2018
20	Central Relief Drain CSO In-Line Storage, Green Infrastructure & Distributed Storage, *LOR_MF_155_M_09B_B_B_4-1*	Ohio River	N/A	N/A	N/A	N/A	8 overflows per TY for CSOs 028, 029, 034, 036, 178, 181, 193, 195, 196, 197, 199, 200X, 202	Diversion, Weir Modifications, Green Infrastructure	$2,184,000	2020	2012. Project was added to the IOAP in order to split the Central Relief Drain work from the 13th Street & Rowan Project.	8 overflows per TY for CSOs 028, 029, 034, 036, 178, 181, 193, 195, 196, 197, 199, 200X, 202	Diversion, Weir Modification, Green Infrastructure	$569,572	2018
21	Morris Forman WQTC Headworks Improvements *(formerly Algonquin Parkway Storage Basin and formerly SOR2), L_OR_MF_160_S_08_A_A_0*	Ohio River	*former project subsequently eliminated and replaced in 2012: 8 overflows per TY for CSO 016, 210, 211*	*former project subsequently eliminated and replaced in 2012: 4.84 MG Storage Basin*	*former project subsequently eliminated and replaced in 2012: $17,300,000*	*former project subsequently eliminated and replaced in 2012: 2018*	8 overflows per TY for CSOs 016, 210, 211	In-Line Storage at two locations SOR1, SOR2	$3,544,000	2018	2012. In 2012, eliminated SOR2 project and replaced with flow control improvements at the Main Diversion Structure and rehabilitation of Morris Forman WQTC Headworks in order to increase maximum sustainable treatment capacity to 330 MGD.	8 overflows per TY for CSOs 016, 210, 211	Flow Control, Treatment Improvement	$13,175,805	2018
22	Clifton Heights Storage Basin, *L_MU_MF_154_M_09B_B_A_8*	Beargrass Creek Muddy Fork	8 overflows per TY for CSOs 132, 154, 167	6.55 MG Storage Basin	$13,870,000	2018	4 overflows per TY for CSOs 132, 154, 167	4.28 MG Storage Basin	$14,166,000	2018	2012, 2014. In 2012 revised basin from 6.55 MG to 4.28 MG and level of control from 8 overflows per Typical Year to 4. In 2014, revised basin size to 7.0 MG.	4 overflows per TY for CSOs 088, 131, 132, 154, 167	7.0 MG Storage Basin	$33,390,500	2018
23	Portland CSO Basin, *L_OR_MF_019_S_13_B_A_8*	Ohio River	8 overflows per TY for CSO 019	6.37 MG Storage Basin	$20,000,000	2019	No Change	6.37 MG Storage Basin	No Change	No Change	2015. Increased basin size from 6.37 MG to 6.7 MG. The larger size does not reduce CSO occurrences significantly but does provide a reduced residual AAOV.	8 overflows per TY for CSO 019	6.7 MG Storage Basin	$37,894,500	2019

Table 4.0-1 Summary of Final LTCP Project Modifications

		FINAL LTCP PROJECT NAME AND IOAP ID	RECEIVING STREAM	2009 CSO(S) CONTROLLED & LEVEL OF CONTROL	2009 TECHNOLOGY AND SIZE	2009 COST ESTIMATE	2009 FINISH DATE	2012 CSO(S) CONTROLLED & LEVEL OF CONTROL	2012 TECH AND SIZE	2012 COST ESTIMATE	2012 FINISH DATE	MODIFICATION APPROVAL YEAR AND DESCRIPTION	2021 CSO(S) CONTROLLED & APPROVED LEVEL OF CONTROL	2021 TECH AND SIZE	2021 COST ESTIMATE	2021 COMPLETION SCHEDULE DATE OR CERTIFIED YEAR
24		Southwestern Parkway Storage Basin, *L_OR_MF_105_M_13_B_A_0*	Ohio River	0 overflows per TY for CSOs 104, 105, 189	5.08 MG Storage Basin	$17,620,000	2018	0 overflows per TY for CSOs 104, 105, 189	11.07 MG Storage Basin	$30,937,000	2018	2012, 2015, 2018. In 2012, increased basin size form 5.08 MG to 11.07 MG. In 2015, increased basin size from 11.07 MG to 20 MG, with a level of control of 8 overflows per Typical Year and no net system-wide increase in AAOV. In 2018, Revised project deadline to June 30, 2019 and corrected inline storage volume submitted with 2015 minor modification fact sheet to 6.3 MG.	8 overflows per TY for CSOs 104, 105, 189	20 MG Storage basin, 6.3 MG In-Line Storage	$80,623,100	2019
25	Waterway Protection Tunnel	*(formerly I-64 & Grinstead CSO Basin), L_MI_MF_127_M_09B_B_A_8)*	Beargrass Creek Middle Fork	8 overflows per TY for CSOs 125, 126, 127, 166	2.74 MG Storage Basin	$12,950,000	2014	4 overflows per TY for CSOs 125, 126, 127, 166	8.5 MG Storage Basin + Storm water Diversions	$48,591,000	2020	2012, 2015, 2016, 2018.In 2012, basins sizes were adjusted based on re-calibration. In 2015, basin sizes were adjusted as part of Basin Balancing Modification. In 2016, revised design to a 31.8 MG tunnel solution that consolidates CSO controls for 13th Street and Rowan Street, Story Avenue and Main Street, and Lexington and Payne Street Storage Basins. In 2018, changed project name to "Waterway Protection Tunnel" and revised design to a 52.2 MG tunnel solution that consolidates CSO controls for Ohio River Tunnel and I-64 & Grinstead Drive Storage Basin.	8 overflows per TY for CSOs 020, 022, 023, 050, 051, 052, 053 ,054, 055, 056, 058, 062, 150, 155 4 overflows per TY for CSOs 125, 126, 127, 166 0 overflows per TY for CSOs 082, 083, 084, 118, 119, 120, 121, 141, 153	52.2 MG CSO Storage Tunnel	$253,401,700	2022
		(formerly 13th Street & Rowan Street Storage Basin), L_OR_MF_155_M_09B_B_B_4)	Ohio River	4 overflows per TY for CSOs 022, 023, 050, 051, 052, 053 ,054, 055, 056, CRD, 150, 155	14.44 MG Storage Basin	$49,680,000	2020	8 overflows per TY for CSOs 022, 023, 050, 051, 052, 053 ,054, 055, 056, 058, 150, 155	4.36 MG Storage Basin	$27,863,200	2020					
		(formerly Story Avenue & Main Street Storage Basin), L_OR_MF_020_S_09B_B_A_8)	Ohio River	8 overflows per TY for CSO 020	0.13 MG Storage Basin	$1,580,000	2013	8 overflows per TY for CSO 020	5.42 MG Storage Basin	$12,576,000	2020					
		(formerly Lexington Road & Payne Street Storage Basin), L_SO_MF_083_M_09B_B_A_8)	Beargrass Creek South Fork	8 overflows per TY for CSOs 082, 084, 118, 119, 120, 121,141, 153	7.31 MG Storage Basin	$25,200,000	2020	0 overflows per TY for CSOs 082, 084, 118, 119, 120, 121,141, 153	8.18 MG Storage Basin	$25,904,000	2020					

Table 4.0-2. Waterway Protection Tunnel

ELIMINATED CSO BASINS NOW CONSOLIDATED INTO WATERWAY PROTECTION TUNNEL	IOAP PROJECT NUMBER	CSOS	LEVEL OF CONTROL (OVERFLOWS PER TYPICAL YEAR)	WATERWAY PROTECTION VOLUME CAPTURE COMMITMENTS	EXPECTED WATERWAY PROTECTION TUNNEL VOLUME
13th Street & Rowan Street Storage Basin	L_OR_MF_155_M_09B_B_A_4	12 CSOs 022, 023, 050, 051, 052, 053 ,054, 055, 056, 058, 150, 155)	8	9.8 MG	31.8 MG
Story Avenue & Main Street Storage Basin	L_OR_MF_020_S_09B_B_A_8	2 CSO (020, 062)	8	8.3 MG	
Lexington Road & Payne Street Storage Basin	L_SO_MF_083_M_09B_B_A_8	9 CSOs (082, 083, 084, 118, 119, 120, 121,141, 153)	0	13.7 MG	
Additional storage based on final tunnel design					3.4 MG
I-64 & Grinstead Road Storage Basin Elimination	L_MI_MF_127_M_09B_B_A_8	4 CSOs (125, 126, 127, 166)	0	8.5 MG 1.5 MG	10 MG
Approximate additional storage provided by tunnel extension					7 MG
TOTAL				**41.8 MG**	**52.3 MG**

4.1. FINAL SELECTION OF RECOMMENDED PLAN

MSD developed a Final LTCP to address CSOs discharging to four receiving streams:

- Ohio River
- Beargrass Creek Muddy Fork
- Beargrass Creek Middle Fork
- Beargrass Creek South Fork

As presented in Chapter 3 and in Figure 3.3-1, the process for final selection of CSO control solutions followed these sequential steps:

- Develop Initial Solutions List
- Apply Initial Solutions Screening Criteria
- Prepare Conceptual Design
- Prepare Planning-level Cost Estimates
- Determine Risk Reduction/Benefit Increment
- Calculate Benefit - Cost Ratio
- Develop Recommended Solutions List
- Perform Recommended Solutions Performance Optimization
- Select CSO Control Solutions

The selection and sizing of the CSO controls was based on CSS model results using Jefferson County, 2001 rainfall data and the InfoWorks Collection System (InfoWorks CS) software. To fully incorporate a Green Infrastructure Program into the Final LTCP, programmatic decisions were made by MSD and a technical team, the Wet Weather Team (WWT), and the Stakeholder Group. The proposed Green Infrastructure Program will reduce stormwater runoff into the CSS, and implementation of future Real Time Control (RTC) projects will maximize storage within the existing collection system along with actively managing flow diversions. These programmatic elements downsize the gray infrastructure solutions, satisfying the WWT Stakeholder Group and community requests to merge environmental and aesthetic values of green infrastructure solutions with traditionally constructed facilities (gray infrastructure).

The objective of applying CSO control solutions to a CSS is to reduce combined sewage discharge to receiving streams as required by the 1972 Clean Water Act (CWA) and the 1994 CSO Control Policy (59 Code of Federal Regulations {CFR} 18688). One element of the Consent Decree is the reduction of CSO discharges to levels prescribed in the CSO Control Policy by December 31, 2020. The 2021 IOAP Modification extends this date to December 31, 2026.

The 2021 IOAP Modification clarifies that overall, the MSD system should capture a minimum of 85% of the CSS volume. MSD's hydraulic model indicates a 95 percent capture rate is achievable for the combined system in a Typical Year evaluation. MSD anticipates being able to exceed 85 percent under most wet weather conditions. However, the aging condition of much of the conveyance and treatment infrastructure may present temporal impacts to the overall system, limiting the ability of the system to capture and treat flow.

4.1.1. PROCESS OF GRAY SOLUTIONS ANALYSIS

The MSD CSS had 106 CSO discharge points during the 2009 LTCP development, spatially distributed across 37 square miles of Louisville Metro. A total of 198 gray infrastructure CSO control alternatives were originally proposed by the technical team and MSD staff. An initial screening by the technical team pared this list to 136 viable alternatives that consisted of different types of control technologies, widespread geographic siting, and numerous consolidations of CSO control structures such as outfall, localized, or regionalized solutions. These projects, in turn were subjected to the benefit-cost evaluation process at a level of control of four overflows per year that resulted in a suite of 19 preferred gray infrastructure projects. To determine whether the technology comparison performed at four overflows per year was valid, three of the preferred projects were re-assessed at a level of control of two overflows per year to determine if the same technology would be selected. The outcome of this exercise produced identical results. The details and summary of this information is included in Appendix 4.1.1.

Appendix 4.1.1 Re-evaluation of LTCP Projects Technical Memorandum

Appendix is same as 2012 IOAP Modification and is provided on external USB storage drive.

The 19 preferred gray infrastructure projects were further subjected to an optimization exercise at performance level of control of zero, two, and eight overflow events per year. The 19 alternatives were re-sized (based on volume of overflow with the associated level of control), new conceptual designs prepared, new costs estimated, and associated benefit-cost ratios calculated. Next, a matrix of CSO control alternative versus benefit-cost ratio at zero, two, four, and eight overflow events per year was created. The level of control selected from the evaluation for the LTCP projects is presented in Table 4.0-1.

4.1.2. PRESENTATION OF RECOMMENDED PLAN

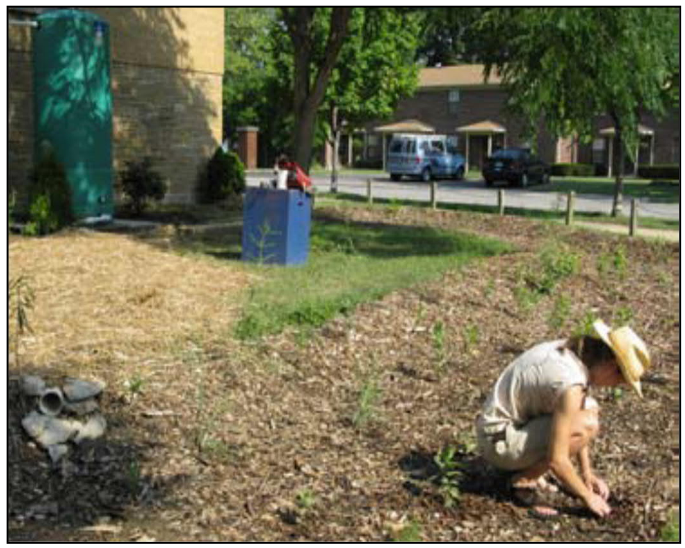
MSD is one of the first CSO communities in the U.S. to fully integrate a comprehensive Green Infrastructure Program into the Final LTCP planning process. Several Green Infrastructure Program components are being implemented at the outset of the IOAP and will complement the Gray Infrastructure Program. All elements of the Final LTCP, the Green Infrastructure Program, the Gray Infrastructure Program, and Flood Pump Station Modification Projects are explained in the following sections.

4.1.2.1. GREEN INFRASTRUCTURE PROGRAM

MSD's Green Infrastructure Program will utilize both specific green demonstration projects and program elements. Integrated with traditional gray solutions, various green techniques will continue to be used to capture, treat, and/or infiltrate stormwater runoff from existing impervious areas.

After an extensive evaluation of impervious surface types and local physical conditions such as soils and geology, MSD has proposed a Green Infrastructure Program that includes the following diverse elements:

- Vegetated roofs
- Downspout disconnection
- Rain barrels
- Green streets
- Urban reforestation
- Green alleys
- Biofiltration
- Rain gardens



A rain garden is a great way to capture runoff before it reaches storm drains. The one above is located at the Americana Community Center.

4.1.2.1.1. DEMONSTRATION PROJECTS

In 2009, MSD identified 19 locations for green infrastructure demonstration projects. These projects were completed in 2010 and 2011, in accordance with the previously approved IOAP schedules, or as modified in subsequent quarterly or annual reports (refer to Table 4.1-1).

The 19 green demonstration projects cost approximately $3 million. More importantly, these projects represent an opportunity to demonstrate various green techniques, develop more accurate and locally based cost information, and gain an understanding of planning, design, and construction best-practices. All the green demonstration projects described below are complete and their wide variety of technologies and geographic spread informed the green program implementation described in Section 4.1.2.1.2.

Table 4.1-1 Final Constructed Green Demonstration Project List

	PROJECT NAME	LOCATION	CSO CONTROLLED	ORIGINAL PROJECT AND TECHNOLOGY	TECHNOLOGY	GALLONS REMOVED ANNUALLY (MG)	CAPITAL COST	COST PER GALLON REMOVED	COMPLETION DATE
1	MSD Main Office Parking Lot Bioswale	Ohio River	CSO053	MSD Main Office Parking Lot Bioswale	Biofiltration Technique	1.4	$648,506	$0.09	12/31/2010
2	Seventh and Cedar Green Parking Lot	Ohio River	CSO022	Seventh and Cedar Green Parking Lot	Biofiltration Technique	1.4	450,000	$0.46	12/31/2010
3	Scholar House Green Parking Lot	South Fork	CSO146	Second and Broadway Green Parking Lot	Biofiltration Technique	1.2	108,000	$0.09	12/31/2010
4	Third and Ormsby Biofiltration Swales	Ohio River	CSO198	Third and Ormsby Biofiltration Swales	Biofiltration Technique	1.80	117,187	$0.07	12/31/2010
5	Sixth and MLK (Federal Building) Parking Lot	Ohio River	CSO026	Sixth and Muhammad Ali Green Parking Lot	Biofiltration Technique	1.2	235,000	$0.20	12/31/2010
6	Housing Authority Green Roof at 801 Vine Street	Ohio River	CSO084	Sixth and Broadway Rain Garden	Biofiltration Technique	0.27	$60,000	$0.22	12/31/2010
7	W. Gaulbert and W Hill Permeable Alley	Ohio River	CSO015	Seventeenth and W Hill Permeable Alley	Permeable Alley	1.74	72,000	$0.04	12/31/2010
8	2300 Congress Permeable Alley	Ohio River	CSO053	Seventh and Market Permeable Alley	Permeable Alley	0.25	40,000	$0.05	12/31/2010
9	Billy Goat Strut Permeable Alley	South Fork	CSO121	Campbell and Main Permeable Alley	Permeable Alley	0.84	40,000	$0.05	12/31/2010
10	Swift Parking Lot Bioswale	Ohio River	CSO130	Twelfth and Jefferson Green Street	Biofiltration Technique	1.05	57,000	$0.05	12/31/2010
11	Speed Art Museum Infiltration Trench	Middle Fork	CSO211	I-264 Off-Ramp Dry Well	Biofiltration Technique	2.60	252,000	$0.10	12/31/2011
12	CSO 130 Green Street	Middle Fork	CSO130	I-264 On-Ramp Dry Well	Green Street	7.67	364,096	$0.10	12/31/2011
13	University of Louisville – Grawemayer Hall Green Parking Lot	Ohio River	CSO191	I-264 and Gibson Dry Well	Biofiltration Technique	9.74	$207,093	$0.02	12/31/2011
14	Wilson Crossings- Green Parking Lot	Ohio River	CSO015	Russell Lee Drive Dry Well	Biofiltration Technique	0.15	$30,000	$0.20	12/31/2011
15	3rd Street Ventures	Ohio River	CSO211	JFK Montessori Area Dry Well	Biofiltration Technique	1.84	$154,452	$0.08	12/31/2011

Table 4.1-2 Final Constructed Green Demonstration Project List

	PROJECT NAME	LOCATION	CSO CONTROLLED	ORIGINAL PROJECT AND TECHNOLOGY	TECHNOLOGY	GALLONS REMOVED ANNUALLY (MG)	CAPITAL COST	COST PER GALLON REMOVED	COMPLETION DATE
16	Clifton Triangle Rain Garden	Muddy Fork	CSO132	Additional Rain Garden Site	Biofiltration Technique	0.035	$10,000	$0.29	12/31/2010
17	Brandeis Apartments Rain Garden	Ohio River	CSO105	Additional Rain Garden Site	Biofiltration Technique	0.075	$10,000	$0.13	12/31/2010
18	German/Paristown Green Street/Rain Garden	South Fork	CSO146	Additional Rain Garden Site	Green Street/ Biofiltration Technique	1.45	$91,000	$0.063	12/31/2011
19	Brown Forman Green Roof	Ohio River	CSO 015	Additional Rain Garden Site	Biofiltration Technique	1.0	$42,000	$0.042	12/31/2011
				TOTAL		**35.71**	**$2,988,000**	**$0.08**	

4.1.2.1.2. GREEN INFRASTRUCTURE PROGRAM ELEMENTS

The IOAP proposed a multi-faceted green infrastructure program that could be adapted as MSD gathered more flow monitoring data and refined the hydraulic model, began to implement and study green infrastructure installations, and gained additional data regarding how the CSS would respond to green infrastructure and other capital improvements. As MSD designed and constructed LTCP projects, system and programmatic needs evolved. To keep pace with these changes and meet the objectives listed above, MSD intermittently shifted the focus and methodology of the Green Infrastructure Program.

Throughout the evolution, varying program elements were used as tools to implement the objectives. These program elements were: Green Infrastructure Capital Projects, Green Infrastructure Incentive Projects, the Downspout Disconnection Program, and the Urban Reforestation Program. Each of these elements contributed to the objectives above. The Program Elements are defined below.

Program Element #1 – Green Infrastructure Capital Projects

Capital projects are defined as projects that MSD spends capital dollars on and either self-performs or directly contracts for the work to be done (including planning, design, modeling, construction, maintenance, and monitoring activities). Nineteen demonstration projects originally identified in the IOAP were intended as an opportunity to gain understanding of means and methods and inform the Green Program and larger capital projects identified through “right-sizing” moving forward.

At the onset of the IOAP implementation, MSD recognized that both MSD and the engineering community in Louisville did not have significant experience with green infrastructure practices. MSD determined that constructing a limited number of projects would serve as an opportunity for MSD staff and the local engineering community to begin to understand how to implement this relatively new technology in the most effective manner possible. These projects are referred to as demonstration projects. Some of these projects provided some benefit to the CSS and overflow reduction, but the real value and intent of these projects was to allow MSD to learn what practices would provide the most benefit to the CSS and be the most cost effective to construct and maintain. These projects served as case studies to better inform planning, design, construction, and operation practices for the larger future green infrastructure projects. The 19 demonstration projects were all certified as complete prior to December 31, 2011. This information was used in creating a Green Infrastructure Design Manual (Chapter 18 of the MSD Design Manual) and documenting lessons-learned to fulfill project Post-Construction Compliance requirements. The Green Infrastructure Design Manual provides the engineering and development community a resource to use to guide implementation of green infrastructure practices on private property. The Green Management Practice (GMP) specific Fact Sheets offer an overview of each type of GMP, including pros and cons, typical implementation methods, design calculations, and suitability guidance. Additionally, MSD’s Development Plan Review department uses the manual to perform a standardized and consistent review methodology for all GMPs incorporated with all new developments (public and private) with a minimum of 1-acre of land disturbing activity.

The large-scale green infrastructure projects that followed the 19 demonstration projects were implemented via “right-sizing” and have a specific level of control for overflow reduction. These projects typically involved the construction of a suite various hydraulically connected practices within a watershed.

Capital programmatic support were also necessary to ensure best management practices and effectiveness of green applications. These efforts consisted of the ‘behind-the-scenes’ components of green-infrastructure investments and commissioning, including hydraulic modeling, analysis of alternatives, review of practice performance, review of alternatives, evaluation of long-term operations and maintenance needs, as well as many other items similar in nature. This effort began at the onset of IOAP implementation and continued through December 31, 2020. MSD has also partnered with EPA's Office of Research and Development (ORD) since 2011 to monitor and assess data associated with two of these green practices. This cross-agency collaboration has helped shape MSD's green program in regard to informing practice type, design, location, and maintenance.

Program Element #2 – Green Infrastructure Incentive Projects

Incentive projects consist of MSD collaborating with private property owners or other municipal entities to add or enhance green infrastructure on new development and/or redevelopment projects. This methodology leverages available funding and allows for construction of green infrastructure on priv/ate property in areas where MSD would not typically be able to easily construct green infrastructure.

Program Element #3 – Downspout Disconnection Program

The Downspout Disconnection Program consists of disconnecting downspouts that are directly connected to the combined sewer system. This program also includes potentially disconnecting sump pumps connected to the Sewer System and installing backflow prevention devices to protect residential basements form potential sewer backups.

Program Element #4 – Urban Reforestation Program

Urban reforestation consists of MSD's efforts to incentivize tree planting projects throughout the community. This is typically done by reimbursing neighborhood, civic, or non-profit groups for expenses associated with tree planting projects.

Alignment of Program Elements with Green Program Objectives

Each of the program elements defined above have influenced the success of the Green Program, with different combinations of elements satisfying the various objectives. Table 4.1-3 below identifies each program element and the Green Infrastructure Objective to which it contributes.

Table 4.1-3 Green Program Objectives and Program Elements

GREEN PROGRAM OBJECTIVES	GREEN PROGRAM ELEMENTS			
	CAPITAL PROJECTS	INCENTIVE PROJECTS	DOWNSPOUT DISCONNECTION	URBAN REFORESTATION
Right-Sizing	X	X	X	X
Factor of Safety		X	X	X
Enhanced Community Benefits			X	X

Green Program Objectives Satisfied Through Program Elements

Objective 1 – Downsize or Eliminate Gray Infrastructure Projects

Objective 1 was largely met using capital projects developed using the right-sizing methodology. Two LTCP gray storage basin projects were replaced by green infrastructure project suites: the Story and Spring Street Green Infrastructure Project that mitigated CSO130 overflows and the Portland Green Infrastructure Project that mitigated CSO190 overflows.

The first step of rightsizing was evaluating practices installed during the demonstration phase to gauge cost, effectiveness, and long-term sustainability. CSO130, was initially selected due to its relatively small gray infrastructure size and a general suite of practices was developed within the sewershed. This suite was evaluated using detailed modeling of the proposed practices, and the practices were then updated based upon the results. These iterations continued until a suite of practices was developed that created the same Level of Control as the gray infrastructure basin. Costs and benefits for this practice were developed using the same methodologies as the gray basin projects, and the benefit-cost ratio was compared. For this area, the suite of green practices had the highest benefit-cost ratio. The suite of projects was then designed and constructed, and monitoring of the overflow as well as detailed monitoring of the performance of each practice was performed. Monitoring data would be used to assess the performance of this project and to assist in the implementation of future projects.

A similar process was used for the CSO190 watershed, where green infrastructure was selected to remove the gray basin. This same process was used in other areas as well, but the green infrastructure suites of projects did not have higher benefit-cost ratios and were not selected. Generally, MSD learned that for capital project construction, only the full removal of the basin would produce a higher-cost benefit ratio. Hybrid solutions that consisted of down-sizing of basins combined with green practices did not typically result in higher benefit-cost ratios than the gray basins alone.

Concurrent with the right-sizing analysis of LTCP projects, MSD was developing and implementing the incentive program. The monetary values used in the incentive program reflected a cost similar to that used for the rightsizing approach, as reduced impervious areas from redevelopment projects could reduce basin sizes. The reduced impervious areas were taken into account through model calibration and taken into consideration in the final selection of the gray project sizes.

Objective 2 – Provide Programmatic Factor of Safety

Due to design and construction timeframe needs ahead of LTCP schedule deadlines, the right-sizing approach to green infrastructure was no longer feasible to use beginning in 2017. At that time, the primary objective shifted to maximizing system-wide capture. Recognizing that modeling and monitoring have inherent variabilities, and that new and existing infrastructure does not always perform as planned, MSD developed a methodology that allowed additional green infrastructure area removal to be used to create a factor of safety for the overall performance of the combined sewer system as well as incentivize implementation of green projects within priority sewersheds. MSD targeted a 5% factor of safety for overall system AAOV. Based on current modeling with the Waterway Protection Tunnel in place, a 5% reduction in system-wide AAOV is projected to be achieved with approximately a 1% (63 acres) reduction in effective impervious area.

To meet the goal, MSD modified the incentive program to provide values based on costs to provide similar factors of safety using gray infrastructure. The impervious area removal performed for this objective was achieved entirely through the incentive program.

Objective 3 – Community Enhancements

The Green Infrastructure Program's objective to provide additional community benefits beyond direct impacts to system performance has continually been met throughout the duration of the program through a variety of program elements. Several elements were used to implement this objective, including urban reforestation and downspout disconnection, as well as the incentive program and capital projects.

The main program element contributing to this objective is the Urban Reforestation program. This program allows MSD to partner with various entities (non-profit organizations, neighborhood associations, etc.) to provide funding for tree planting projects in previously developed areas. Tree planting has an indirect impact on overflow volumes as increased tree canopy reduces runoff volume and attenuates peak runoff discharges. Tree planting also improves air quality, reduces the heat island effect, indirectly improves flooding, beautifies neighborhoods, and improves overall health and quality of life in neighborhoods. MSD set a goal of planting approximately 1,000 trees annually, which equates to approximately 14,000 trees over the life of the program (which is planned to extend through 2024). Through December 31, 2020, MSD has provided approximately $2.2M in funding for urban reforestation. This equates to approximately 12,250 trees already planted.

The downspout disconnection program also contributes to this objective. Downspout disconnection allows MSD to redirect downspouts to grassed or other overland flow areas and to protect basements from sewer backups. This element also has an indirect impact on overflow volumes as re-directing downspouts helps attenuate peak flows. Furthermore, this also incrementally reduces flooding and protects individual homeowners from basement back-ups. This provides a health, safety, and economic benefit to the individual property owner and the community. As of December 31, 2020, MSD has spent approximately $4.5M on the downspout disconnection program.

Lastly, capital projects and incentive projects contribute other community benefits beyond overflow reduction. In CSO130 and CSO190, existing areas of asphalt and concrete were replaced with green infrastructure, improving the aesthetics of the overall neighborhood. Many of the demonstration projects also performed similar functions. Incentive projects provide additional green infrastructure within new (and existing for re-developments) parking areas and other hardscapes, improving aesthetics and providing some incremental benefit to the heat island effect.

Summary

MSD's Green Infrastructure Program includes a vast array of project types and methodologies that together meet the overall programmatic objectives and intent outlined in the IOAP. The program as a whole has reduced gray infrastructure sizing, provided an additional factor of safety for CSS percent elimination / capture and treatment, and provided additional community benefits beyond combined sewer overflow reduction.

Since 2010, MSD has spent $41.9M on Green Infrastructure. A county-wide map of projects implemented over the course of the program is provided in Appendix 4.1.2. This map has been updated to reflect all green infrastructure projects constructed through December 31, 2020.

Appendix 4.1.2 Map of County-Wide Green Infrastructure Projects
This appendix has been updated and is provided on an external USB drive.

Conclusion & Remaining Program Activities

Comparing the overall green infrastructure program to the objectives defined in this memorandum, MSD has met each of the objectives as described below.

Downsize or Eliminate Gray Infrastructure Projects – Objective Complete

Two major gray projects, the Story & Spring Basin, and the Northwestern Parkway Basin, were eliminated using the CSO 130 and CSO 190 Green Infrastructure Projects, respectively. Additionally, other major basin projects were evaluated but remained as gray projects using the same methodology. The valuation used in the early stages of the incentive program also reflected costs used to downsize CSO basins. No additional effort is needed to complete this objective.

Provide Programmatic Factor of Safety – Objective Complete

After gray basin sizes were set, the green infrastructure program shifted to provide system-wide value, allowing for a factor of safety in prioritized sewersheds. A final target value of 63 acres (1%) of impervious area removal was established, and as of April 30, 2019, 75 acres of impervious area had been removed. No additional effort is needed to complete this objective, although MSD will continue with the committed incentive projects, pending continued partnership with the private property owners.

Community Enhancements – Objective Complete

As of December 31, 2020, MSD has successfully funded the planting of 12,250 trees and anticipates providing funding for an additional 1,750 trees throughout the remainder of the program. The downspout disconnection and backflow prevention program protects thousands of additional basements and removes direct stormwater contribution from the system. Finally, the incentive projects and capital projects lead to additional green space in existing urban areas and in newly developed areas, replacing vast areas of asphalt and concrete. MSD has met this objective through the programs currently in place.

Overall, to fulfill the IOAP Green Program commitments, MSD will complete the remaining projects that have been initiated. However, because the majority of these are incentive projects that rely upon the continued cooperation of the private property owners and are subject to factors like development schedules that are beyond MSD's control, all the expected projects may not have been completed. Because the impervious area reduction target in Objective 2 has already been met, the completion of these projects would not impact the completion of this objective and only further enhance the programmatic factor of safety. MSD will also continue with tree planting partnerships through December 31, 2024.

4.1.2.2. GRAY INFRASTRUCTURE PROGRAM

The 2009 LTCP 19 optimized gray infrastructure project technologies, plus four additional gray project technologies identified during the optimization process, are listed in Table 4.1-4.

Table 4.1-4 Optimized CSO Control Gray Infrastructure Project Technologies (2009)

PROJECT TYPE	NUMBER OF PROJECTS	RECEIVING STREAM(S)
Pump Station Expansion	1	Beargrass Creek South Fork
Sewer Separation	6	Beargrass Creek Middle Fork Beargrass Creek South Fork Ohio River
Off-line Storage	10	Beargrass Creek Middle Fork Beargrass Creek Muddy Fork Beargrass Creek South Fork Ohio River
Hybrid Technology: Off-line Storage w/In-line Storage (RTC)	3	Ohio River
Hybrid Technology: Treatment w/In-line Storage (RTC)	1	Ohio River
In-Line Storage	1	Beargrass Creek South Fork
Miscellaneous Technology: Beargrass Creek Parallel Interceptors – Upper and Lower Reaches	1	NA
TOTAL	23	

Please note the four additional projects are described in detail at the end of this Section. The following sub-sections are descriptions of the project technologies.

Pump Station Expansion

This project is associated with CSO018. In 2009, the project scope was to replace the aging 37 MGD Nightingale Pump Station flow diversion facility on Beargrass Creek South Fork. This project was modified based on downstream limitations to replace the outdated pump station with a 33 MGD pump station and provide a 7.7 MG offline storage basin. A minor modification letter was submitted and approved for this modification.

Sewer Separation

A total of six sewer separation projects were initially recommended at CSO058, CSO093, CSO123, CSO140, CSO160 and CSO206. After additional review, CSO058, 093.140, and 160 were modified to weir modification projects. The separation projects at CSO123 and CSO206 were a continuation of sewer separation projects partially completed at the beginning of the LTCP.

Off-Line Storage

A total of ten off-line storage projects, ranging from 0.01 MG to 14.5 MG, were recommended in the 2009 LTCP. The projects have been re-analyzed, and several of the projects were combined, and the 2021 LTCP now includes 4 offline storage facilities (including Nightingale), ranging in size from 7 MG to 52 MG.

These off-line storage projects store a total of approximately 84 MG of combined sewage, an increase of 34 MG of additional storage when compared to the 2009 LTCP. A summary of off-line and online storage volumes can be found in Table 4.1-4.

System pump-back operation into the Morris Forman WQTC tributary CSS was conceptually designed for 24-hour pump out of the tanks; however, final design can configure pumping units for a variety of return scenarios. It is envisioned that an integrated control system will manage the storage basin pump-back operations, coordinating interceptor capacities and capacity at Morris Forman WQTC. If necessary, odor control facilities can be incorporated into final design should septic odor generation be a concern of facility operation.

Hybrid Technology: Off-Line Storage with In-line Storage (RTC)

Three hybrid technologies were initially recommended at CSO019, CSO105 and CSO211 that discharge into the Ohio River. CSO211 was modified to In-line storage Hybrid Technology: Treatment with In-Line Storage (RTC)

The hybrid technology treatment with In-line storage (RTC) is recommended at CSO015 and CSO191, on the common outfall that discharges into the Ohio River. The proposed treatment process is equivalent primary treatment utilizing a retention treatment basin. Effluent water quality produced by this technology is discussed in Chapter 3 Section 3.3. Operation of the treatment plant is specific to wet weather events only (that is, only for an established volume of CSO into the Southwestern Outfall to warrant plant startup). The facility was initially to be located adjacent to the Southwestern Outfall near the Paddy's Run Flood Pump Station. The station location was moved upstream, just downstream of the Southwestern Gate Structure.

In-Line Storage

During the optimization process of the CSS it was determined that by making modifications to a control dam at CSO108, that associated overflow frequency would be reduced to less than eight events per year. Thus, a new project was created, anticipating installation of a bending weir at this location to raise the elevation by one foot. The CSS at this location has sufficient unused capacity to store the necessary volume within the collection system. Additionally, the offline storage basin proposed at CSO211 as part of the 2009 LTCP was removed as part of the 2012 LTCP, but the in-line storage upstream of CSO211 remains in the Final LTCP. Furthermore, RTC Phases 1 and 2 provided inline storage at existing facilities. Table 4.1- displays the total storage volume for each facility.

Table 4.1-4 Wet Weather Storage in CSS

WET WEATHER STORAGE AND REAL TIME CONTROL	STORAGE VOLUME (MG)	DATE STORAGE ON-LINE
Early Action Projects (Real Time Control Phase 1) - ILS		
Southwestern Pump Station Sluice Gates Chamber (SWSG)	14.3	2006
Brady Lake & Executive Inn Storage Basin (Upper Dry Run Trunk System)	21.5	2006
Ashland In-Line Storage Facility	1.0	2008, Upgraded 2019
Ohio River Interceptor (MDS)	1.8	2008
Sneads Branch In-Line Storage	2.5	9/30/2006
Southwest Outfall Retention Basin #2 (SWOR2) - ILS	4.1	12/31/2008
Southern Outfall In-Line Storage @43rd Street (SOR1) - ILS	14.1	11/30/2018
Logan & Breckinridge Street CSO Basin	17	12/20/2017
Nightingale Pump Station Replacement & Storage (NGPS)	8.0	6/30/2017
Clifton Heights CSO Storage Basin	6.9	12/21/2018
Southwestern Parkway Storage Basin (20.0 OLS/6.3 ILS)	26.3	3/29/2019
Portland CSO Basin (6.7 OLS/1.8 ILS)	8.5	8/30/2019
Waterway Protection Tunnel	52.3	12/31/2022
Total	**178.3**	

4.1.2.3. FLOOD PUMP STATION MODIFICATIONS PROJECTS

Table 4.1-5 summarizes the five flood pump station physical modification projects. These projects were developed in response to the provision under the Consent Decree; MSD is required to provide for the following outcomes:

- Paragraph 25b. (2) A. (i) - "The final Long-Term Control Plan shall meet the following goals: Ensure that if CSOs occur, they are only as a result of wet weather (this goal shall include addressing those discharges resulting from MSD's compliance with the requirements of the USACE' Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);"
- Paragraph 25b, (2) B. (i) - "The final Long-Term Control Plan shall include, at a minimum, the following elements: The results of characterization, monitoring, modeling activities and design parameters as the basis for selection and design of effective CSO controls (including controls to address those discharges

resulting from MSD's compliance with the requirements of the USACE's Ohio River Flood Protection System Pumping Operations Manual, dated 1954 and revised 1988);"

Pursuant to this requirement of the Consent Decree, the flood pump station projects identified in Table 4.1-5 are a component of the selected plan and were not subject to the cost benefit analysis. Flood pump station projects were identified for the following facilities:

- 27th Street Flood Pump Station
- 34th Street Flood Pump Station
- Shawnee Flood Pump Station
- 4th Street Flood Pump Station
- 17th Street Flood Pump Station

To implement these projects the following actions needed to occur:

- Develop plans and specifications for each of the identified projects.
- Prepare revisions to the USACE Manual that reflects the operational and physical modifications proposed in the USACE Flood Pump Station Operation Modification Technical Memorandum (See Appendix 2.3.1).
- Secure review and approval by the USACE. Coordination with, and approval by the USACE will be required prior to any modifications being made to the congressionally authorized flood protection works for Louisville, Kentucky. The implementation schedule includes two nine-month review periods per project for USACE review of the conceptual plans and proposed Manual revisions and the final plans and specifications. Delays in USACE approval and responses beyond this time estimate could impact scheduled completion dates, as detailed in Table 4.1-5.

Table 4.1-5 2021 Final Recommended Flood Pump Station Project List

PROJECT NAME	WATERSHED	CSO CONTROLLED	TECHNOLOGY	CAPITAL COST (2008 DOLLARS)	COMPLETION DATE
34th Street Flood Pump Station L_OR_MF_019_S_03_A_B	Ohio River	CSO019	Flow Control	$541,000	12/31/2012
4th Street Flood Pump Station L_OR_MF_022_S_03_A_A	Ohio River	CSO022, CSO023	Flow Control	$944,000	12/31/2012
27th Street Flood Pump Station L_OR_MF_019_S_03_A_A	Ohio River	CSO019	Flow Control	$476,000	06/30/2013
Shawnee Flood Pump Station L_OR_MF_189_S_03_A_A	Ohio River	CSO104, CSO105, CSO189	Flow Control	$411,000	06/30/2013
17th Street Flood Pump Station L_OR_MF_190_S_03_A_A	Ohio River	CSO190	Flow Control	$625,000	12/31/2014

4.1.3. KNEE OF THE CURVE EVALUATION

2021 Update: The "knee-of-the-curve" analysis discussed in this section was performed for the 2009 Final LTCP utilizing data available at that time. Because overall Final LTCP, produces a similar performance to the 2009 LTCP, the general conclusions stated in this chapter should still be relevant.

An accepted method for evaluating alternatives is by constructing cost/performance curves. The evaluation can be done either by comparing similar alternatives over a range of designs (that is, a storage basin for a range of percent overflow reductions) or by comparing a range of control alternatives for a given design condition (that is, storage basin, treatment facility and sewer separation for a specific design condition). These curves, or comparisons, typically indicate that for lower levels of control, small increments of increased cost (investment) result in large increments of improved performance. As well, for higher levels of control, large increments of increased cost results in small increments of improved performance. Collectively, these points on the curve make up the cost/performance curve. The optimal point or "knee of the curve" is identified as the point where the incremental change in cost per increment of performance changes the most rapidly indicating that the slope of the curve is changing from shallow to steep or vice versa.

The knee of the curve analysis was used extensively to validate the level of control selected through the benefit-cost project size optimization analysis described in Chapter 3. Optimal points or knees of the curve were developed for many program performance factors. Each indicates that the recommended LTCP level of control is supported by the knee of the curve analysis.

MSD utilized the Ohio River Water Quality Model and the Beargrass Creek Water Quality Tool (WQT) to calculate fecal coliform concentrations in the Kentucky side of the Ohio River and the three forks of the Beargrass Creek for various control scenarios using the typical rainfall. The CSS model was utilized to calculate the CSO wet weather percent capture for the preferred suite of projects using the typical rainfall. MSD also used the Project Cost Estimating Document discussed in Chapter 3 to calculate system-wide program planning-level capital costs for the preferred suite of projects corresponding to CSO level of control of zero, two, four, and eight overflows per year.

The water quality information presented in this chapter remains relevant for the Final LTCP in terms of providing the regulatory agencies the information needed to determine that the proposed level of treatment in MSD's LTCP approach will achieve water quality standards. It should be noted that consistent with the Presumption Approach in the CSO Policy, MSD is not intending to conduct water quality sampling or update the water quality model for the purpose of verifying these results or determining post-construction compliance. The 2009 graphs of this data, including water quality corresponding to baseline (no CSO controls) condition are shown in Figure 4.1-1 through Figure 4.1-7 for each of the following:

- CSO Wet Weather Percent Capture vs. Capital Cost (Entire System)
- Fecal Coliform Peak vs. Percent Capture (Ohio River)
- Peak Fecal Coliform vs. Capital Cost (Ohio River)
- Monthly Maximum Non-Compliance - Recreation Season vs. Percent Capture (Ohio River)
- Fecal Coliform vs. Percent Capture (Beargrass Creek)
- Fecal Coliform Peak vs. Capital Cost (Beargrass Creek)
- Fecal Coliform Geometric Mean vs. Capital Cost (Beargrass Creek)

The results shown in these curves are presented for the Ohio River near shore segment just downstream of the Morris Forman WQTC and the mouth of Beargrass Creek where it enters the Ohio River. Since the approval of the 2012 IOAP Modification, MSD has experienced a reduction in wet weather treatment capacity at Morris Forman WQTC. This reduction in wet weather treatment capacity results in a percent capture of CSO volume of 95 percent. The 2021 IOAP update includes significant capital projects to restore the wet weather capacity at Morris Forman WQTC. However, due to the age and nature of the infrastructure at the WQTC, and to be more inline with standard engineering practices, the 2021 IOAP will be based on the firm capacity of the Morris Forman WQTC. While MSD fully intends to operate the WQTC at its maximum capacity as often as possible, planned and emergency maintenance and repair projects may require specific plant components to be repaired or replaced, which would limit the plant capacity. Therefore, the 2021 LTCP modification results in a commitment to a minimum overall percent capture of 85%, consistent with the Presumption Approach minimum requirements. With facilities operating at their firm capacity, modeling indicates a 95% capture is anticipated. Water quality results from 2009 and the knee of the curve analysis from 2009 demonstrate that this level of control results in an appropriate, cost-effective level of CSO control that would result in full compliance with water quality standards in a Typical Year, if background loads were not present. Some water quality information is still provided for reference in this document. However, the 2021 Final LTCP exceeds the requirements of the presumption approach.

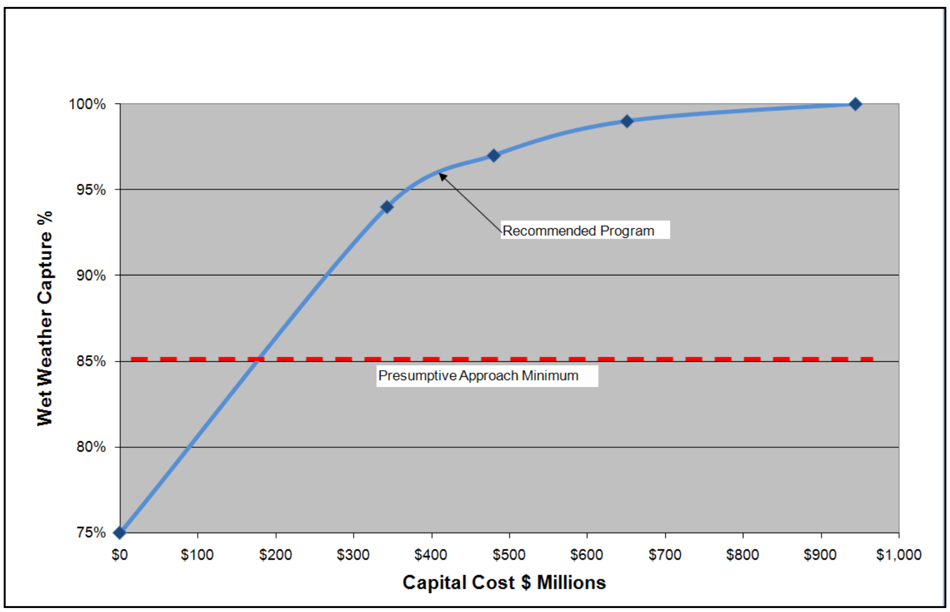


Figure 4.1-1 CSO Wet Weather Percent Capture Vs. Capital Cost (Entire System), 2009

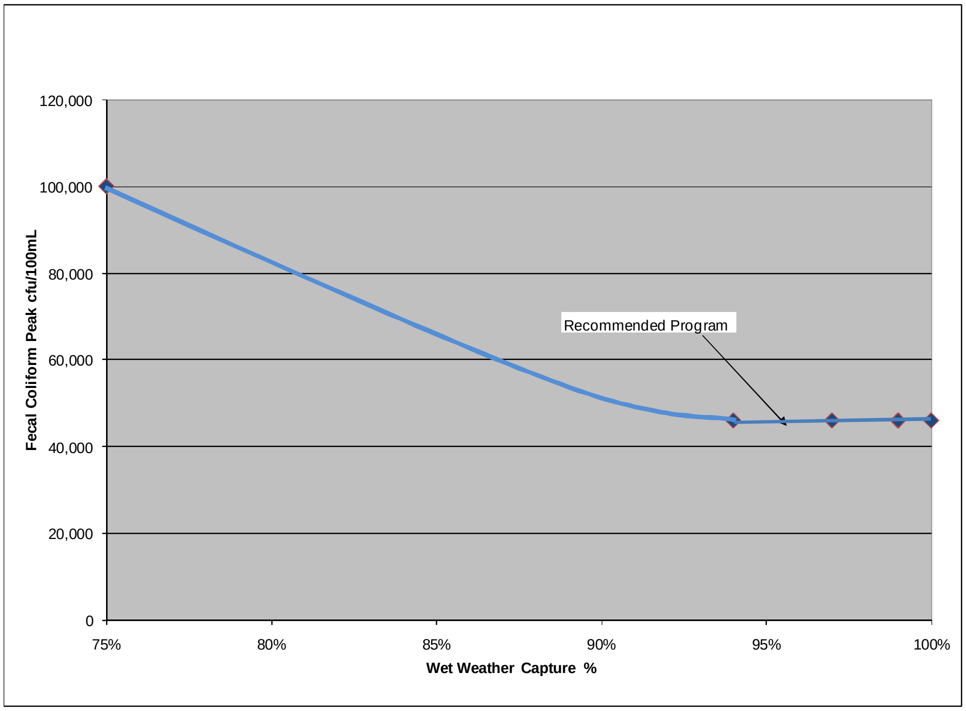


Figure 4.1-2 Fecal Coliform Peak Vs. Percent Capture (Ohio River), 2009

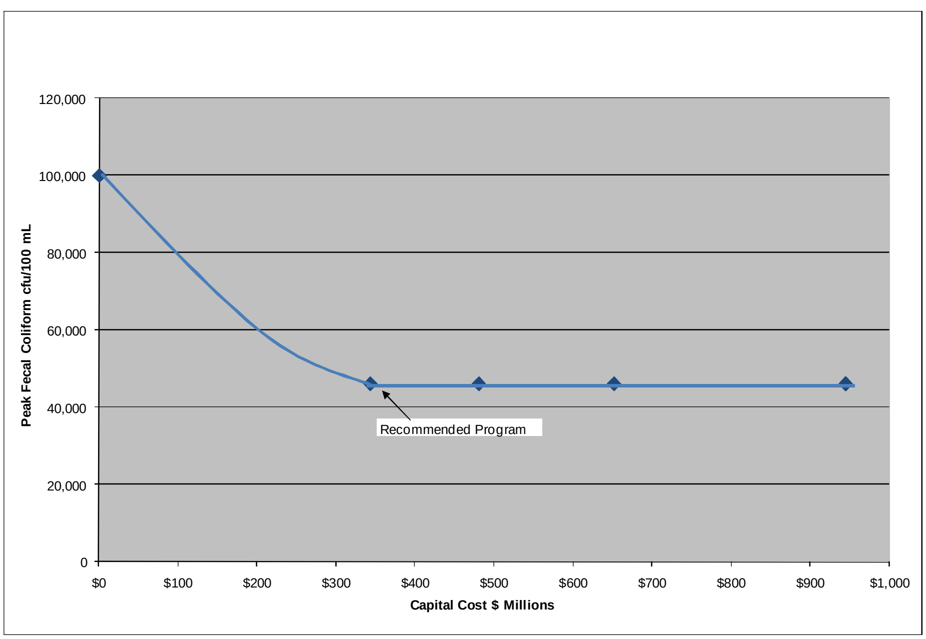


Figure 4.1-3 Peak Fecal Coliform Vs. Capital Cost (Ohio River), 2009

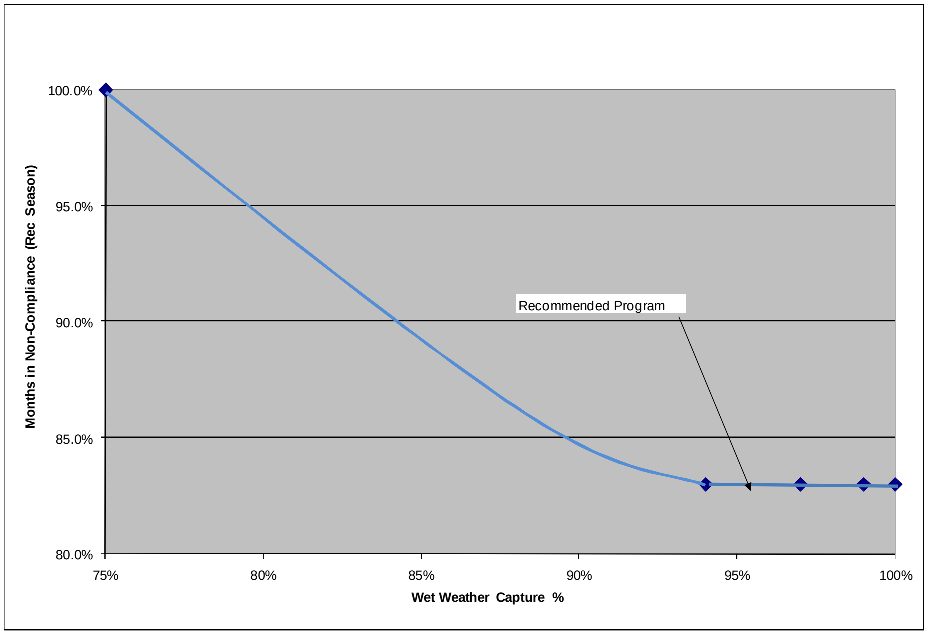


Figure 4.1-4 Monthly Max. Non-Compliance-Recreation Season Vs. Percent Capture (Ohio River), 2009

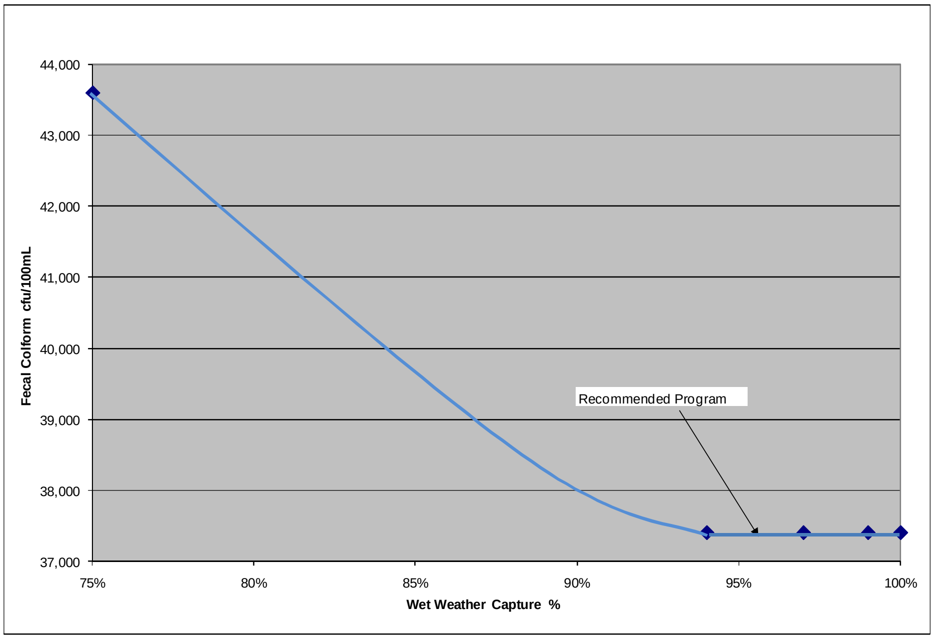


Figure 4.1-5 Fecal Coliform Vs. Percent Capture (Beargrass Creek), 2009

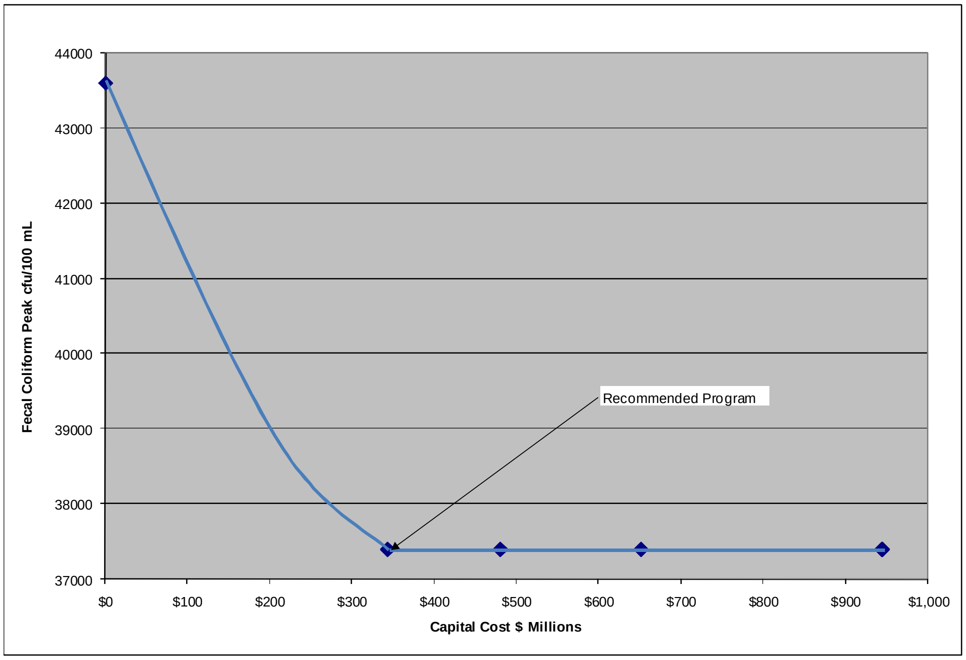


Figure 4.1-6 Fecal Coliform Peak Vs. Capital Cost (Beargrass Creek), 2009

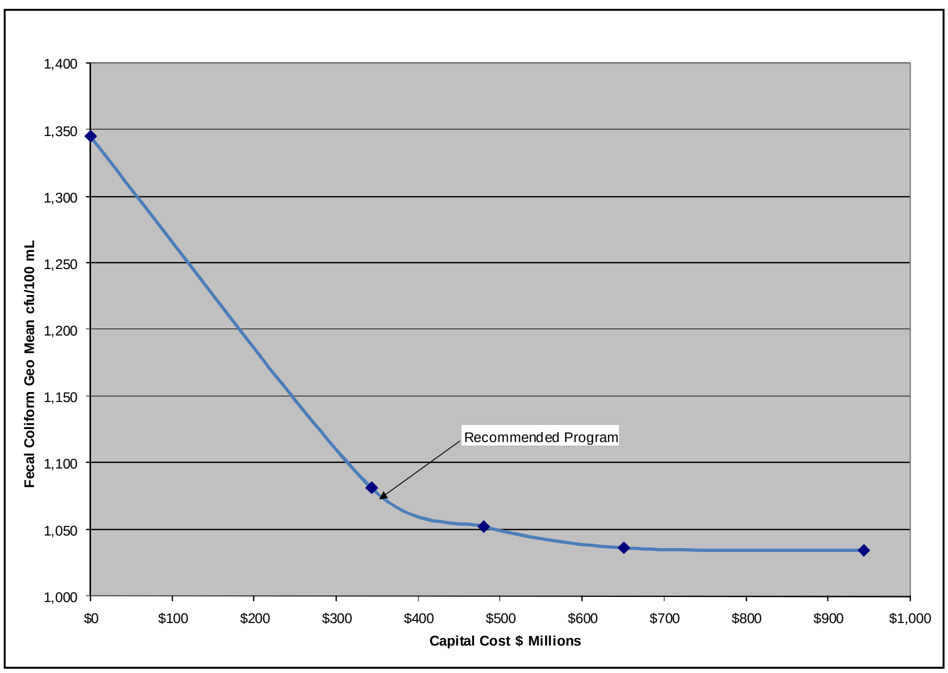


Figure 4.1-7 Fecal Coliform Geometric Mean Vs. Capital Cost (Beargrass Creek), 2009

4.1.4. PRIORITIZATION OF PROJECTS

The Ecological Reach Characterization Study presented in Chapter 2 Section 2.8 developed ecological ratings for each stream reach for each fork of Beargrass Creek. As detailed in the Ecological Reach Characterization Study, a stream reach is defined as the length between existing CSO discharge points.

In order to use the stream reach ratings for prioritizing the Final LTCP projects, the ratings were re-compiled to include the collective ratings of all reaches contained within the project area. These re-compiled ratings were applied to finalize an implementation schedule for the Final LTCP. Some minor reordering of the implementation schedule was performed to normalize cash flow.

Table 4.1-6 for the Final LTCP presents the compiled stream reach rating along with the schedule for completion of construction for each of the Final LTCP projects located in the Beargrass Creek watershed. The Table indicates good correlation between project ecological value versus the stream segment ecological Improvement potential.

Table 4.1-6 Ecological Reach Prioritization for the Final LTCP

PROJECT ID	CONSTRUCTION COMPLETION	CSO	REACH ID	INDIVIDUAL REACH RATING	SCORE	COMPOSITE RANKING	COMMENT
L_SO_MF_108_S_09B_B_A_4	2010	CSO108	S108	Highest	101		Scheduled per score and quick implementation (bending weir).
SCORE					**101**	**High**	
L_MI_MF_206_S_08_A_A_0	2013	CSO206	M206	Highest	110		Scheduled per score and length of program (public/private separation program).
				SCORE	**110**	**High**	
L_MI_MF_127_M_09B_B_A_8	2014	CSO127	MI127	Medium	79		Middle Fork natural stream, good ecological improvement potential.
	2014	CSO126	MI126	High / Medium	82		
	2014	CSO125	MI125	Medium	76		
	2014	CSO166	MI166	Medium	79		
SCORE					**79**	**Medium**	
L_SO_MF_093_S_08_A_A_0	2015	CSO093	S093	Medium	70		Scheduled for the opportunity to eliminate CSO (Sewer Separation).
SCORE					**70**	**Medium**	
L_MI_MF_140_S_08_A_A_0	2015	CSO140	MI140	Medium	57		Scheduled for the opportunity to eliminate CSO (Sewer Separation).
SCORE					**57**	**Medium**	
L_SO_MF_130_S_09B_B_A_8	2016	CSO130	S130	Medium	64		Scheduled per score
SCORE					**64**	**Medium**	
L_SO_MF_097_M_09B_B_D_8	2017	CSO151	S151	Medium / Low	37		3 of 6 CSOs currently discharge into stream, approximately 1/4 mile upstream of improved channel; short reach ecological improvement potential.
	2017	CSO106	S106	High / Medium	89		
	2017	CSO137	S137	High / Medium	94		
	2017	CSO110	S110	Lowest	36		
	2017	CSO111148	S111/148	Medium / Low	39		
	2017	CSO097	S097	High / Medium	93		
SCORE					**65**	**Medium**	
L_SO_MF_092_M_09B_B_D_8	2017	CSO117	S117/149/179	Lowest	30		Scheduled per score/Improved Channel.
	2017	SBR	S142	Lowest	33		

Table 4.1-6 Ecological Reach Prioritization for the Final LTCP

PROJECT ID	CONSTRUCTION COMPLETION	CSO	REACH ID	INDIVIDUAL REACH RATING	SCORE	COMPOSITE RANKING	COMMENT
	2017	CSO146147	S146/147	Lowest	23		
	2017	CSO091	S091	Medium / Low	43		
	2017	CSO092	S092	Medium / Low	41		
	2017	CSO152	S152	Lowest	36		
	2017	CSO113	S113	Medium / Low	37		
SCORE					**35**	**Lowest**	
L_MU_MF_154_M_09B_B_A_8	2018	CSO154	MU132/154/167	Medium / Low	44		Muddy Fork habitat poor, as a result of Ohio River backwater influence.
SCORE					**44**	**Medium / Low**	
L_SO_MF_083_M_09B_B_A_8	2020	CSO082	S082	Lowest	32		Scheduled per score/Improved Channel.
	2020	CSO153	S153	Lowest	32		
	2020	CSO121	S121	Lowest	31		
	2020	CSO141	S141	Lowest	32		
	2020	CSO120	S120	Lowest	26		
	2020	CSO084	S084	Lowest	27		
	2020	CSO119	S119	Lowest	33		
	2020	CSO083118	S083/118	Lowest	21		
SCORE					**29**	**Lowest**	
	LEGEND						
	Range:	**95-130**	Highest Priority				
		80-94	High / Medium Priority				
		46-79	Medium Priority				
		37-45	Medium / Low Priority				
		13-36	Lowest Priority				

4.1.5. IMPLEMENTATION SCHEDULE TO COMPLY WITH CONSENT DECREE REQUIREMENTS

The Second ACD requires that the Final LTCP program be completed as soon as practical but no later than December 31, 2026. As noted in Table 4.0-1, MSD has completed 24 of the 25 LTCP projects. The remaining project, the Waterway Protection Tunnel, is scheduled to be completed no later than June 30, 2022. The wet weather treatment capacity at the Morris Forman WQTC will be fully available when rehabilitation of the existing Sedimentation Basins is complete in December 2026.

Project Fact Sheets and Maps for Green Infrastructure Demonstration Projects, Gray Infrastructure Projects, and Flood Pump Station Projects detailing project specifics are at the end of this chapter. Each fact sheet includes a project description for the abatement solution, associated capital cost and benefit-to-cost ratio, and focuses on CSOs addressed by the project solution. Detailed project maps for each of the Final LTCP projects specify project location and type of solutions.

Final Recommended Project Cost Estimates, Benefits, and Ground Truthing documents are located in Appendix 4.1.2, Appendix 4.1.3, and Appendix 4.1.4 respectively.

Appendix 4.1.3 Recommended Project Cost Estimates
Appendix 4.1.4 Recommended Project Benefits
Appendix 4.1.5 Recommended Project Ground Truthing Documents
These appendices are same as 2012 IOAP Modification and are provided on external USB storage drive.

4.2. PUBLIC PARTICIPATION

As defined by the EPA LTCP Guidance, the development of the LTCP should involve citizens in the development of alternatives solutions to protect local waterways and to consider the financial impacts to the community. Additionally, the Consent Decree requires that a public participation process be incorporated into the plan. Details of the approach and public involvement are presented in Volume 1, Chapter 3.

4.3. ENVIRONMENTAL BENEFIT OF RECOMMENDED PROGRAM

Environmental benefits were a critical component of the performance measures used for selecting the recommended plan to reduce CSOs. No overflow control program will be acceptable to the community unless it meets appropriate environmental standards. This section focuses on determining and measuring the environmental benefits of the Final LTCP.

Through the Stakeholder process, the WWT developed a list of project-specific values (in addition to programmatic values) determined to be important to the community.

Built upon these values, the benefit-cost analysis tool was used to score projects. This tool provided the means to track and rate the environmental benefits of each solution. The benefit-cost analysis tool also provided a list of criteria that could not be violated (fatal flaws) regardless of any cost advantage, such as constructed facilities that impair habitat for threatened or endangered species.

FIVE VALUES

1. Asset Protection
2. Eco-friendly Solutions
3. Environmental Enhancement
4. Public Health
5. Regulatory Performance

Environmental Benefits of the Final LTCP, Table 4.3-1, provides an overview of how the program performs when measured with these five values.

Table 4.3-1 Environmental Benefits of the Final LTCP

VALUE		LTCP MEASURE
Asset Protection	Eliminating or reducing basement back-ups and/or surface flooding	For sewer separation projects, the recurrence of surface flooding and basement backups will be reduced as the stormwater flow will be removed from the combined sewer system.
Eco-Friendly Solutions	Non-Renewable Energy Consumption	Use of eco-friendly solutions is maximized through the Green Infrastructure Program.
	Use of Natural Systems	The Green Infrastructure Program will address the use of natural systems.
	Multiple Use Facilities	Eco-friendly solutions will primarily focus on adding green space where none or little exists. Examples include covered concrete tanks where the cover can be green space; unless an existing facility exists that must be restored to original use.
	Source Control of sub-watershed pollutant loads	The Green Infrastructure Program will reduce stormwater runoff from impervious surfaces through various technologies such as green roofs, bioswales, etc.
	Non –Obtrusive Construction Techniques	Neighborhood impacts resulting from construction of final recommended projects on traffic, noise and dust were considered and will be minimized, working with neighborhood associations
	Consistent Land Use	Project features will be consistent with the area. Effort will be made to restore the top surface area of covered storage basins to be consistent with the area or replaced with community amenities.
	Impermeable Surfaces	The Green Infrastructure Program will include permeable pavement or other means to reduce imperviousness. For covered storage basins, an improved use on top of the basin will be pursued.
	Leadership in Energy and Environmental Design (LEED) Performance	LEED standards are applicable to alternatives that include above ground building structures. Opportunities for LEED certification in treatment plant and storage basin projects will be sought.
Environmental Enhancements	Aquatic and Terrestrial Habitat Protection	Final LTCP projects will have minimal effect on both aquatic and terrestrial habitat through changes in base flow, peak flow, water quality, tree cover, channel shape, and characteristics, etc.
	Aesthetics - Solids and Floatables (S&F)	Most Final LTCP projects will have some form of enhanced S&F control. Improvements in current capture rates can be expected with screening or other advanced treatment options
	Aesthetics - Odor and Air Emissions	Odors and air emissions were estimated and addressed as part of the project development. No increase in nuisance odors.
	Dissolved Oxygen Impacts	Dissolved oxygen deficiencies (less than 2 mg/l) in Beargrass Creek will improve marginally. The Final LTCP will have no effect on dissolved oxygen levels in the Ohio River.
	Downstream Impacts	The Final LTCP measures are calculated to reduce pollutant and bacteria loads, resulting in improved downstream water quality.
	Stream Flow Impacts (Peak Flows)	High peak flows within Beargrass Creek will be lowered as a portion of the flow during rain events will be stored in basins.
	Stream Flow Impacts (DWF only)	No project affects dry weather stream flow conditions.
Public Health	Potential for Human Contact with Suspected Disease-Causing Organisms	Fecal coliform bacteria counts are predicted to be decreased in Beargrass Creek and the Ohio River, and the number of overflow events that create the potential for human contact with raw sewage will be greatly reduced

Table 4.3-1 Environmental Benefits of the Final LTCP

VALUE		LTCP MEASURE
Regulatory Performance	Untreated CSO AAOV and Frequency	Exceeded the criteria established within the EPA CSO Guidance of 85% capture of volume, to an increase in percent capture and treatment of volume by approximately 95% system-wide CSS overflow occurrences and volumes will be substantially reduced by implementing the Final LTCP.

4.4. MEASURES OF SUCCESS

2021 Update: MSD is complying with the Presumption Approach in accordance with EPA's CSO Policy. The water quality benefits noted herein are anticipated to be realized. MSD does not intend to verify this information with sampling or an updated water quality model.

Traditional measures of success, such as reduction of CSOs, reduction of CSO volume and meeting water quality criteria within Beargrass Creek and Ohio River, etc., are defined in EPA's Guidance Document for preparing LTCPs (EPA, 1995). Additionally, various environmental measures of success were defined as part of the WWT process. These environmental measures of success and how the Final LTCP compares to these measures were presented in Section 4.3. The following sections describe the benefits of the Final LTCP in terms of percent capture and reduction in overflow volume and water quality benefits to different portions of Beargrass Creek and the Ohio River.

4.4.1. PERCENT CAPTURE AND REDUCTION IN OVERFLOW VOLUME

The Presumption Approach as defined by EPA Guidance Document is a level of control that meets a criterion of no more than four overflows per year, or elimination or capture of 85 percent by volume of the combined sewage collected by the CSS during the Typical Year precipitation events, or elimination or capture of 85 percent by mass load of pollutant. As presented in Chapter 3, the Presumption Approach was applied to initially size control alternatives (at four overflows per year) for the CSOs. Furthermore, the Presumption Approach will be used to achieve the objectives of the CSO policy. As shown in Table 4.4-1, the final recommended projects in conjunction with the application of the programmatic elements captures and treats approximately 95 percent of the volume of combined sewage collected in the CSS during a defined wet weather period as analyzed using the Typical Year rainfall data. This 95 percent capture far exceeds the minimum volume capture (85 percent) defined by the Presumption Approach requirements. Table 4.4-1 shows the breakdown of the percent capture and AAOV reduction by watershed. Additionally, Figure 4.4-1 shows the projected AAOV capture for various milestones of the program.

Table 4.4-1 CSS Percent Capture

	NO CONTROLS (PRE-BASELINE)	2008 BASELINE	2026 FINAL LTCP MODELED VALUES	2026 FINAL LTCP MIN. REQUIREMENT
Volume of combined sewage collected in the CSS during precipitation events (MG)	19,700	19,700	19,700	19,700
Volume of combined sewage captured or treated (MG)	13,200	16,190	18,800 (19,360)	16,745
% of volume captured or treated	**67%**	**82%**	**95% (98%)**	**85%**
Volume of remaining CSOs (MG)	6,500	3,510	900 (340)	2,955
% of CSO remaining	33%	18%	5% (2%)	15%

*2008 Baseline values have been updated with the current hydraulic model. Volume of CSS updated to include flow from SSS entering sewer system. 2026 Modeled Values at 98% represent modeled values if all system components are functioning at maximum capacity. 95% represents modeled values if system components are generally operating at firm capacity. 85% represent minimum required % capture.

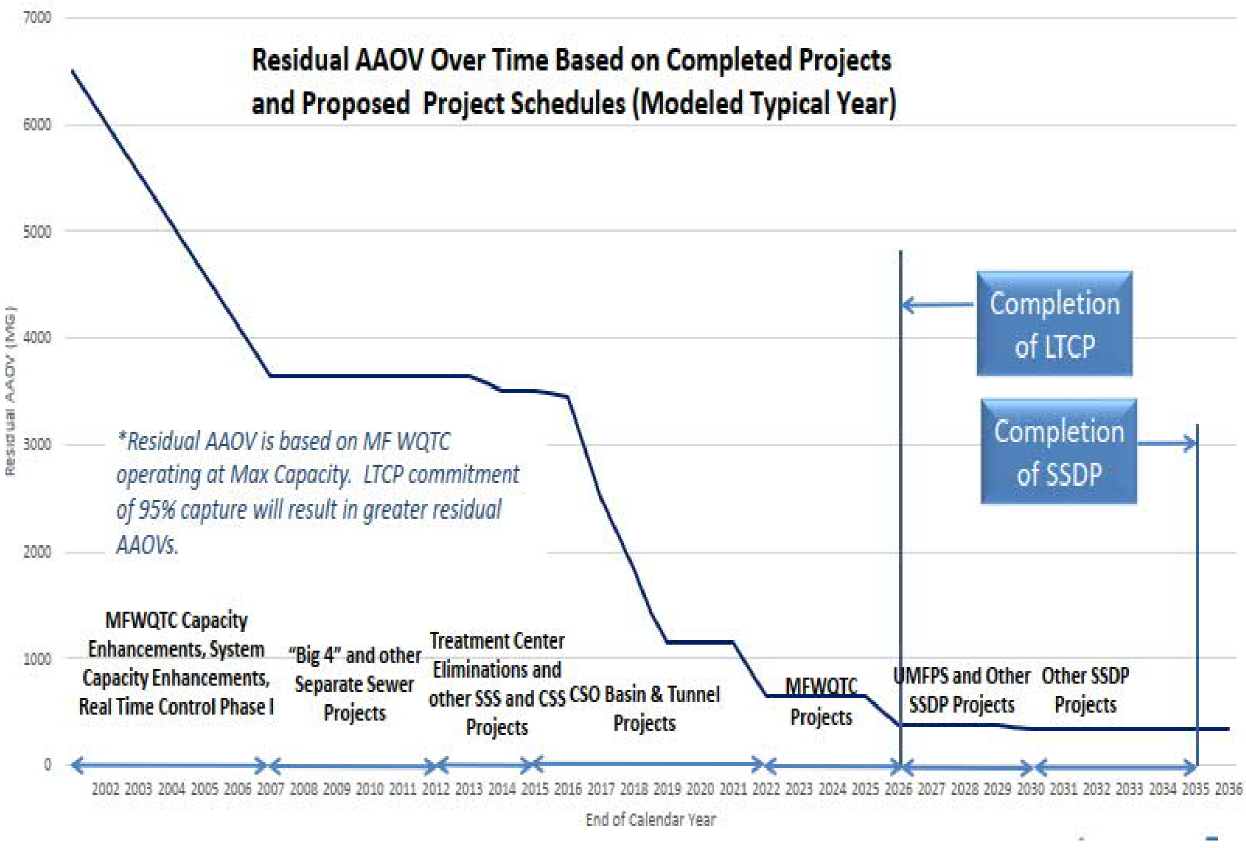


Figure 4.4-1 Projected Impact of CSO Program Improvements

The success of this Final LTCP, in meeting the Consent Decree compliance requirements will be measured incrementally as the plan is implemented and upon completion in December 2020:

- The performance of the green demonstration projects and comprehensive Green Infrastructure Program will be measured to determine if source reduction goals are being achieved. As the first set of green infrastructure demonstration projects is built, the controls will be monitored and data on the effectiveness in reducing stormwater runoff will be generated and analyzed.

- Since engineering design of gray infrastructure projects will parallel reporting of green performance, any impact to gray solutions performance requirements will be integrated, including design characteristics to incorporate future modifications or retrofits. MSD will use the schedule developed for the design and construction of gray projects to assist in targeting the location selection for green projects in an attempt to implement and monitor efficacy of green projects before implementing gray projects. When possible, green projects will be constructed, and system monitoring data collected before gray infrastructure projects move into the final design phase. After the green monitoring results have been analyzed, a sizing evaluation, using the CSS hydraulic model, will be performed to determine the efficacy of green controls (or system changes) that have taken place since the original sizing of the gray control. The gray projects will be sized to provide the committed level of protection based upon this analysis.
- The performance evaluation of both green technologies and gray technologies will be an on-going process under the Post Construction Compliance Monitoring program. If the result of the green controls performance proves to be ineffective for a particular basin, then MSD will ensure that the design of the gray project reflects the size needed to achieve the necessary level of control. MSD will downsize the gray project if the green controls prove to be more cost-effective for a particular basin.
- As performance metrics are established and data collected, any modifications to the Final LTCP will be executed through adaptive management techniques to modify controls as necessary to bring operation of the CSS into compliance with the CWA and CSO Control Policy requirements, and the Consent Decree.

Future conditions may require a higher level of CSO control than is provided for in this Final LTCP. Higher levels of control may be obtained through expansion of existing controls (where space allows), addition of facilities such as supplemental storage in other locations or retrofitting modifications to existing facilities (such as making process additions, for example coagulant addition and disinfection to convert storage basins to discharging equivalent primary treatment under some flow conditions). Other opportunities to modify the level of CSO controls may include enhancement or expansion of the Green Infrastructure Program should monitoring indicate cost-effective source runoff reduction.

4.4.2. BEARGRASS CREEK WATER QUALITY BENEFIT

Beargrass Creek is an urban stream with a diverse watershed. Wet weather discharges from CSOs have significant impacts on the stream's water quality, as measured from monitoring results and modeling with the Beargrass Creek Water Quality Tool (WQT). The IOAP will significantly improve water quality in Beargrass Creek. The modeling simulation from the WQT predicts that CSOs alone would cause exceedances of the fecal coliform criteria less than two percent of the time if other sources of bacteria (stormwater and groundwater) could be controlled.

The CSS has a profound effect on the hydrology and water quality of the Beargrass Creek watershed and stream. Runoff that previously infiltrated into the soils and flowed more slowly through surface waterways is now collected in the combined sewers and transported out of the basin for many storm events, with some portion reaching the stream when the sewers overflow.

The results of this major redirection of runoff are:

- Reduced groundwater recharge because of reduced infiltration into the soil, resulting in lower dry weather or base flow rates.
- Reduced volume of runoff reaching Beargrass Creek, also lowering stream base flow.
- Increased runoff flow rates during wet weather because the sewer system routes flow quickly and directly to the stream, resulting in high peak flows; and
- Increased pollutant loads (biological, chemical, and physical) from lack of runoff pollutant removal and mixing with sanitary sewage.

4.4.2.1. HYDROLOGIC EFFECTS

One hydrologic effect of the CSS is the increase in peak flows because watershed runoff is rapidly delivered to the stream by the CSO and stormwater outfalls. These discharges can cause several problems including erosion, damage to the aquatic habitat in the stream, and recreational use impacts. The proposed Final LTCP reduces the CSO discharge amounts and frequencies and therefore the effects of higher peak flow rates during wet weather. At the same time, the Green Infrastructure Program increases the amount of stormwater that infiltrates into the groundwater. Much of this shallow groundwater will eventually discharge into the surface water, increasing base flows and positively impacting water quality in a number of ways.

Another hydrologic change related to CSS is the reduced base flow in Beargrass Creek during dry weather. The Final LTCP includes sewer separation projects, which will route more runoff water to Beargrass Creek, water that currently is routed out of the basin in the combined sewer.

4.4.2.2. DISSOLVED OXYGEN

Biochemical oxygen demand and nutrients in CSO and stormwater discharges may reduce in-stream dissolved oxygen below the water quality criteria. The Kentucky Department of Environmental Protection (KDEP) has developed a Total Maximum Daily Load (TMDL) that identifies large reductions needed in pollutant loads from multiple sources.

CSOs affect the in-stream dissolved oxygen concentration in Beargrass Creek in several ways. During discharge, the CSOs can add oxygen-depleted water to the stream, potentially reducing in-stream dissolved oxygen levels. Following a discharge event, the oxygen-demanding pollutants released by the CSO will consume dissolved oxygen as the pollutants decompose. The pollutants also accumulate in the lower stream reaches where flow velocities are lower due to Ohio River backwater effects. Dissolved oxygen problems in these backwater areas are therefore more significant than other areas of Beargrass Creek. As the accumulated pollutants in the sediments decay over time, a demand on dissolved oxygen is exerted (i.e., sediment oxygen demand). This demand can lower dissolved oxygen for days or weeks during periods of low flow. CSOs can also contribute nutrients to the stream that may increase algal populations, leading to high dissolved oxygen levels during the day (due to photosynthesis) and low dissolved oxygen levels at night (due to algal respiration).

Immediate impacts of CSOs are believed to be small due to reaeration and dilution with high stream flows, and field monitoring staff have communicated that in-stream dissolved oxygen during discharge events is not always depressed. However, flow from CSOs can start prior to the arrival of the flood wave from the upstream watershed, so short-lived impacts may occur at the beginning of CSO events. Overall, the Final LTCP reduces the amount and frequency of CSOs and as a result should improve compliance with the dissolved oxygen criteria in Beargrass Creek.

4.4.2.3. FECAL COLIFORM

CSOs, SSOs, non-point sources, and stormwater may cause large increases in the in-stream concentration of fecal coliform bacteria that is an indicator of pathogenic organisms and was frequently used as the basis of water quality criteria for recreational use. Even after a wet weather event, sediment in the stream can hold coliform bacteria that continue to grow and are re-suspended in the water column by animal or human activity or in the next high flow event. The proposed Final LTCP reduces the number and amount of CSOs and, therefore, the bacteria load to Beargrass Creek.

Table 4.4-2 shows the percent noncompliance with the fecal coliform criteria during the "Typical Year" (represented by data from calendar year 2001) at selected locations in Beargrass Creek for three scenarios:

- The current conditions (baseline),
- Conditions after implementation of the proposed IOAP projects, and
- A scenario in which the IOAP projects are implemented and CSOs are the only source of fecal coliform (isolating their effects from other sources of bacteria such as stormwater and baseflow).

Table 4.4-2 demonstrates that sources other than CSOs provide most of the fecal coliform loadings to Beargrass Creek. Noncompliance percentages do not change significantly from the "Baseline" condition to the "IOAP" condition. In contrast, the "IOAP (CSOs only)" condition shows full compliance with WQS if background loads are removed.

Table 4.4-2 Percent Noncompliance with Water Quality Standards in Typical Year[1]

STATION	PERIOD	GEOMETRIC MEAN CRITERION			INSTANTANEOUS MAXIMUM CRITERION		
		BASE-LINE (2001)	IOAP	IOAP (CSOS ONLY)	BASE-LINE (2001)	IOAP	IOAP (CSOS ONLY)
SF1 South Fork at Trevilian Way	All Data	40%	39%	0%	27%	27%	0%
	Winter	0%	0%	0%	22%	22%	0%
	Rec Season	79%	78%	0%	33%	32%	0%
SF2 South Fork at Winter Avenue	All Data	62%	61%	0%	49%	48%	0%
	Winter	27%	24%	0%	23%	23%	0%
	Rec Season	97%	97%	0%	75%	72%	0%
South Fork at Mouth / Confluence with Middle Fork	All Data	65%	64%	0%	59%	48%	0%
	WINTER	32%	31%	0%	25%	25%	0%
	Rec Season	97%	97%	0%	92%	72%	0%
SF6 South Fork at Flood Pumping Station	All Data	67%	66%	0%	62%	55%	0%
	Winter	36%	35%	0%	31%	31%	0%
	Rec Season	97%	97%	0%	93%	78%	0%
MI2 Middle Fork at Old Cannons Lane	All Data	54%	54%	0%	36%	35%	0%
	Winter	10%	10%	0%	21%	21%	0%
	Rec Season	97%	97%	0%	50%	50%	0%
MI4	All Data	63%	58%	0%	48%	41%	0%

Table 4.4-2 Percent Noncompliance with Water Quality Standards in Typical Year[1]

STATION	PERIOD	GEOMETRIC MEAN CRITERION			INSTANTANEOUS MAXIMUM CRITERION		
		BASE-LINE (2001)	IOAP	IOAP (CSOS ONLY)	BASE-LINE (2001)	IOAP	IOAP (CSOS ONLY)
Middle Fork at Lexington Road	Winter	27%	18%	0%	23%	23%	0%
	Rec Season	97%	97%	0%	74%	59%	0%
Middle Fork at Mouth / Confluence with South Fork	All Data	64%	62%	0%	46%	42%	0%
	Winter	31%	28%	0%	24%	25%	0%
	Rec Season	97%	97%	0%	68%	58%	0%
MU2 Muddy Fork at Indian Hills Trail	All Data	46%	46%	0%	30%	30%	0%
	Winter	0%	0%	0%	20%	20%	0%
	Rec Season	92%	92%	0%	39%	39%	0%
MU4 Muddy Fork at Mockingbird Valley Road	All Data	48%	48%	0%	32%	31%	0%
	Winter	0%	0%	0%	22%	22%	0%
	Rec Season	95%	95%	0%	42%	41%	0%
Muddy Fork at Mouth / Confluence with Beargrass Creek	All Data	65%	65%	0%	53%	52%	0%
	Winter	34%	33%	0%	31%	30%	0%
	Rec Season	96%	96%	0%	74%	74%	0%
Beargrass Creek at Mouth / Confluence with Ohio River	All Data	72%	70%	0%	67%	60%	0%
	Winter	48%	44%	0%	40%	39%	0%
	Rec Season	96%	95%	0%	94%	81%	0%

[1]Typical year presented by data from calendar year 2001

Table 4.4-3 Typical Year[1] Fecal Coliform Concentrations (CFU/100 mL)

Table 4.4-3 shows the average annual geometric mean and peak fecal coliform concentrations for the current conditions (baseline), under the Final LTCP assuming all other sources of bacteria were eliminated. The table is not a measure of regulatory compliance, but an illustration of relative changes. As shown, the Final LTCP will reduce bacteria concentrations and the CSOs alone will result in annual geometric mean concentrations less than one colony forming units (cfu) per 100 mL and peak fecal coliform concentrations that are orders of magnitude smaller than current conditions. These results are shown graphically in Figure 4.4-2 and Figure 4.4-3. The results for the mouth of Beargrass Creek for the three simulations are shown in Figure 4.4-4 and Figure 4.4-5.

Table 4.4-3 Typical Year[1] Fecal Coliform Concentrations (CFU/100 mL)

STATION	ANNUAL GEOMETRIC MEAN			ANNUAL PEAK		
	BASE-LINE (2001)	IOAP	IOAP (CSOS ONLY)	BASE-LINE (2001)	IOAP	IOAP (CSOS ONLY)
SF1 South Fork at Trevilian Way	224	223	0	196,830	196,830	0
SF2 South Fork at Winter Avenue	507	471	0	261,340	166,510	7,003
Upstream of Mouth at Middle Fork	896	701	0	170,000	145,000	20,400
SF6 South Fork at Beargrass Flood Pumping Station	1,069	813	0	104,000	87,100	6,560
MI2 Middle Fork at Old Cannons Lane	342	341	0	181,250	181,250	0
MI4 Middle Fork at Lexington Rd	477	422	0	172,650	156,480	0
Upstream of Confluence with South Fork	547	455	0	145,000	142,000	28,200
MU2 Muddy Fork at Indian Hills Trail	258	256	0	228,540	228,540	0
MU4 Muddy Fork at Mockingbird Valley	281	278	0	233,210	233,210	0
Upstream of Confluence With BGC	547	455	0	90,500	90,400	8,920
Upstream of Confluence with Ohio River	1,381	1,033	0	44,300	38,000	1,860

Typical year presented by data from calendar year 2001

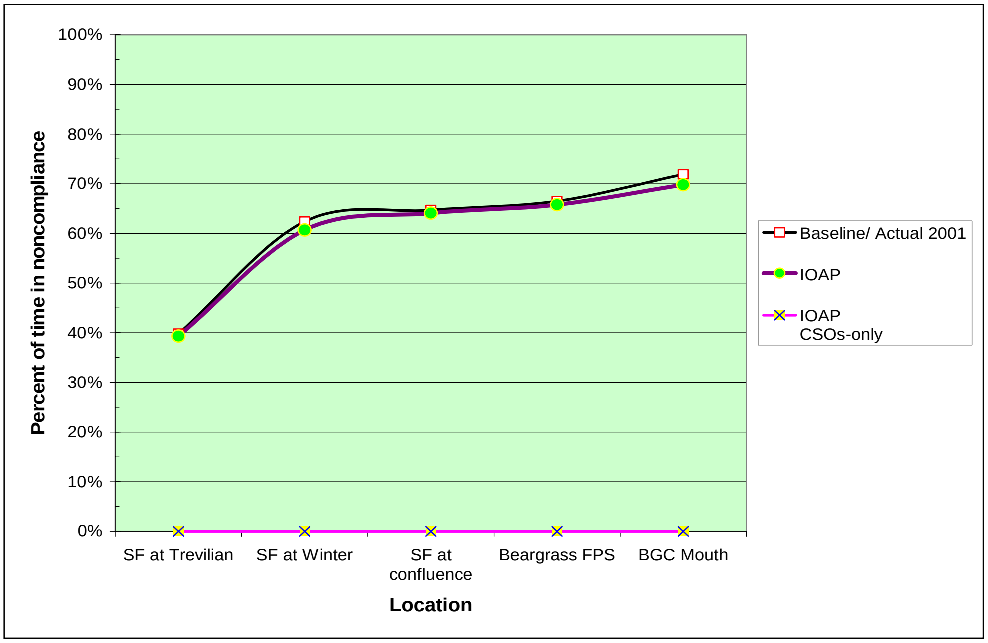


Figure 4.4-2 Geometric Mean Standard in South Fork Stations

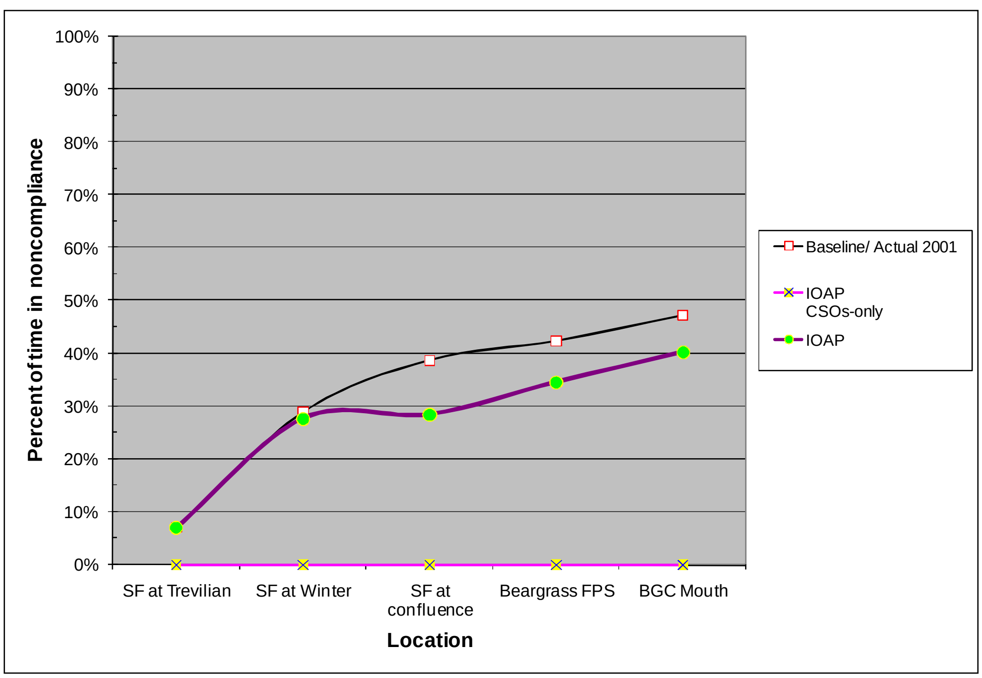


Figure 4.4-3 Maximum Standard In South Fork Stations

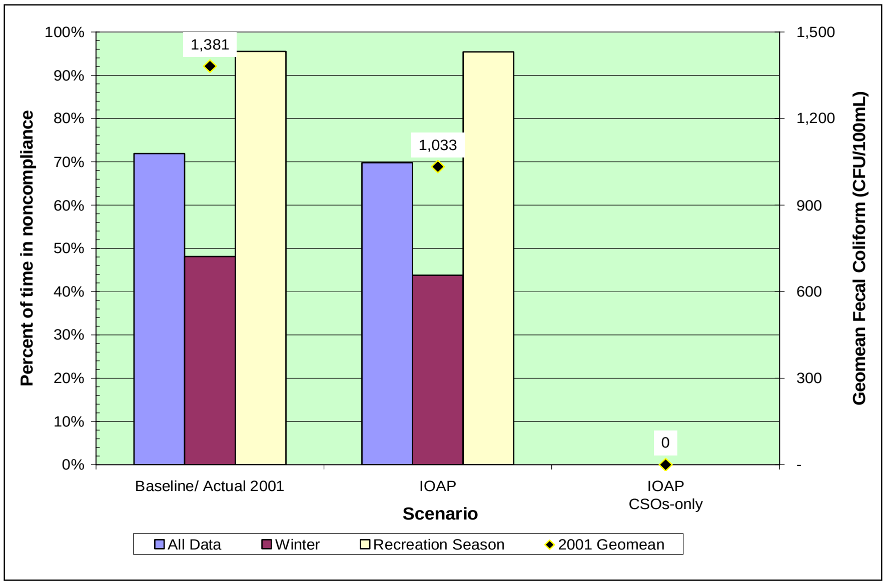


Figure 4.4-4 Nonattainment of Geometric Mean Standard at Mouth of Beargrass Creek

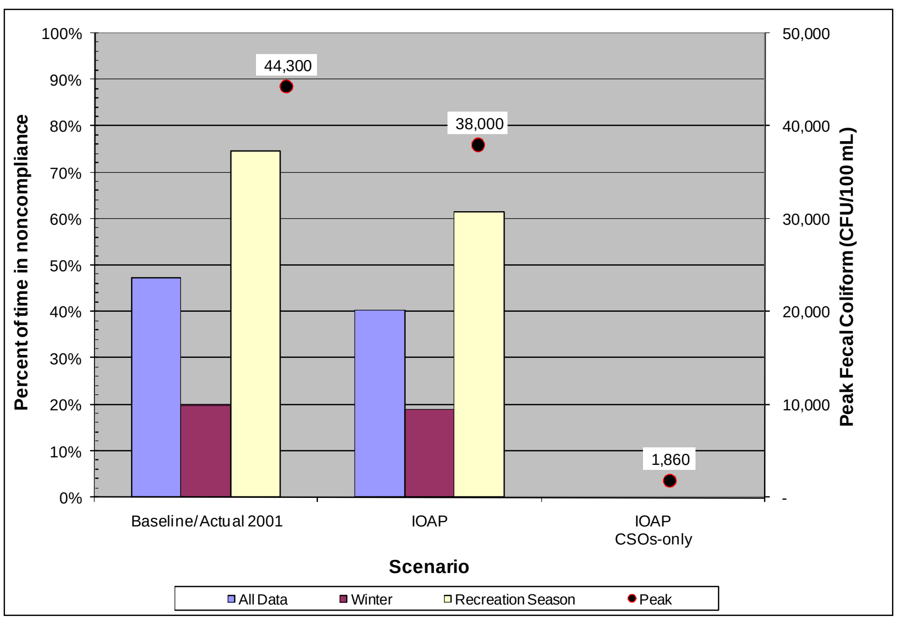


Figure 4.4-5 Nonattainment of Monthly Maximum Standard at Mouth of Beargrass Creek

4.4.3. OHIO RIVER WATER QUALITY BENEFITS

The Ohio River is also affected by CSOs, both from direct discharges to the river and indirectly from CSO discharges to Beargrass Creek that eventually flows into the Ohio River. Because the size of the Ohio River watershed upstream of Louisville Metro is so large, CSO impacts on the Ohio River are not as significant as the effects are on Beargrass Creek. In fact, CSOs have shown relatively little hydrologic effect on the Ohio River nor is there a noticeable effect on dissolved oxygen. However, CSOs do have an effect on instream concentrations of fecal coliform bacteria in the Ohio River. Wet weather monitoring data demonstrate significant increases fecal coliform concentrations in response to CSO events, especially in areas closer to shore and immediately downstream of overflow locations. The IOAP will therefore improve water quality in the Ohio River, but not as significantly as in Beargrass Creek. The Ohio River Water Quality Model calculates that the CSOs resulting from the IOAP will result in 100% compliance with both the geometric mean and peak representation of the fecal coliform criteria, if other sources of bacteria (upstream and tributary) could be controlled.

The Final LTCP reduces the number and amount of CSOs and, therefore, the fecal coliform load to the Ohio River. The following tables and figure show that the Ohio River Water Quality Model predicts improved compliance in the near shore (Kentucky-side) areas with the monthly maximum recreational water quality criterion and reduced geometric mean and peak fecal coliform concentrations as a result of the IOAP projects. There is 100 percent compliance with the geometric metric criterion under both current (baseline) conditions and the IOAP. This is because of the significant dilution provided by the river and the assignment of the upstream concentrations of bacteria during the 2001 simulations.

The IOAP increases compliance with the monthly maximum criterion, with the maximum benefit seen in downtown Louisville Metro where the rate of non-compliance decreases from 100 percent under baseline conditions to 33 percent under the IOAP (Table 4.4-4 and Figure 4.4-6). The simulations also show that if CSOs were the only source of bacteria to Beargrass Creek and the Ohio River, that the CSOs would not cause violations of the fecal coliform criteria in the Ohio River.

Table 4.4-4 Percent Noncompliance with Ohio River Water Quality Standards in Typical Year

STATION	GEOMETRIC MEAN CRITERION			MONTHLY MAXIMUM CRITERION		
	BASELINE (2001)[1]	IOAP	IOAP (CSOS ONLY)	BASELINE (2001)[1]	IOAP	IOAP (CSOS ONLY)
Upstream	0%	0%	0%	33%	33%	0%
Above Beargrass	0%	0%	0%	33%	33%	0%
I-65	0%	0%	0%	33%	33%	0%
Downtown	0%	0%	0%	100%	33%	0%
Morris Forman	0%	0%	0%	100%	83%	0%
Salt River	0%	0%	0%	67%	67%	0%

Typical year presented by data from calendar year 2001

Average and maximum fecal coliform concentrations are also decreased by the IOAP when compared to baseline conditions. The largest benefit in geometric mean concentrations is observed in downtown Louisville Metro, where concentrations decrease from 74 to 34 cfu/ 100 ml. The largest benefit in maximum concentrations is observed below the Morris Forman WQTC, where concentrations decrease from 100,000 to

46,000 cfu/ 100 ml (Table 4.4-5). The table is not a measure of regulatory compliance, but an illustration of relative changes.

Table 4.4-5 Typical Year[1] Ohio River Fecal Coliform Recreational Season Concentrations (CFU/100 ml)

STATION	GEOMETRIC MEAN			MAXIMUM		
	BASELINE (2001)[1]	IOAP	IOAP (CSOS ONLY)	BASELINE (2001)[1]	IOAP	IOAP (CSOS ONLY)
Upstream	86	86	0	650	650	0
Above Beargrass	22	22	0	9900	9900	0
I-65	27	29	0	6600	6700	9
Downtown	74	34	0	6900	5300	3,230
Morris Forman	82	51	0	100,000	46,000	13,100
Salt River	69	55	0	56,000	57,000	4,380

Typical Year Presented By Data From Calendar Year 2001

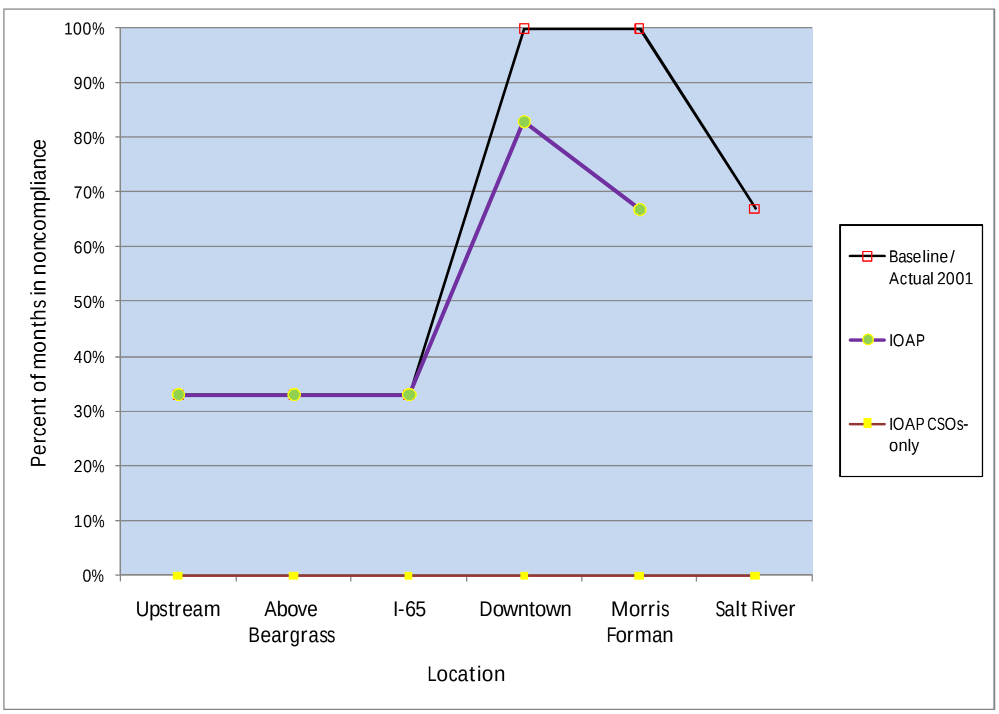


Figure 4.4-6 Nonattainment of Maximum Standard in Ohio River

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On the front cover:
Middle Fork Beargrass Creek

Safe, clean waterways

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