NEORSD
Appendix 3 Green Infrastructure

Performance Report

Northeast Ohio
Regional Sewer District

December 2021

Appendix 3 GI PCMP Performance Report

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Executive Summary

Background

On July 7, 2011, the District entered into a Consent Decree (CD) with the U.S. and the State of Ohio. The control measures required by the CD are estimated to cost NEORSD $3 billion (2009$$) and will take 25 years to complete. The CD included a requirement for a combination of upsized gray infrastructure and green infrastructure (GI) to achieve the agreed-upon Level of Control (LOC), and the performance requirements for GI projects were defined to capture a minimum of 44 MG of wet weather flows in a typical year that would otherwise be discharged by District's CSOs at a prescribed expenditure of at least $42 million. These GI requirements were memorialized in Appendix 3 of the CD.

Appendix 3 GI Projects

In accordance with Appendix 3, the District implemented a GI program that consisted of the identification of GI project location opportunities resulting in the construction of nine (9) projects at a total project cost of $53 M. A detailed listing of the Appendix 3 GI Projects is provided in **Section 2, Table 2-1**, and details on the design concepts for each project are presented in **Sections 2.1** and **2.2**. As required by Appendix 3, the District developed a GI Post Construction Monitoring Program (GI PCMP) to evaluate the performance and effectiveness of the constructed Appendix 3 GI projects. The main elements of the GI PCMP were as follows:

- **Site-Specific Monitoring and Data Collection** - A process to evaluate the effectiveness of the GI projects on a site scale, including the monitoring/assessment methods that will be used to evaluate the performance and effectiveness of the various types of GI.
- **Sewershed-Specific Monitoring and Data Collection** - A process to evaluate the performance and effectiveness of the GI projects on a sewershed scale including monitoring/assessment methods that will be used to evaluate the performance and effectiveness of the GI projects.
- **Model-Based Approach to Assessing Compliance** - A process for evaluation and analysis of the monitoring data to determine whether GI projects are achieving desired outcomes and for reporting progress to the Agencies and general public.

Appendix 3 GI Projects Performance Assessment Summary

The model-based approach for assessing compliance was performed to quantify the reduction in CSO volume above the required Appendix 1 gray infrastructure Control Measures attributed to implementing the GI during the District's simulated Typical Year (TY) of rainfall events. This assessment resulted in an overall reduction in CSO volume achieved through the implementation of the nine GI projects of 8.6

MG in a TY above what is achieved by the Appendix 1 gray infrastructure.[1] **Table ES-1** provides a breakdown of CSO volume reduction and design and construction costs for each of the individual Appendix 3 GI projects.

Table ES-1. Appendix 3 GI Projects TY CSO Reduction Estimates and Design and Construction Expenditures

Appendix 3 GI Project	Tributary CSO	CSO Reduction - TY (MG)	Total Design and Construction Cost[1] ($M)
E 140th Consolidation and Relief Sewer GI	CSO 211 and 232	0	20.6
Green Ambassador Fairhill-MLK GI	CSO 073	1.6	5.5
University Circle GI	CSO 224	0.2	0.3
Buckeye GI	CSO 073	0.7	6.0
Union GI	CSO 036	0.1	
Green Ambassador Slavic Village Demonstration GI	CSO 036	0	0.2
Fleet Ave GI	CSO 036	0.5	1.6
Green Ambassador Urban Agriculture GI	CSO 040	2.4	5.2
Woodland Central GI	CSO 040	3.1	13.6
	Totals	**8.6**	**53.0**

[1] Costs in 2011$$, ENR CCI 10165.86 (Oct 2011)

Appendix 3 GI Projects Progress Reporting

Green Infrastructure program and project status have been reported to the Agencies and the general public over the course of the Consent Decree on a semi-annual basis in the CSO Consent Decree Semi-Annual Progress Reports submitted to the Agencies and posted to NEORSD.ORG. Additionally, the District's Communication and Community Relations department maintains an ongoing blog with green infrastructure information as well as website posts related to green infrastructure. A link to posts on NEORSD.ORG tagged as "green infrastructure" is included here: https://www.neorsd.org/tag/green-infrastruture.

A copy of the GI Performance Report will be uploaded to NEORSD.ORG.

[1] Modeled using only available storage capacity above that required under Appendix 1 Design Criteria, based on discussions with USEPA on August 31, 2021.

1.0 Introduction

Appendix 3 requires the District to demonstrate the effectiveness of implementation of the GI Plan by January 3, 2022.[2] This report fulfills that requirement and provides an overview of the GI Plan and GI PCMP (Section 1.0), details the Appendix 3 GI projects constructed (Section 2.0), analysis of the effectiveness of these projects based on the site-specific (Section 3.0) and sewershed-specific (Section 4.0) flow monitoring conducted, and an assessment of the performance of the Appendix 3 GI projects in a TY (Section 5.0).

1.1 Consent Decree Appendix 3 Requirements

Per Appendix 3 of the CD, the District developed and submitted a GI Plan (*Green Infrastructure Plan, Northeast Ohio Regional Sewer District, April 23, 2012* [ref. 2]) to capture a minimum of 44 MG of wet weather flows in a typical year that would otherwise be discharged by the District's CSOs at a prescribed expenditure of at least $42 million. As part of the implementation effort, the District also developed a GI Post-Construction Monitoring Program (GI PCMP) to evaluate the performance and effectiveness of the GI projects (*Green Infrastructure Post-Construction Monitoring Programs, July 2013 Revised July 2015, Combined Sewer Overflow (CSO) Long-Term Control Plan Consent Decree Case 1:10-CV-02895-DCN* – [ref. 3] **Attachment 3**). The GI PCMP [ref. 3] detailed the elements required under Section 6 of Appendix 3 of the CD and considered the GI projects already advanced to design and/or construction at the time of the plan development. The content of this report contains the results of the GI PCMP efforts including a model-based performance assessment of the implemented GI projects and documentation of the expenditures.

Key dates with the U.S. EPA approvals of the GI implementation plan and GI PCMP include the following:

- GI design and construction completion by July 7, 2019, and demonstration of effectiveness by January 3, 2022
- Achievement of full operation of the GI within 12 years from the date of entry of the CD (or July 7, 2023).
- If the GI PCMP Performance report demonstrates that the GI has not met the 44 MG performance criteria, then within 180 days of the original due date of the GI PCMP Performance Report (or January 3, 2022), the District must submit a corrective action (CA) proposal to define the GI or gray infrastructure improvements to achieve the 44 MG performance criteria.

[2] Modified under the Third Amended Consent Decree filed July 15, 2021.

1.2 GI PCMP Elements

The purpose of the GI PCMP is to verify that the GI projects constructed as part of Appendix 3 meet the Performance Criteria set forth in Section 2 of Appendix 3 of the CD. The main elements of the program are as follows:

- **Site-Specific Monitoring and Data Collection -** A process to evaluate the effectiveness of the GI projects on a site scale, including the monitoring/assessment methods that will be used to evaluate the performance and effectiveness of the various types of GI.
- **Sewershed-specific Monitoring and Data Collection -** A process to evaluate the performance and effectiveness of the GI projects on a sewershed scale including monitoring/assessment methods that will be used to evaluate the performance and effectiveness of the GI projects.
- **Model-Based Approach to Assessing Compliance -** A process for evaluation and analysis of the monitoring data to determine whether GI projects are achieving desired outcomes and for reporting progress to the Agencies and general public.

2.0 Appendix 3 GI Projects Implemented

The District ultimately implemented nine Appendix 3 GI projects in the Easterly and Southerly CSO Districts based on model-estimated impacts on CSO performance and community support/co-benefits. These GI project concepts were incorporated in the GI PCMP and included three (3) different GI technology types including: infiltration basins, detention basins, and biorention basins. **Table 2-1** identifies the constructed GI projects, technology type, implementation cost and date the facility became fully operational. The locations of the GI projects are shown in **Figure 2-1**.

Figure 2-1. District's Appendix 3 GI Projects

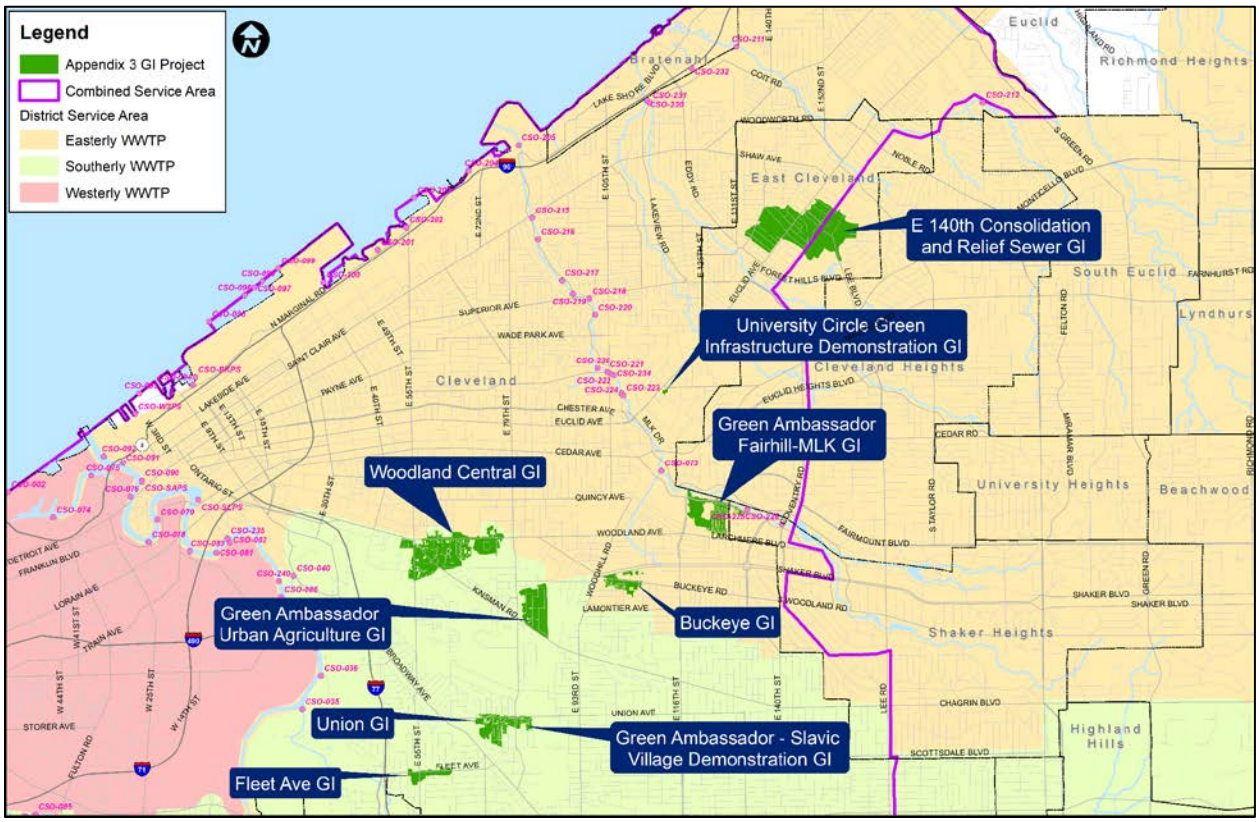


Table 2-1. Appendix 3 GI Projects Implemented

Appendix 3 GI Projects	CSO District	Downstream Permitted CSO	Technology Type	Date of Full Operation
E 140th Consolidation and Relief Sewer GI	Easterly	211/232(2)	Detention	Oct 10, 2018
Green Ambassador Fairhill-MLK GI	Easterly	073	Bioretention	Oct 31, 2016
University Circle GI	Easterly	224	Infiltration	July 26, 2013
Buckeye GI(1)	Easterly	073	Detention	Sep 10, 2019
Union GI(1)	Southerly	036	Detention	Sep 10, 2019
Green Ambassador - Slavic Village Demonstration GI	Southerly	036	Bioretention	Oct 31, 2014
Fleet Ave GI	Southerly	036	Infiltration	August 9, 2016
Green Ambassador Urban Agriculture GI	Southerly	040	Bioretention	Dec 2, 2016
Woodland Central GI	Southerly	040	Detention	Dec 31, 2019

2.1 Easterly CSO District GI Projects

Four (4) Appendix 3 GI projects were implemented in the Easterly CSO District service area. These GI technologies reduce stormwater runoff, through bioretention, detention or infiltration, before releasing captured stormwater back into the combined system or offloading directly to the environment, and include:

- E 140th St Consolidation and Relief Sewer GI (E140CRS GI)
- Green Ambassador Fairhill/MLK GI (GAFM)
- University Circle GI (UCGI)
- Buckeye GI (BGI)

2.1.1 E 140th St Consolidation and Relief Sewer GI

The District completed GI along with gray infrastructure improvements with the overall E140CRS GI project. The project consisted of three (3) dry detention basins and constructed storm sewers, installed primarily on residential streets in the City of East Cleveland. The basins reduce stormwater inflow to the combined sewer system tributary to the E140th Project and the Euclid Creek/Dugway Storage Tunnel system (CM 6). The newly installed storm sewers collect runoff from limited drainage areas of previously combined sewers and specific non-residential properties, where the internal storm sewer system is not interconnected to the sanitary sewer and redirect that flow from the existing storm sewer system.

The storm sewers are designed to convey the 5-year, 6-hour storm event without surcharging. The storm sewers capture runoff from approximately 223 acres. Captured stormwater runoff is treated and offloaded from the combined sewer system via new connections to the existing storm sewer outfall to Shaw Brook, shown in **Figure 2-2**. The detention basins were fully operational as of July 2019, ahead of the CM 6 gray infrastructure components. The separate sewers draining to the three basins are generally bound by E 133rd St between Garden Rd and Lakefront Ave, and Terrace Rd, between Beersford Rd and Chapman Ave, shown in **Figure 2-3**.

The basins are designed as extended dry detention basins that detain stormwater flows and slowly release them back into the existing storm sewer system (with a drawdown time of approximately 25 hours) and provide additional storage volume to control peak flows during the 5-year, 6-hour design storm. The basins are also sized to capture the water quality volume. All basins share similar components such as an inlet structure, pretreatment area, outlet structure, and emergency spillway. A pretreatment area that captures solids and grit from influent runoff, sized for 20% of the water quality volume (WQv), occupies

a portion of the basin. The pretreatment area consists of a sectioned off portion at the basin inlet, separated by a weir wall, where solids and grit can settle before exiting the basin. The tributary area and storage volume of each basin is provided below:

- Page Ave Basin - receives runoff from approximately 86 acres, and has an available storage volume of approximately 2.6 MG. The basin drains to the Shaw Brook Culvert on Strathmore Ave at Elderwood Ave.
- Scioto Ave Basin - receives runoff from approximately 102 acres and has an available storage volume of approximately 3.1 MG. The basin drains to the storm sewer on E 133rd St at Garden Rd, which drains to the Shaw Brook Culvert.
- Second Ave Basin - receives runoff from 35 acres and has an available storage volume of approximately 1.2 MG. The basin drains to a local storm sewer on E 133rd St at Second Ave, which drains to the Shaw Brook Culvert.

Prior to construction of the E140CRS GI basins, stormwater flows contributed to the CSO volume experienced at permitted outfalls CSO 211 and CSO 232. The estimated CSO reduction benefit during design, based on system-wide modeling, was approximately 5.8 MG annually in the TY.

Figure 2-2. E140CRS GI Location

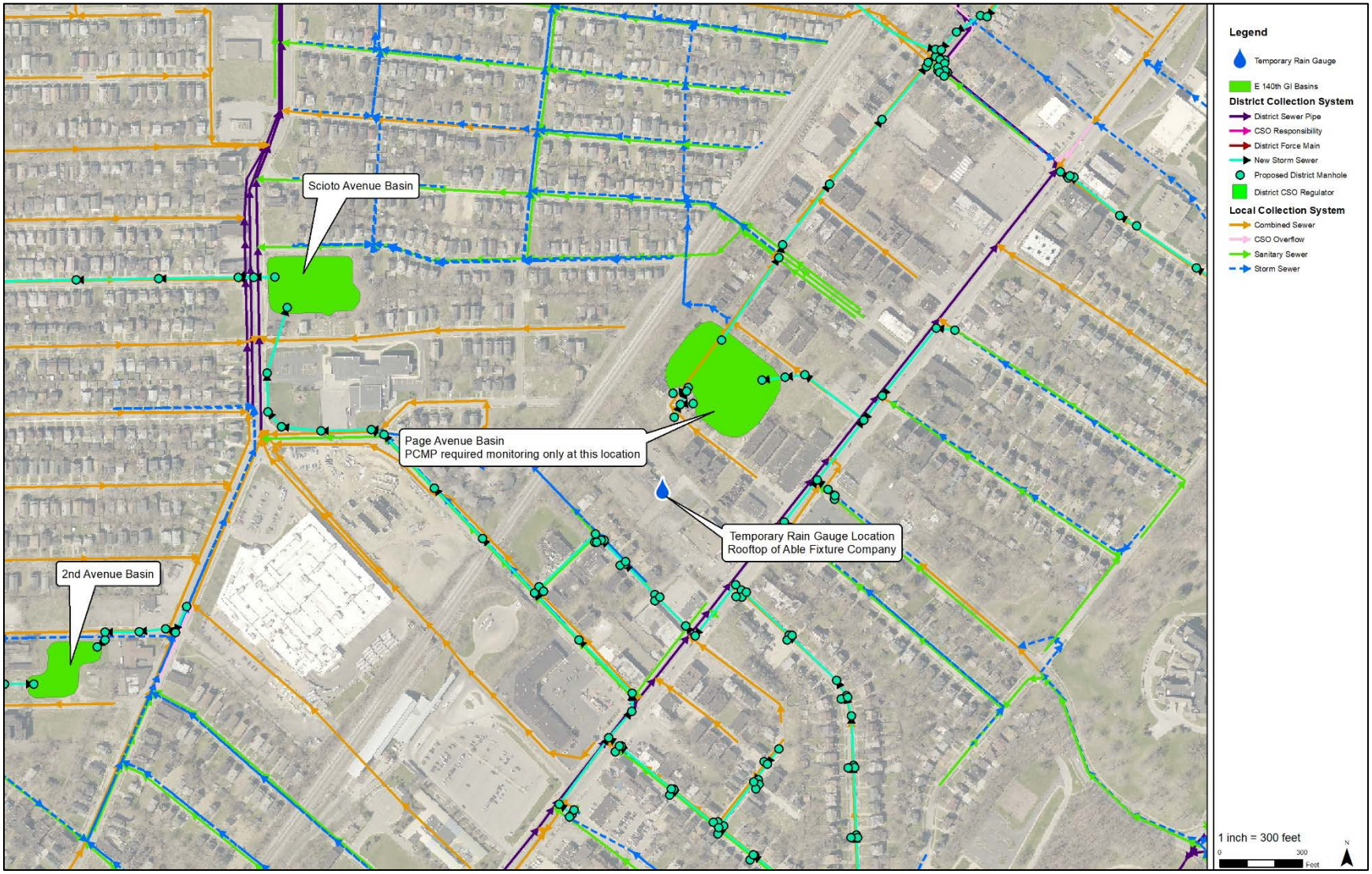
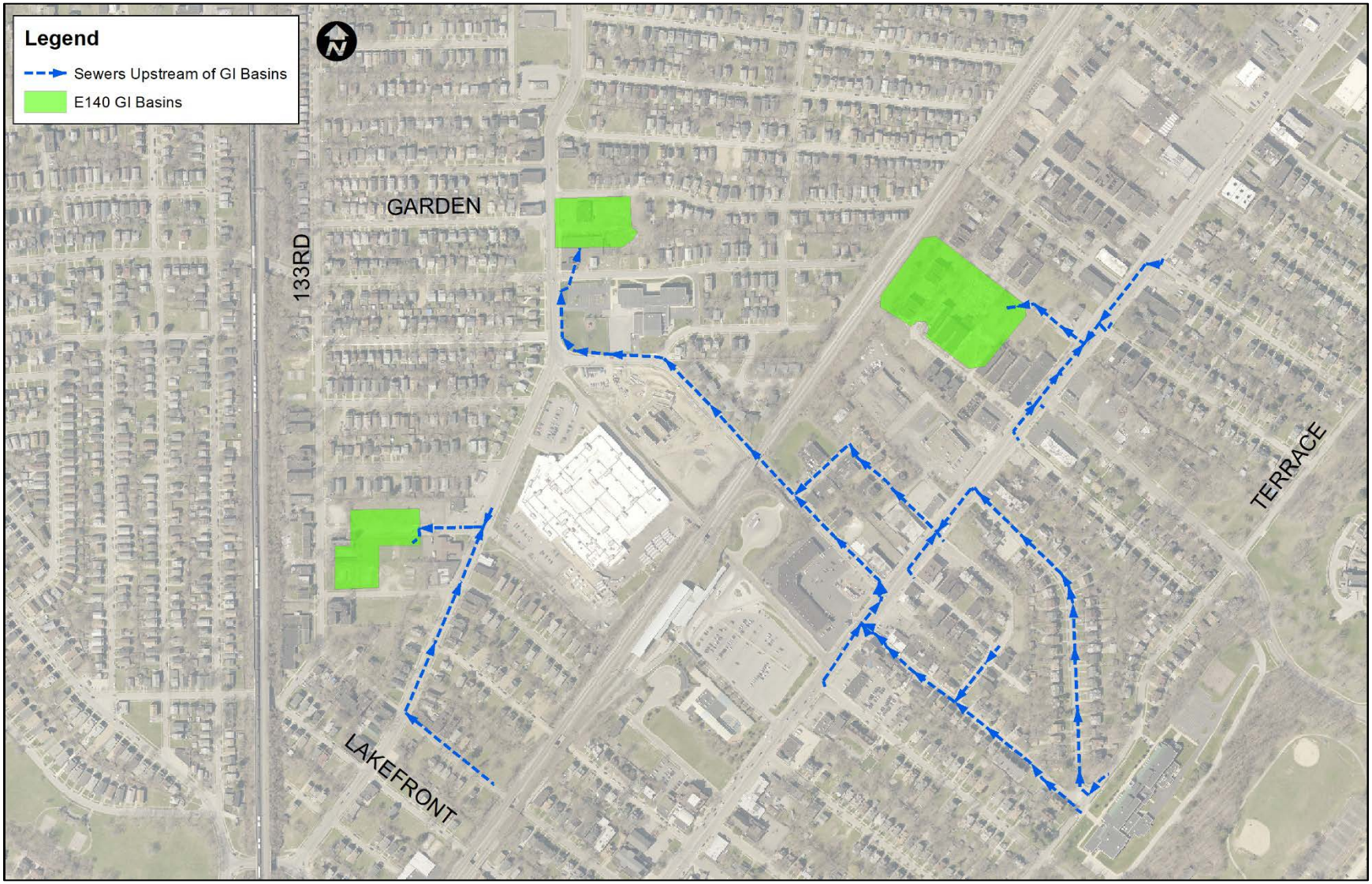


Figure 2-3. E140CRS GI Storm Sewer Overview



2.1.2 Green Ambassador Fairhill/MLK GI

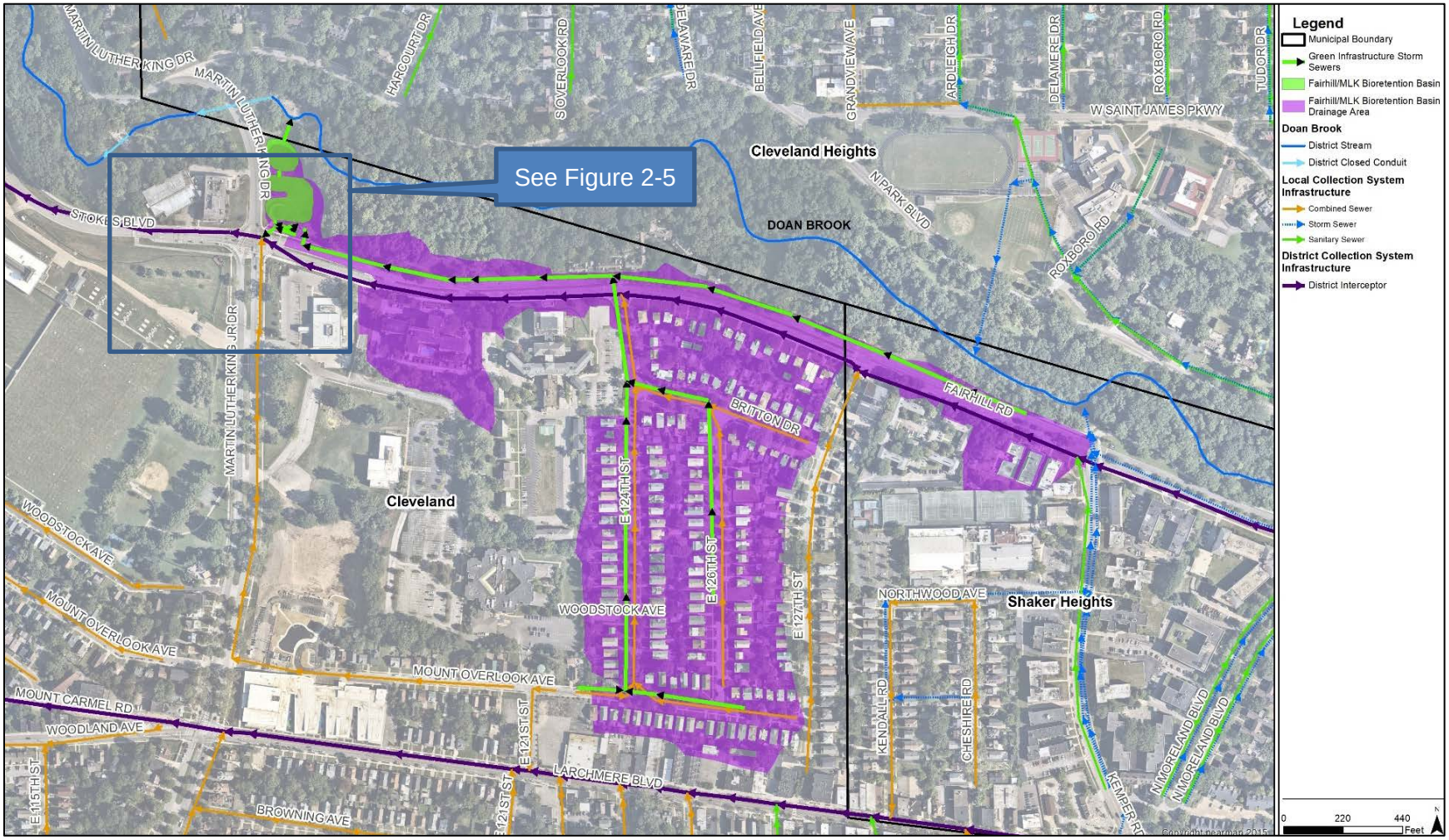
The GAFM GI project captures stormwater runoff using new storm sewers to convey flows into two in-line bioretention basins designed to temporarily store and passively treat stormwater before draining to Doan Brook. The storm sewers conveying runoff to the GAFM bioretention basins are generally located along Fairhill Rd, between Martin Luther King Jr Dr (MLK) and Kemper St, and along E 124th and E 126th St, between Fairhill and Mount Overlook Ave, shown on **Figure 2-4**. Due to property acquisition issues with a concurrent developer on the corner of Fairhill and MLK Dr , a section of proposed storm sewer along MLK Dr was ultimately removed from the project scope during construction, reducing the overall drainage area to the basins from 63 acres to 38.4 acres. The storm sewers were generally designed with adequate capacity to convey the 10-year design storm with the exception of a small section of storm sewer lower in elevation to avoid conflict with the existing combined sewer and water line along Fairhill Rd. The project removes stormwater from the combined sewer system on Fairhill Rd upstream of the Doan Valley Tunnel (DVT) diversion system near CSO-073.

The GI facility consists of two bioretention basins, identified as the upper and lower bioretention basin. Both basins share similar components such as an inlet structure, outlet structure, emergency spillway, and underdrain system. Both basins have a 6-inch PVC gate valve positioned at the downstream end of the underdrain system which regulates flows into the outlet structure. The upper bioretention basin includes a forebay and concrete curbing with v-notch curb cuts at the basin inlet to provide energy dissipation, flow distribution, and sediment capture. The lower bioretention basin utilizes a stilling area and level spreader to diffuse flow.

Flow first enters the GI facility through a diversion structure prior to entering either the pretreatment device, the upper basin, or overflowing back to the combined sewer on Fairhill Dr. The locations of the diversion structure, pretreatment device, and bioretention basins are shown on **Figure 2-5**. The stormwater from the upper basin then gravity drains through either the underdrain system, the outlet structure, or by overtopping the emergency spillway to the lower basin. The lower basin then gravity drains through its own underdrain system, outlet structure, or emergency spillway to Doan Brook.

The bioretention basins were sized to capture the water quality volume defined as the runoff volume from a 0.75-inch rainfall event according to the Ohio EPA standards at time of design work. The estimated CSO reduction benefit during design, based on modeled CD conditions in the TY at CSO 073, was approximately 2.4 MG annually. The removal of proposed storm sewer along MLK Dr was estimated to reduce the CSO benefit by 0.4 MG to 2 MG annually.

Figure 2-4. Green Ambassador Fairhill/MLK GI Storm Sewer Overview



Source: Green Ambassador Fairhill/MLK GI Site-Specific Flow Monitoring Plan (FMP)

Figure 2-5. Green Ambassador Fairhill/MLK GI Bioretention Basins and Diversion Structure Overview

Source: Basis of Design Green Ambassador Fairhill/MLK Project

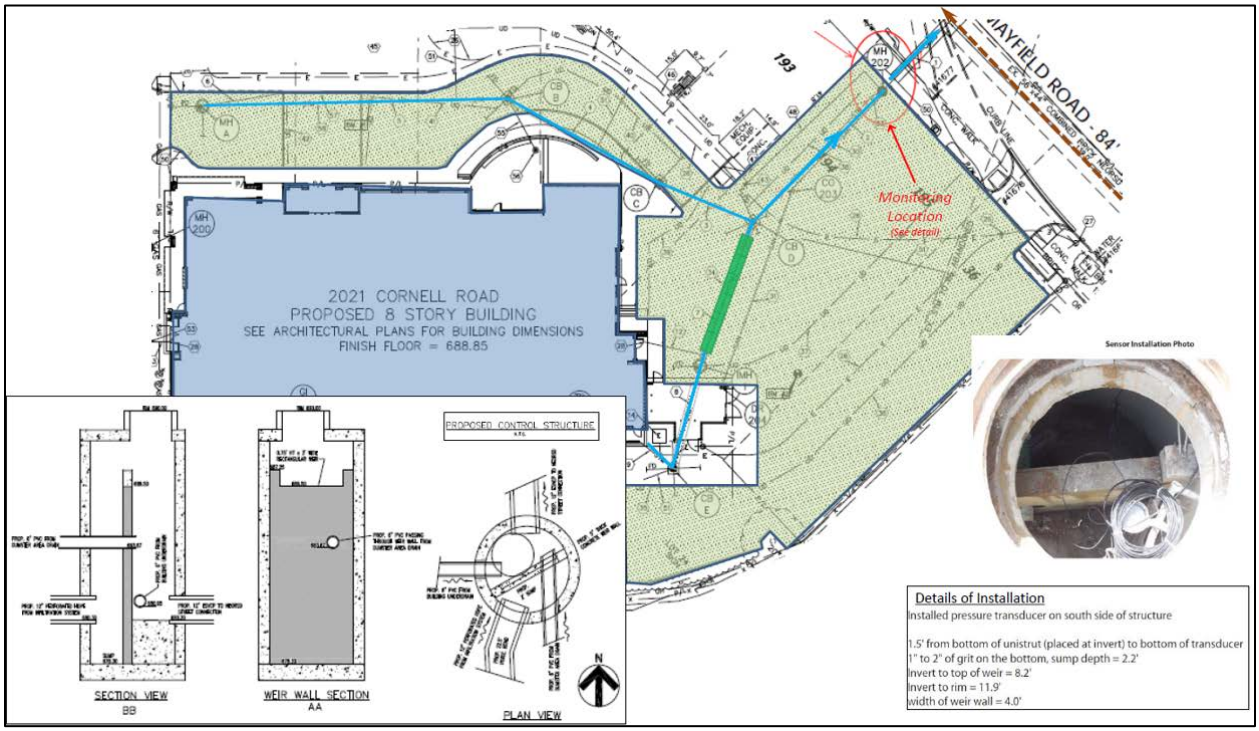
2.1.3 University Circle GI

The University Circle GI project was a demonstration effort that included the implementation an infiltration basin concept designed to capture stormwater volume tributary to the combined system on a small scale. Monitoring and results would then be used to evaluate the potential impact to downstream CD-required traditional gray infrastructure and assess the benefit in supporting the Appendix 3 requirements. The project also tested the District's ability to partner with public and private partnership projects for the implementation and maintenance of opportunity-driven development efforts at a small-scale where on-site stormwater control measures tributary to the combined system could be implemented. The developer, University East LLC, was underway with the design and construction of a new 153-room Courtyard by Marriott Hotel on property it owned with University Hospitals (UH) on Cornell Rd, near Euclid Ave. The project included a new drive isle from Cornell Rd and near half-acre parking lot as part of the project. At the time, the re-development was thought to be a typical example of potential opportunities to utilize GI and provided an opportunity to assess the impact and performance within the Doan Brook combined area. The District secured an agreement to work with the developer to improve the site design to incorporate a stormwater infiltration GI technology to remove stormwater generated on the site from the downstream combined system, taking advantage of the natural sandy soil conditions found onsite.

The project included 20,433 sf of permeable pavement with 30 inches of aggregate subbase for the new driveway and parking area. The permeable pavement was situated over an infiltration bed under the parking area. The paver system was contained within a complete outline boarder of curbing and traditional pavement. Roof drainage from the hotel was designed to direct flow into an open storage chamber system within the aggregate base of the permeable paver system. The open chamber system subsequently disperses the runoff to the subbase and infiltration bed. The point of emergency overflow discharge for the site was placed within a weir-controlled manhole at Mayfield Rd, which is connected to a District combined sewer interceptor. The permeable pavement system (including the roof runoff) has a direct connection to this control manhole prior to the sewer connection. This manhole included a weir wall that set the overflow weir crest at an elevation above the required storage volume of the aggregate infiltration bed. The control manhole with the emergency overflow weir was designed to prevent surface flooding of the parking lot and neighboring areas. The weir outlet was designed to allow for an internal overflow into the combined sewer line for storms larger than 100-year events. Construction of the property was completed in October 2012. **Figure 2-6** illustrates the location of the UCGI parking lot area and PCMP monitoring location. The project design provided a system that was expected to result in no

stormwater discharge from this site up to the 100-year storm, or approximately 1.0 MG of stormwater infiltration for a TY.

Figure 2-6. University Circle GI Overview



Source: Attachment 1 of NEORSD Semi-Annual Progress Report No.7

2.1.4 Buckeye GI

The BGI project was one of two project areas implemented by the District as one design and construction contract – the Union/Buckeye GI project. The Union Ave portion of the project is located in the Southerly CSO District area and is discussed further in **Section 2.2.1**. The BGI project area captures stormwater runoff from the streets via new catch basins, redirecting the flow to an interconnected system of detention basins designed to temporarily detain the flow prior to discharge into the existing combined sewer system. The detention basin cells are located along Buckeye Ave, generally bounded by E 99th St and E 104th St and an underground retention basin is south of Shaker Blvd and north of Buckeye Rd. Detained stormwater is released at a controlled rate into the combined sewer system, upstream of permitted outfall CSO 073. **Figure 2-7** provides an overview of the final design of the BGI project area.

The storm sewers and basins were planned to capture runoff from approximately 22 acres. However, due to utility conflicts identified during detail design along Buckeye Rd, a section of proposed storm sewer

was removed from the project scope along Buckeye. To compensate for some of the lost drainage area, an additional storm sewer was added to capture additional runoff along Shaker Blvd. With these changes, the drainage area was reduced to 12.3 acres. Furthermore, the sizing of the basins was restricted by both property availability and depth to groundwater and rock. These restrictions along with inability to fully offload the stormwater from the combined system limited the opportunity and cost-effectiveness of GI in this location.

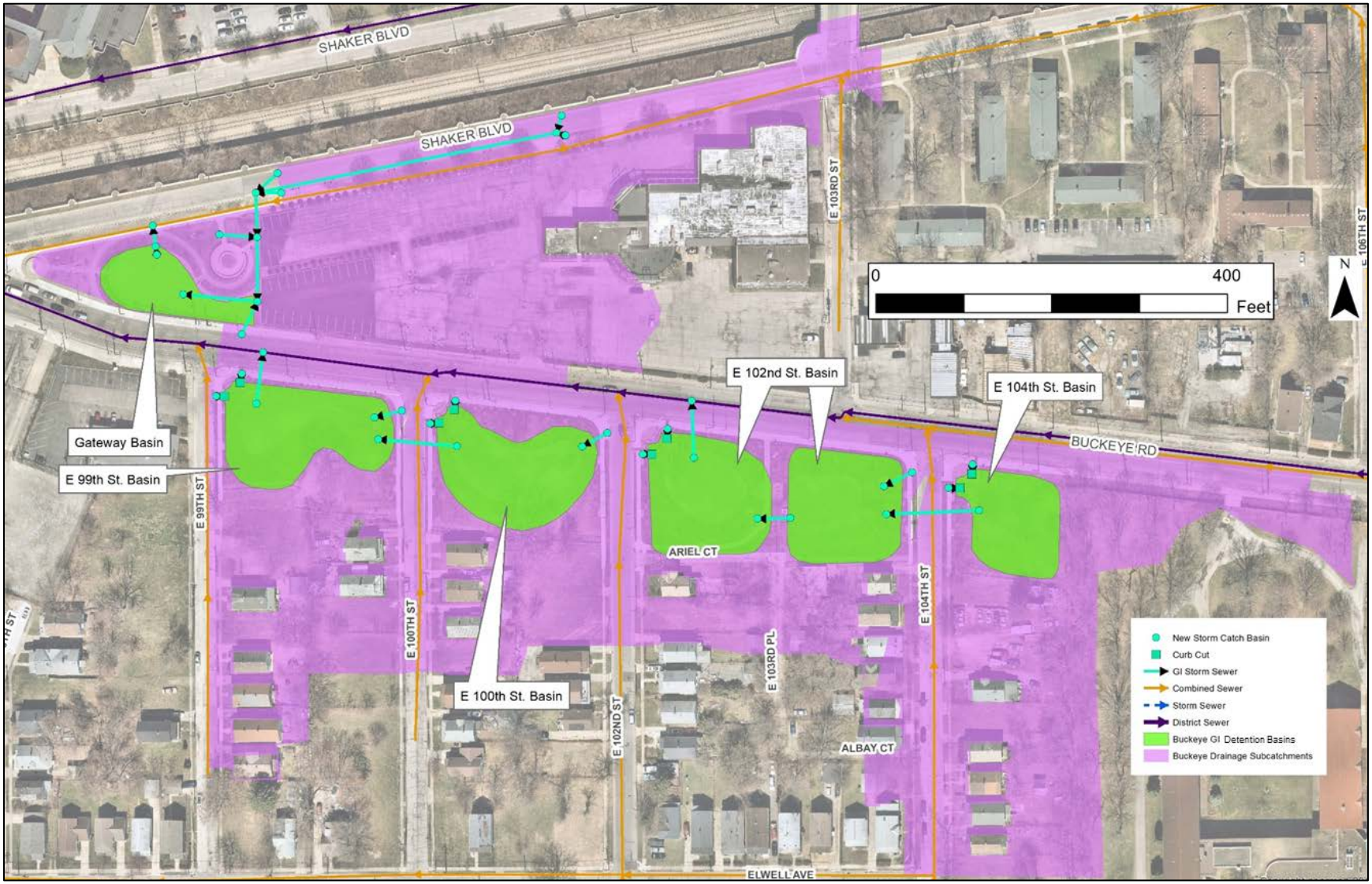
The constructed storm sewers are designed to convey the 10-year, 24-hour design storm. The detention basins were sized to capture the water quality volume prior to discharging into the existing combined sewer systems adjacent to the detention basins. Each basin is designed with additional capacity to capture the entire volume of TY storm 86, to detain the 10-year design storm peak flow, and to discharge excess storm volume to the downstream basin or the District's interceptor along Buckeye Rd. CSO reduction is achieved primarily through attenuating flow.

Three of the GI basins, the Gateway basin, E 102nd St basin, and E 104th St basin, have rain garden-type units at the curb cut inlets to provide pre-treatment prior to the basin. The pretreatment chambers or curb cut inlets were constructed to trap coarse sediment and debris to minimize accumulation in the basins.

At each detention basin, the inlet storm sewers enter at or near the bottom elevation of the basin. Energy dissipation features are included at each inlet to minimize and reduce velocity entering each facility. The basin outlet structures are equipped with backflow preventers and contain a two-stage configuration with a riser pipe to provide required release rates. To manage overflows, an emergency spillway is incorporated to direct emergency flows from the GI project to an existing flow path on Buckeye Rd.

The estimated CSO reduction benefit at the preliminary design stage, based on system-wide modeling, was approximately 1.1 MG annually in the TY. However, with the design level changes noted above, the overall CSO benefit was reduced to an estimated 0.7 MG.

Figure 2-7. Buckeye GI Overview



Source: Buckeye GI Site-Specific FMP

2.2 Southerly CSO District GI Projects

Five (5) Appendix 3 GI projects were implemented in the Southerly CSO District service area. These GI technologies reduce stormwater runoff, through detention or infiltration, before releasing captured stormwater into the combined system or offloading directly to the environment, and include:

- Union GI (UGI)
- Green Ambassador Slavic Village Demonstration GI (SVGI)
- Fleet Ave GI (FGI)
- Green Ambassador Urban Agriculture GI (GAUA)
- Woodland Central GI (WCGI)

2.2.1 Union GI

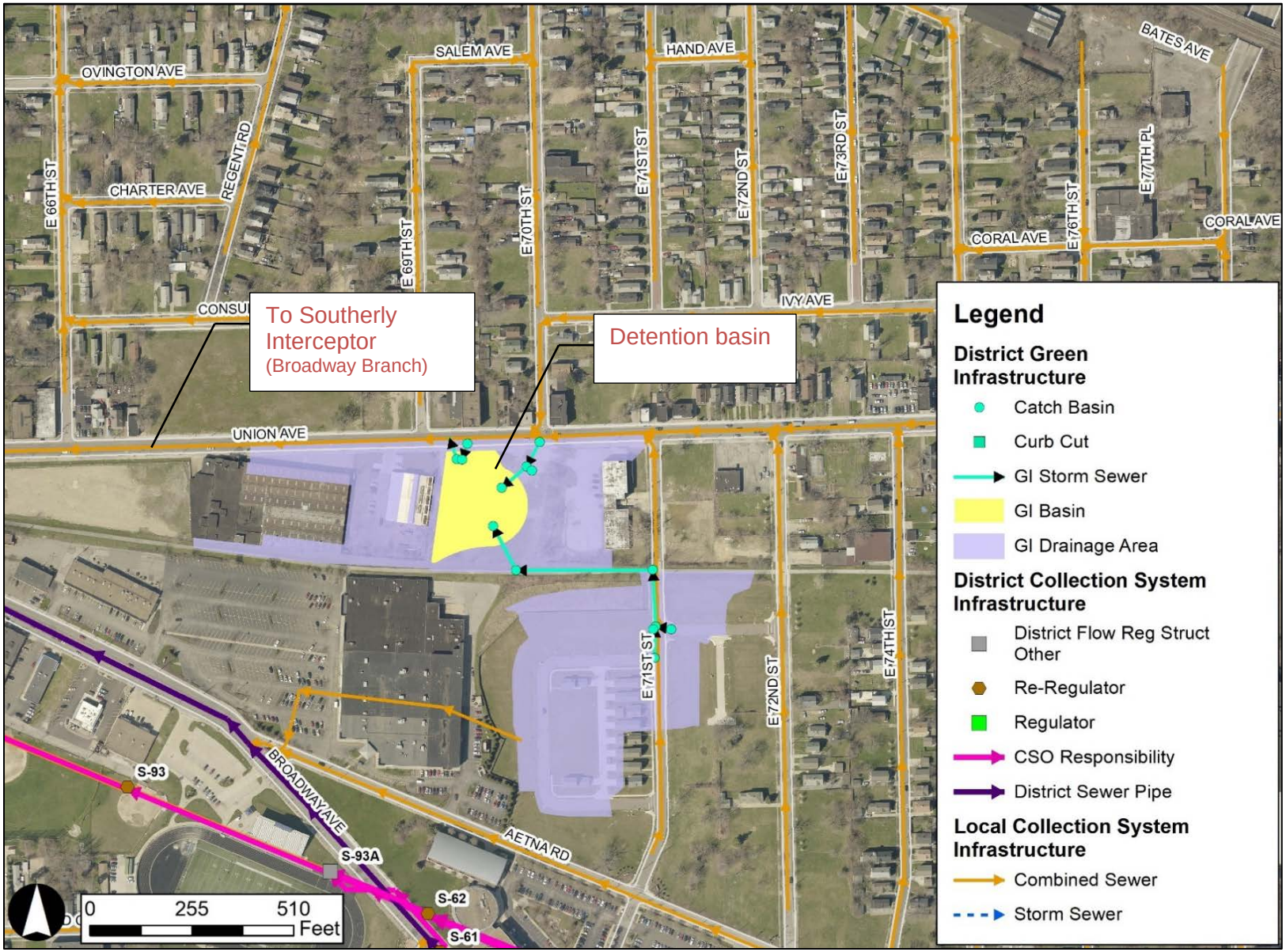
The UGI project was one of two project areas implemented by the District as one design and construction contract – the Union/Buckeye Green Infrastructure project. The Buckeye Ave portion of the project is located in the Easterly CSO District area and was discussed previously in **Section 1.1.4**. The basin is located on the south side of Union Ave bounded by E 72nd and E 69th St. The basin was sized to detain the water quality volume from the contributing drainage areas, which is equivalent to the runoff volume from a 0.75-inch rainfall event according to Ohio EPA standards, as well as control all the rain events in the TY, prior to discharge into existing combined sewer systems along Union Ave that are upstream of permitted outfall CSO 036. **Figure 2-8** provides an overview of the final design of the UGI project area.

The UGI project area as planned included new storm sewers and a detention basin to convey and treat stormwater runoff from an estimated 42 acres total drainage area. During detail design, the drainage area was reduced to 11 acres as a result of extensive underground conflicts along Union Ave, including a large electrical duct bank, and high ground water table in the area of the basins. Furthermore, due to property acquisition issues, contamination, and unforeseen obstructions encountered during construction, the storm sewer to the south of the basin was removed from the project scope reducing the drainage area further to approximately 6.3 acres.

All stormwater redirected from the combined sewer system to the GI basin will ultimately discharge to the combined sewer on Union Ave after being detained during the storm. Basin design features include an inlet energy dissipation structure to minimize erosion and reduce inlet velocities, an overflow structure at the northeast inlet, and a single outlet structure containing a diversion structure and emergency spillway to manage overflows. A backflow preventer was installed in the outlet pipe to prevent combined sewer flows (from Union Ave) from entering the basin.

The estimated CSO reduction benefit at the preliminary design stage, based on system-wide modeling, was approximately 1.2 MG annually in the TY. However, with the design level and construction level changes noted above, the overall CSO benefit was reduced to an estimated 0.1 MG including an estimated 0.9 MG reduction with the design level changes and an additional 0.2 MG reduction with the construction level changes.

Figure 2-8. Union GI Overview



2.2.2 Green Ambassador Slavic Village Demonstration GI

The SVGI demonstration project includes three (3) surface bioretention basins on former land bank/vacant properties in Cleveland's Slavic Village neighborhood. Two (2) of the bioretention basins are located on the east side of E 75th St south of the Morgana Run Trail and one (1) bioretention basin is located on the east side of E 78th St north of the Morgana Run Trail, as shown in **Figure 2-9**. Stormwater runoff from approximately three (3) acres of the adjacent areas is routed into the basins, which overflow during wet weather into the nearby combined sewers, tributary to CSO 036.

The bioretention basins are sized to capture the water quality volume from the contributing drainage area, which is equivalent to the runoff volume from a 0.75-inch rainfall event according to Ohio EPA standards at the time of design. The water quality volume will be stored and infiltrate to a gravel storage layer and underdrain system that ties back to the adjacent combined sewer. Due to the significant distance to any SWO/offload location, saturated soils not conducive to infiltration, and shallow bedrock, the bioretention features were designed to discharge back into the combined sewer system through the outlet structure and underdrain system. Selected vegetation was planted with amended soils (i.e., bio infiltration soil) to promote a metered infiltration rate into a subsurface gravel storage layer. The estimated CSO reduction benefit during design, based on system-wide modeling, was approximately 0.1 MG annually in the TY.

Figure 2-9. Green Ambassador Slavic Village Demonstration GI Location

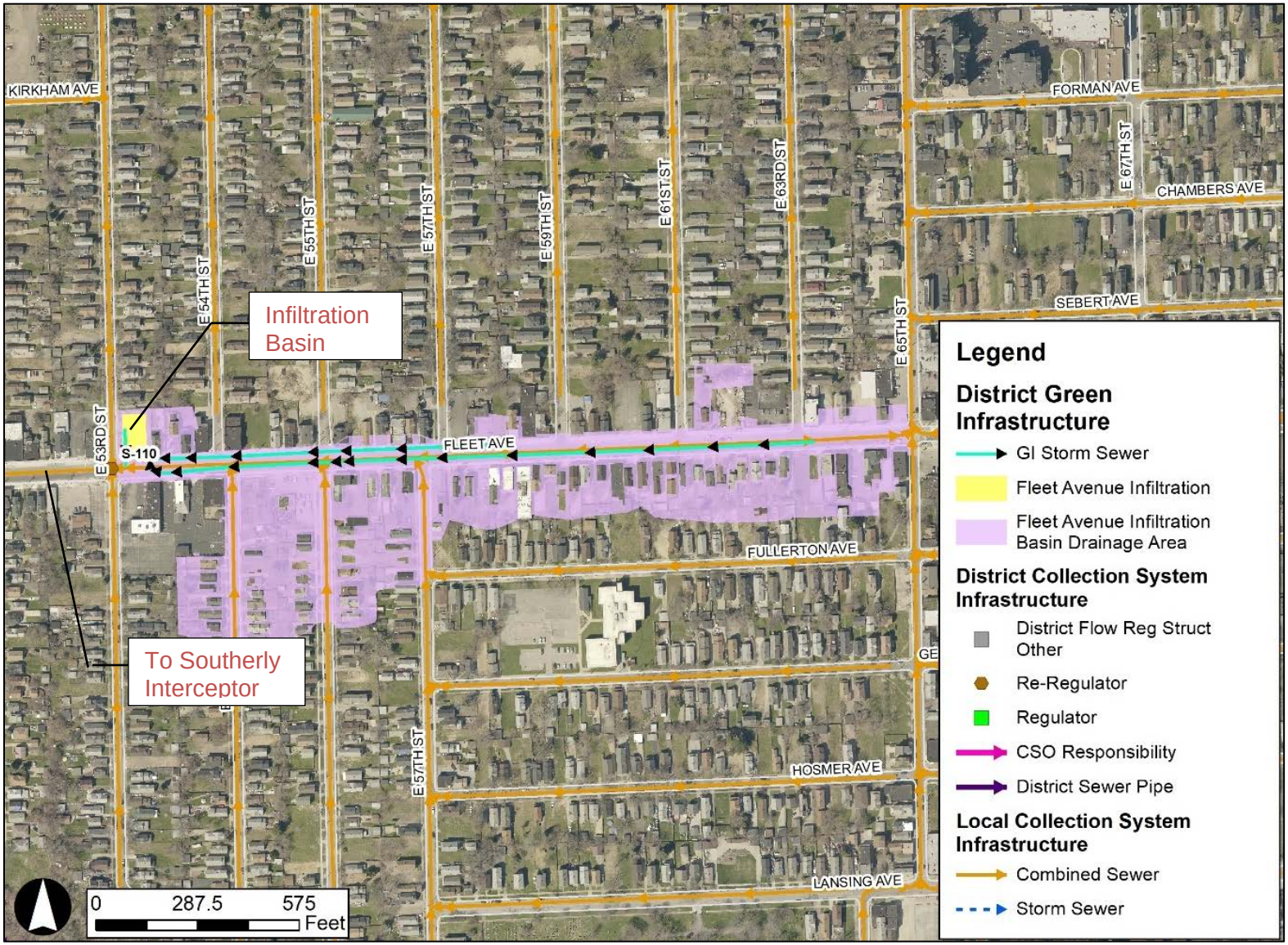
Source: Technical Memorandum Green Ambassador - Slavic Village Demonstration Project

2.2.3 Fleet Ave GI

The FGI project includes new storm sewer systems and an infiltration basin to convey and treat stormwater runoff from an approximate 15-acre drainage area. The new storm sewers are located along Fleet Ave, between E 53rd and E 65th St, within the City of Cleveland. An overview of the FGI project area is shown in **Figure 2-10**. The infiltration basin is located on the northeast corner of E 53rd St and Fleet Ave, shown in **Figure 2-11**.

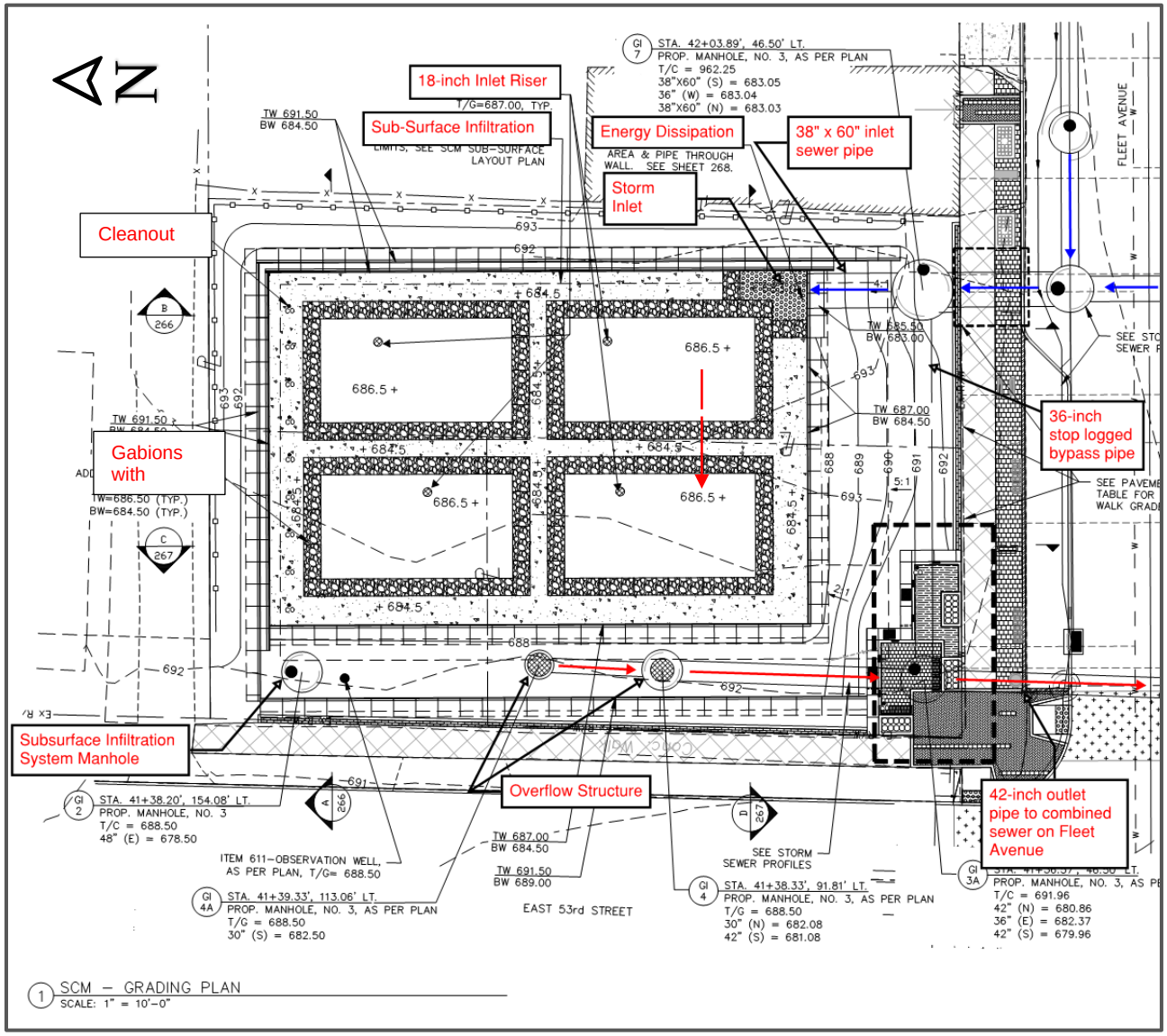
The infiltration basin is sized to store and infiltrate the TY storms. Flows enter the basin through an energy dissipation structure located in the southeast corner of the basin. A 36-inch bypass pipe connects the inlet of the basin to the outlet to allow for isolation of the basin for maintenance and repair activities when needed. Flow enters the basin are treated via infiltration through surface media. Additional storage is provided in the form of nine parallel subsurface conduits. Two overflow structures are located on the west side of the basin, which are connected to the outlet structure. The excess flow is routed to the outlet structure located on the southwest corner of the basin, which discharges to the combined sewer along Fleet Ave which is tributary to CSO 036. The outlet structure is designed with a flap gate to prevent backflow from the combined system. The estimated CSO reduction benefit during design, based on system-wide modeling, was approximately 0.5 MG annually in the TY.

Figure 2-10. Fleet Ave GI Overview



Source: Fleet Ave GI Site-Specific FMP

Figure 2-11. Fleet Ave GI Infiltration Basin Schematic



Source: Fleet Ave Rehabilitation Design Drawings

2.2.4 Green Ambassador Urban Agriculture GI

The GAUA GI project includes new storm sewers and four (4) bioretention basins that convey and treat stormwater runoff from an approximate 60-acre drainage area. The storm sewers are within an area bounded by Greater Cleveland Regional Transit Authority (GCRTA) rapid transit rail lines to the north, Kinsman Ave to the south, E 19th St to the west, and a branch of the Norfolk Southern Railroad to the east, see **Figure 2-12**. The bioretention basins are sized to capture the water quality volume from the contributing drainage area, which is equivalent to the runoff volume from a 0.75-inch rainfall event according to Ohio EPA standards, prior to discharge into a branch of the Kingsbury Run drainage system which is tributary to CSO 040.

The West and East Entry features are located at the south end of the project along Kinsman Rd. The entry features receive local drainage and runoff from Kinsman Rd. The entry features are designed to attenuate flows to the two larger bioretention basins and promote infiltration. Each of the entry features utilize a 4-inch underdrain system and outlet structure designed to limit flow rates. The West Entry feature outlets to the storm sewers in E 81st St while the East Entry outlets to the storm sewers in E 82nd St.

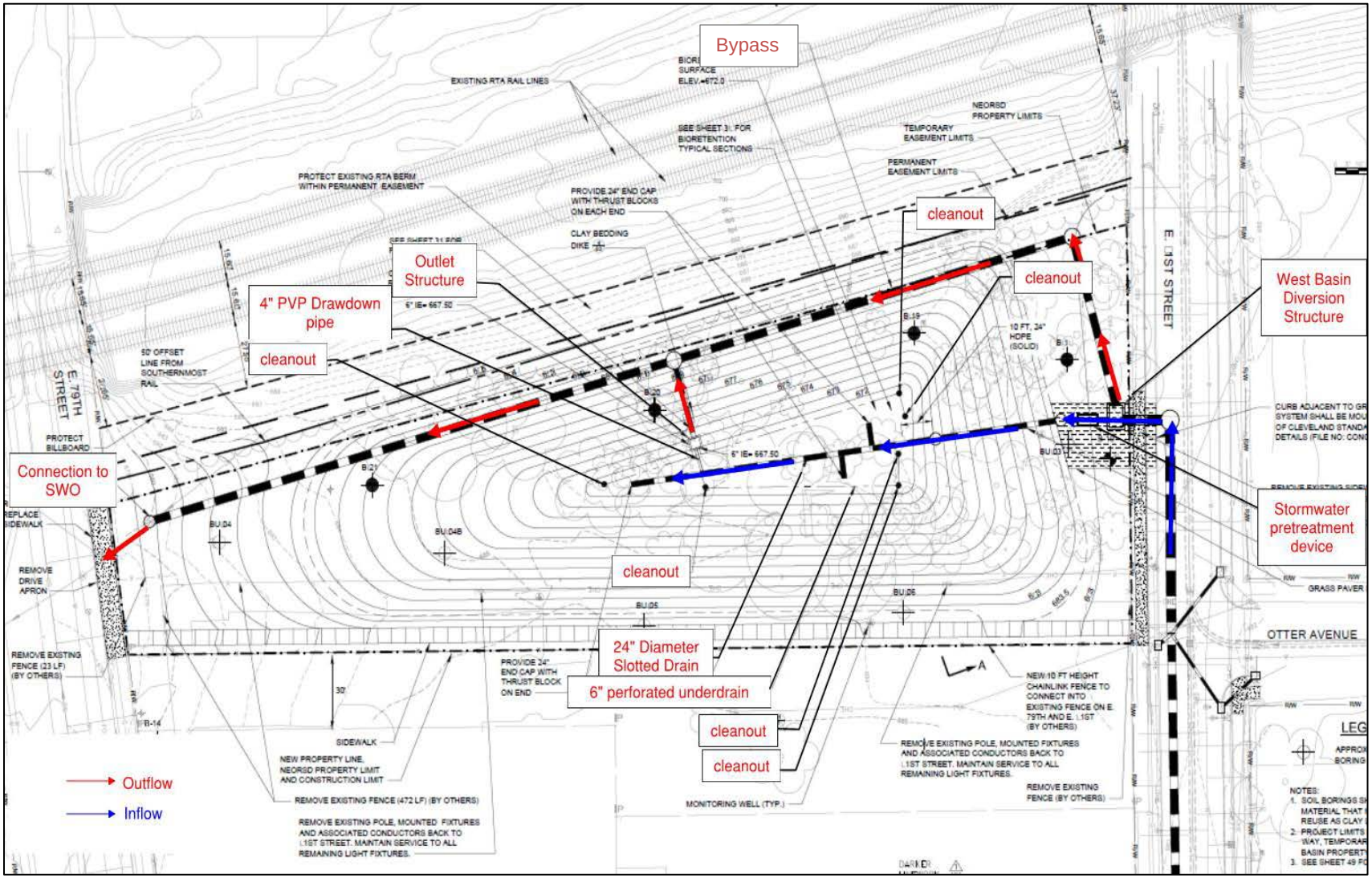
Both the West and East bioretention basins operate in a similar fashion. The West and East bioretention basins receive runoff from E 81st, E 82nd, and E 83rd St. Flows pass through a diversion structure which either directs flows to a pretreatment device prior to entering the basin or diverts excess flows into a bypass line and back to the combined system (see **Figures 2-13** and **2-14**). The diversion structure allows for flows to be isolated from the basin for maintenance, repairs, and during winterized conditions. During winterized conditions, flows are routed through the bypass route.

Flow that passes through the pretreatment device then continues through a 24-inch slotted drain to promote infiltration. The West basin has 1 slotted drain while the East basin has 2 slotted drains. When flow enters the basin at a higher rate than infiltration, flows will trickle up and out of the drains. When flows to the basin are in excess of design flows, water will begin to pond and accumulate. Outlet structures are provided to accommodate overflow conditions, connecting to the bypass pipe or directly to the combined system. The estimated CSO reduction benefit during design, based on system-wide modeling, was approximately 1.6 MG annually in the TY.

Figure 2-12. Green Ambassador Urban Agriculture GI Overview

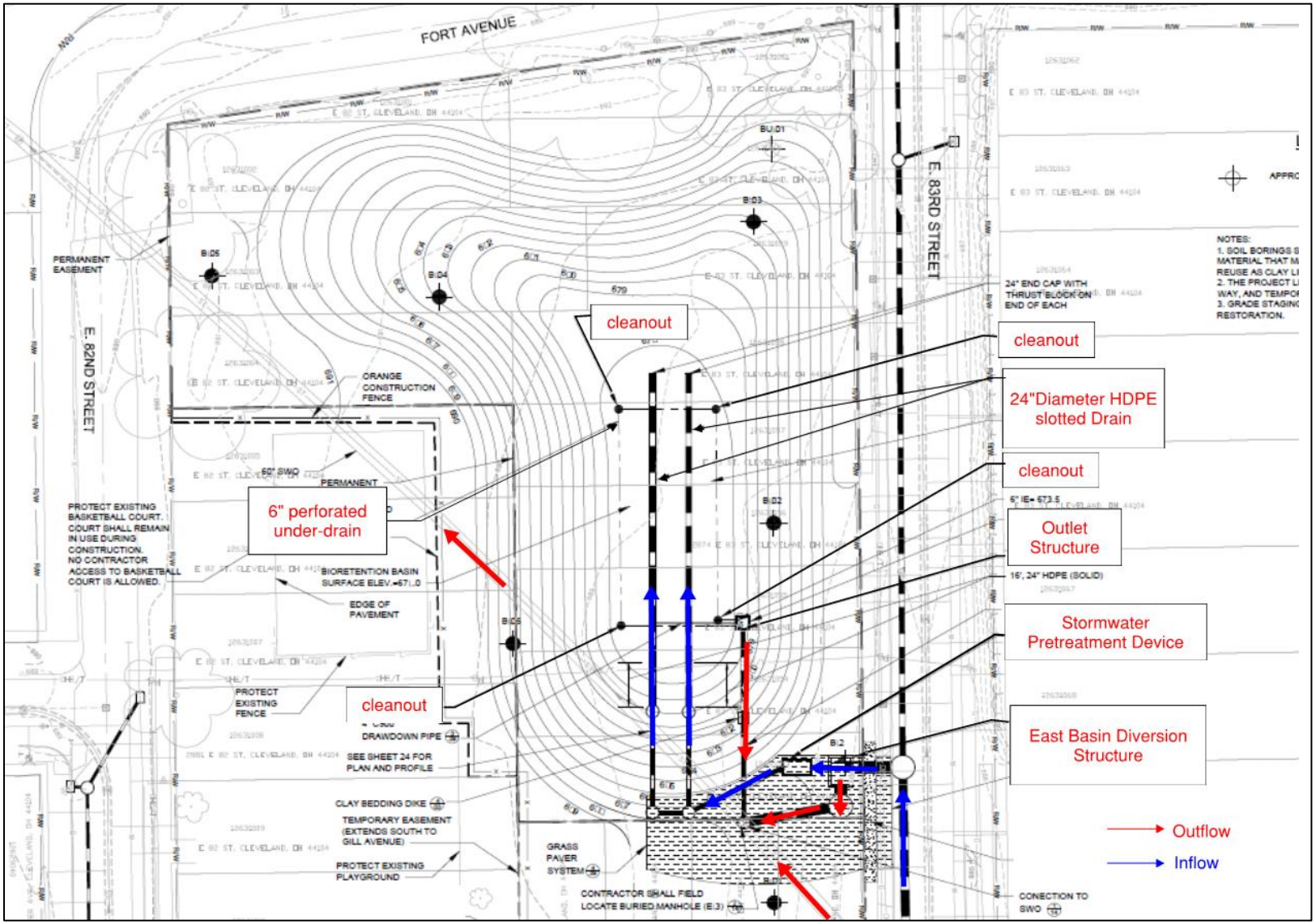
Source: Basis of Design Green Ambassador Urban Agriculture

Figure 2-13. Green Ambassador Urban Agriculture GI Bioretention Basin West



Source: Green Ambassador Urban Agriculture Record Drawing

Figure 2-14. Green Ambassador Urban Agriculture GI Bioretention Basin East



Source: Green Ambassador Urban Agriculture Record Drawing

2.2.5 Woodland Central GI

The WCGI is located in the City of Cleveland's Central neighborhood, roughly bounded by E 55th St to the west, E 75th St to the east, Woodland Ave to the north, and the Norfolk and Southern Railroad to the south. This project consists of new storm sewers and existing separate stormwater system, constructed as part of a separate City of Cleveland streetscape project on Woodland Ave., that convey flow to two (2) offline dry detention basins: East Basin and West Basin. During detail design, the majority of the WCGI western site was found to have extensive environmental contamination on portions of the property resulting in a relocation and downsizing of the planning level basin to minimize the amount of earthwork disturbance. Additionally, there were concerns expressed by community leaders around potential constraints and/or impacts to future development in the tributary area that limited further expansion of the project area. The overall drainage area was reduced from the estimated planning level 144 acres to 82 acres.

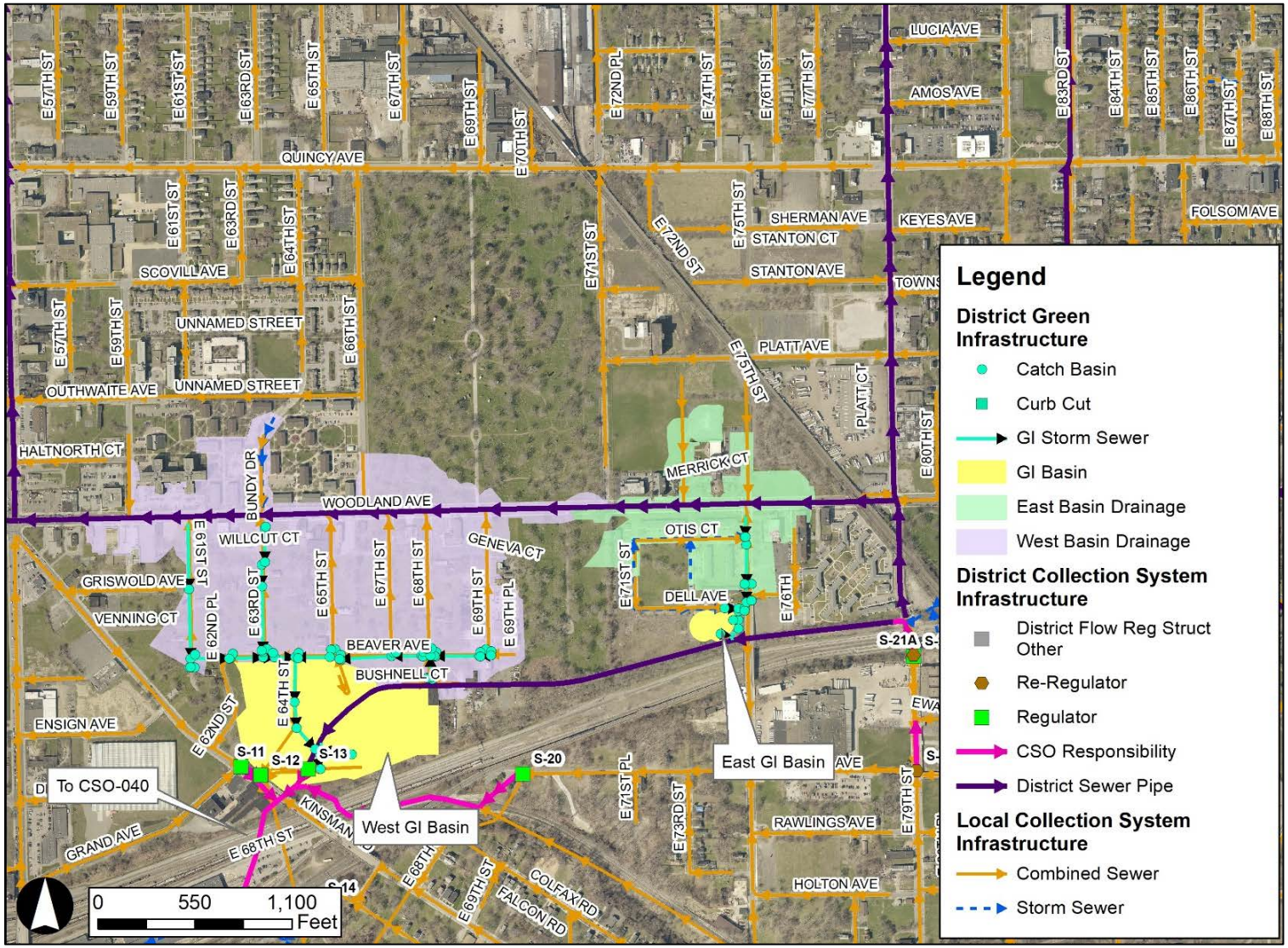
The two bioretention basins have a combined drainage area of 82 acres. The West Basin has an approximate 56.8 acres of drainage and is generally bound by Kinsman Rd to the West, Norfolk Southern Railroad to the South, E 69th St to the east, and Beaver Ave to the north. The East Basin has an approximate 25 acres of drainage and is generally bound by E 71st St to the west, Norfolk Southern Railroad to the south, E 75th St on the east, and Dell Ave to the North. **Figure 2-15** provides an overview of the final design of the WCGI project area**.**

The West Basin is a dry extended detention basin and was sized to capture the water quality volume, which is equivalent to the runoff volume from a 0.75-inch rainfall event according to Ohio EPA standards. The basin has one inlet pipe, with energy dissipation, and one outlet, with an emergency spillway, located on the northern edge of the basin. Stormwater from the 56.8 acres is routed through a diversion structure before passing through to either a pretreatment device (and into the basin) or directly to Kingsbury Run Culvert.

The East Basin is a dry extended detention basin and was sized to capture runoff from the 25-year storm event. A single inlet pipe to the basin has been proposed with full-height headwall, energy dissipation mechanisms at the point of entry to the basin, and one outlet structure. Stormwater from the 25 acres is routed to either a pretreatment device before entering the basin or bypasses the basin and flows directly to Kingsbury Run Culvert which is tributary to CSO 040.

The estimated CSO reduction benefit at the preliminary design stage, based on system-wide modeling of the then estimated drainage area of 144 acres, was approximately 5.7 MG annually in TY. The revised estimated CSO benefit based on final design and the 82 acres drainage area was 4.15 MG annually.

Figure 2-15. Woodland Central GI Overview

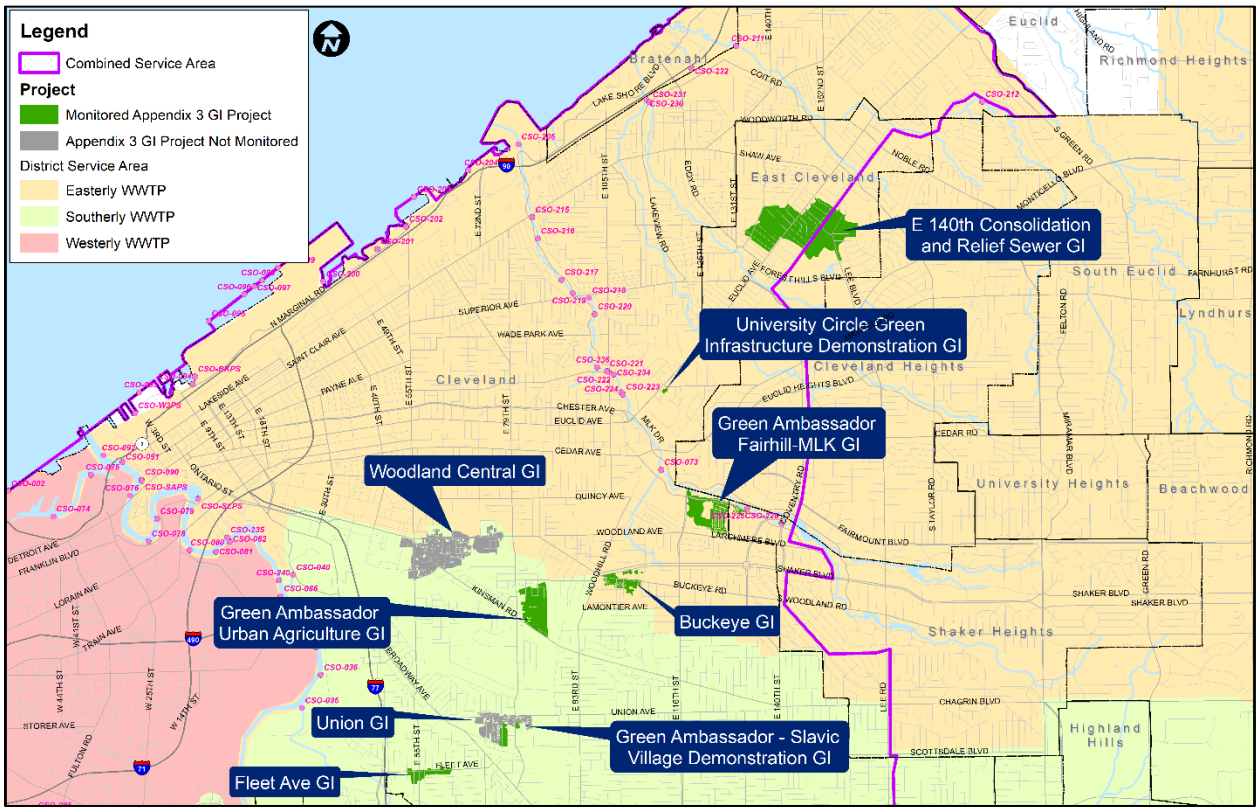


Source: Woodland Central GI Site-Specific FMP

3.0 GI PCMP Site-Specific Monitoring Program

The GI PCMP outlined the elements for the site-specific monitoring program to satisfy the Appendix 3, paragraph 6a requirement. The overall purpose of the program was to implement the methods and procedures identified in the GI PCMP to evaluate the performance of different types of fully constructed GI projects on a site-specific scale to assess the effectiveness of the technology in terms of function (e.g., storage, infiltration). The site-specific monitoring was performed for a minimum of 12-months immediately following the implementation of the GI projects identified in the GI PCMP. **Figure 3-1** shows the locations of the for the site-specific monitoring. The results for each site-specific location monitored are summarized in this section and were also submitted to U.S. and Ohio EPA as part of the subsequent semi-annual report following the close of each monitoring period.

Figure 3-1. Appendix 3 GI Projects Monitored as Part of Site-Specific PCMP FMPs



3.1 Site-Specific Program Status

The approved GI PCMP identified the type of GI technology to be monitored. The overall program was completed in two phases: Phase 1 - addressed GI projects implemented from 2012 through 2015; and Phase 2 – addressed a representative selection of types of GI technologies identified in the District's GI Plan [ref. 2]. In some cases, site-specific monitoring focused on one component of the implemented GI

project rather than the entire project to assess the performance a specific type of GI technology (i.e., bioretention, infiltration, etc.). The results were then extrapolated to the other same or similar GI components in support of the model-based performance assessment of system-wide benefits of GI as outlined in Appendix 3. The first site-specific GI PCMP began on October 15, 2015, and the final program finished on July 31, 2020. **Table 3-1** presents status of the site-specific GI PCMPs completed to meet Appendix 3 requirements.

Table 3-1. Site-Specific GI PCMPs Statuses

Site-Specific Monitoring Program	CSO District	Type of GI Technology	Start Date	Finish Date	Monitoring Period	Semi Annual Report Data Submitted	Comments
Phase 1 Program – projects implemented from 2013 through 2016:							
University Circle GI - permeable pavers/storm chamber/infiltration	Easterly	Infiltration	8/13/2013	6/30/2015	21.5 months	July 2015	Entire project monitored; completed.
Green Ambassador Slavic Village Demonstration GI - E 75th St North Basin – bioretention basin	Southerly	Bioretention	10/15/2015	11/1/2016	12 months	January 2017	One of three bioretention basins monitored; U.S. EPA completed monitoring and assessment of this area.
Phase 2 Program – projects with a representative selection of GI types being implemented in 2017 through 2020:							
Fleet Ave GI - infiltration basin	Southerly	Infiltration	3/4/2017	3/4/2018	12 months	July 2018	Entire project monitored; completed.
Green Ambassador Fairhill/MLK GI - bioretention basin	Easterly	Bioretention	3/4/2017	3/4/2018	12 months	July 2018	One of two biorientation features monitored per GI PCMP; completed.
Green Ambassador Urban Agriculture GI - West Basin including West Entry Feature - bioretention basin	Southerly	Bioretention	3/4/2017	3/4/2018	12 months	July 2018	One of two biorientation features monitored per GI PCMP; completed.

Site-Specific Monitoring Program	CSO District	Type of GI Technology	Start Date	Finish Date	Monitoring Period	Semi Annual Report Data Submitted	Comments
Buckeye GI - E 102nd Basin - dry detention basin	Easterly	Dry Detention	8/1/2019	7/31/2020	12 months	July 2021	One of six dry detention features monitored per GI PCMP; completed.
E 140th Consolidation and Relief Sewer GI - Page Basin - dry detention basin	Easterly	Dry Detention	8/15/2019	8/14/2020	12 months	July 2021	One of three dry detention features monitored per GI PCMP; completed.

3.2 Monitoring and Data Collection

Four of the site-specific projects were in the Easterly CSO District while the other three were in the Southerly CSO District. **Table 3-1** notes the GI technology type monitored, period of monitoring and when monitoring results were reported to U.S. and Ohio EPA. **Figures 3-2** through **3-8** show the locations of the flow and precipitation gauges for each site-specific location.

Flow monitoring and precipitation data were collected and analyzed in accordance with the District's flow monitoring standards and protocols as specified in the GI PCMP. During the course of the site-specific monitoring program, the District standards and protocols were refined and updated since the GI PCMP acceptance in July 2015 and used accordingly. Each flow monitoring plan (FMP) ran for a total of 12 months using a combination of flow monitors, level sensors, and precipitation gauges. For each site-specific location, the overall GI PCMP [ref. 3] specified the locations for monitors and precipitation gauges. In some cases, these locations were shifted and/or modified based on the final GI project construction, accessibility, and/or safety concerns. Details on changes are presented in the individual site-specific flow monitoring reports attached as **Appendices B-1** through **B-5**.

Precipitation data was collected from temporary and District-owned permanent gauges. Event statistics were calculated using EPA SSOAP Toolbox with an event separation time of 12 hours. The data collected during each FMP were analyzed and compared to the District's TY and other regional precipitation patterns. Details on each of the site-specific monitoring programs and data collected are provided in appendices as listed in **Table 3.2**. Data collected from these flow monitors and gauges were used to assess the individual GI projects or GI technology type performance, as discussed in **Section 3.3**.

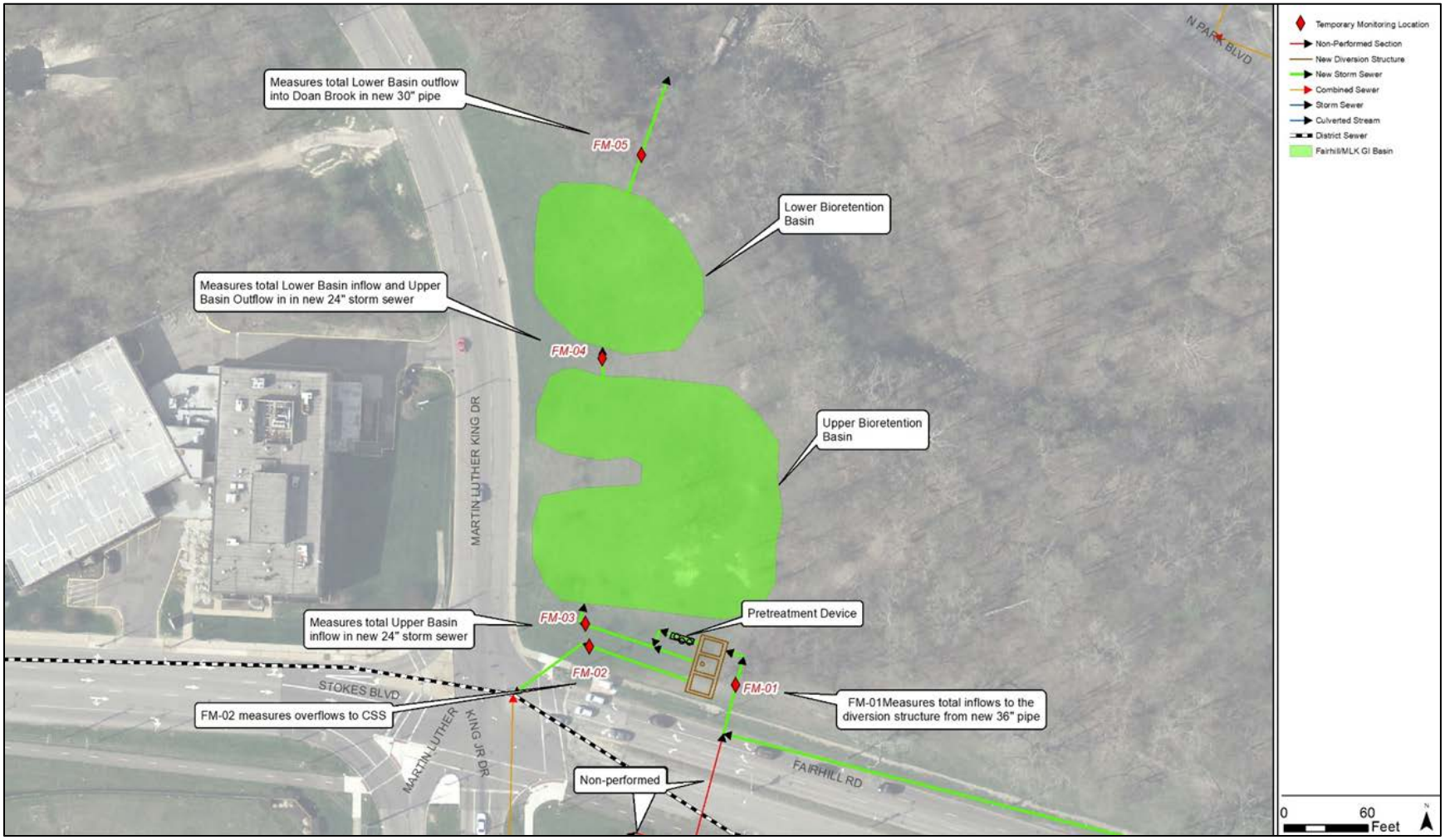
Table 3-2. GI PCMP Site-Specific Monitoring Reporting

Site-Specific Monitoring Program	Appendix	Data/ Reports Attached	Comments
E 140th Consolidation & Relief Sewer GI - dry detention basin	A1	• E 140th Consolidation and Relief Sewer GI PCMP Site-Specific Flow Monitoring Report, Wade Trim, December 14, 2020	Page basin only; overview of monitoring program and results.
Green Ambassador Fairhill/MLK GI - bioretention basin	A2	• Green Ambassador Fairhill/MLK GI PCMP Site-Specific Flow Monitoring Report, Wade Trim, August 17, 2018	Upper basin only; overview of monitoring program and results.
University Circle GI - permeable pavers/storm chamber/infiltration	A3	• Attachment 1 of NEORSD Semi-Annual Progress Report No. 7; Period from January 1, 2015 to June 30, 2015	Entire project review; overview of monitoring program and results.
Buckeye GI – detention basin	A4	• Union-Buckeye GI PCMP Site-Specific Flow Monitoring Report, Wade Trim, December 14, 2020	E 102nd basin only; overview of monitoring program and results.
Green Ambassador Slavic Village Demonstration GI - bioretention basin	A5	• GI monitoring,75th St, Slavic Village are of Cleveland OH: a report of provisional analyses, November 2016, USEPA • Slavic Village USGS Data Evaluation, Wade Trim, February 10, 2017	E 75th St North basin only; overview of monitoring program and results.
Fleet Ave GI - infiltration basin	A6	• Fleet Ave GI PCMP Site-Specific Flow Monitoring Report, Wade Trim, August 17, 2018	Entire project review; overview of monitoring program and results.
Green Ambassador Urban Agriculture GI - bioretention basin	A7	• Green Ambassador Urban Agriculture GI PCMP Site-Specific Flow Monitoring Report, Wade Trim, August 17, 2018	West basin including West entry feature only; overview of monitoring program and results.

Figure 3-2. E140CRS GI – Page Basin Monitoring Plan

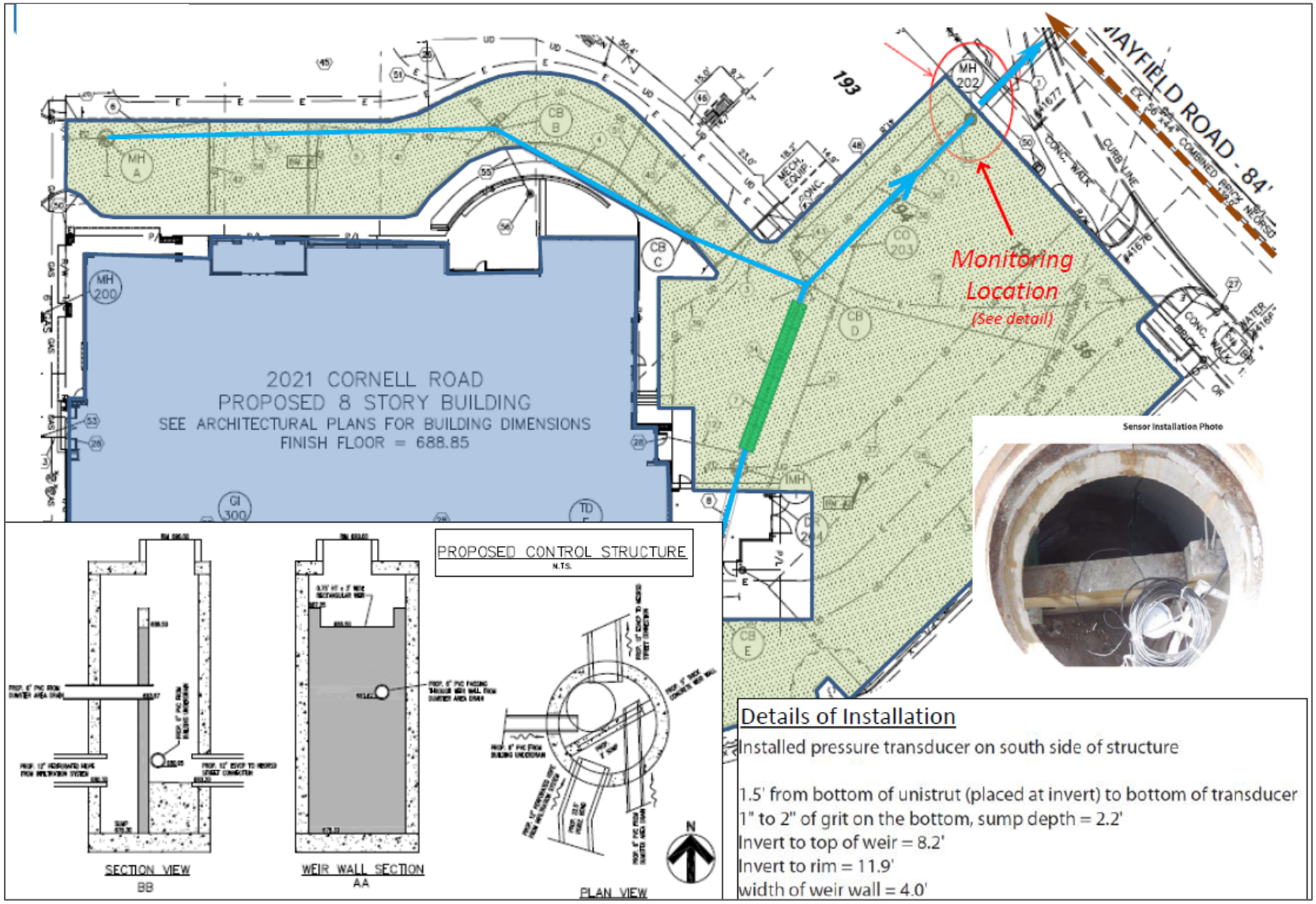
Source: E140CRS GI Site-Specific FMP

Figure 3-3. Green Ambassador Fairhill/MLK GI Monitoring Plan



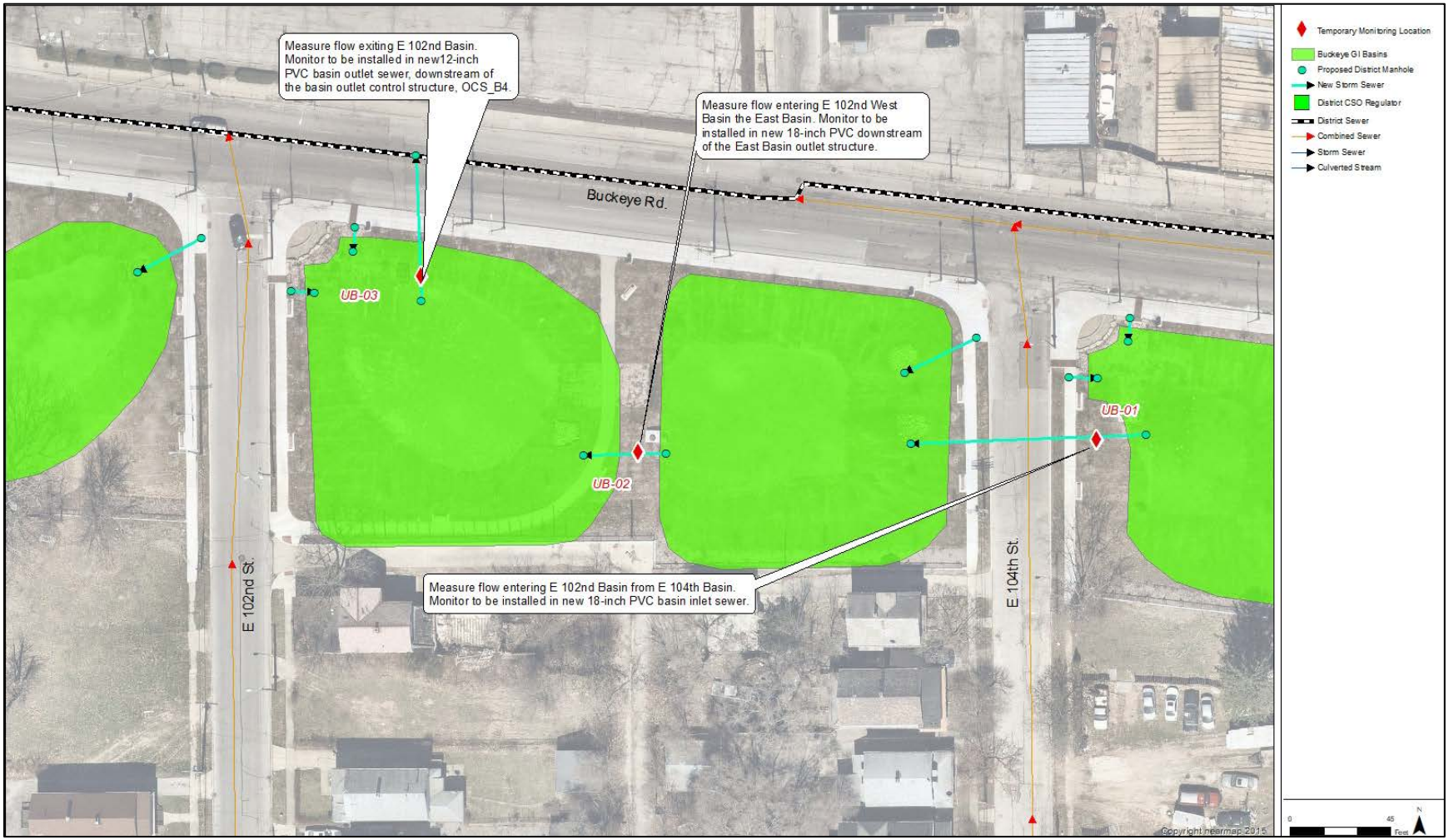
Source: Green Ambassador Fairhill/MLK GI Site-Specific FMP

Figure 3-4. University Circle GI Monitoring Plan



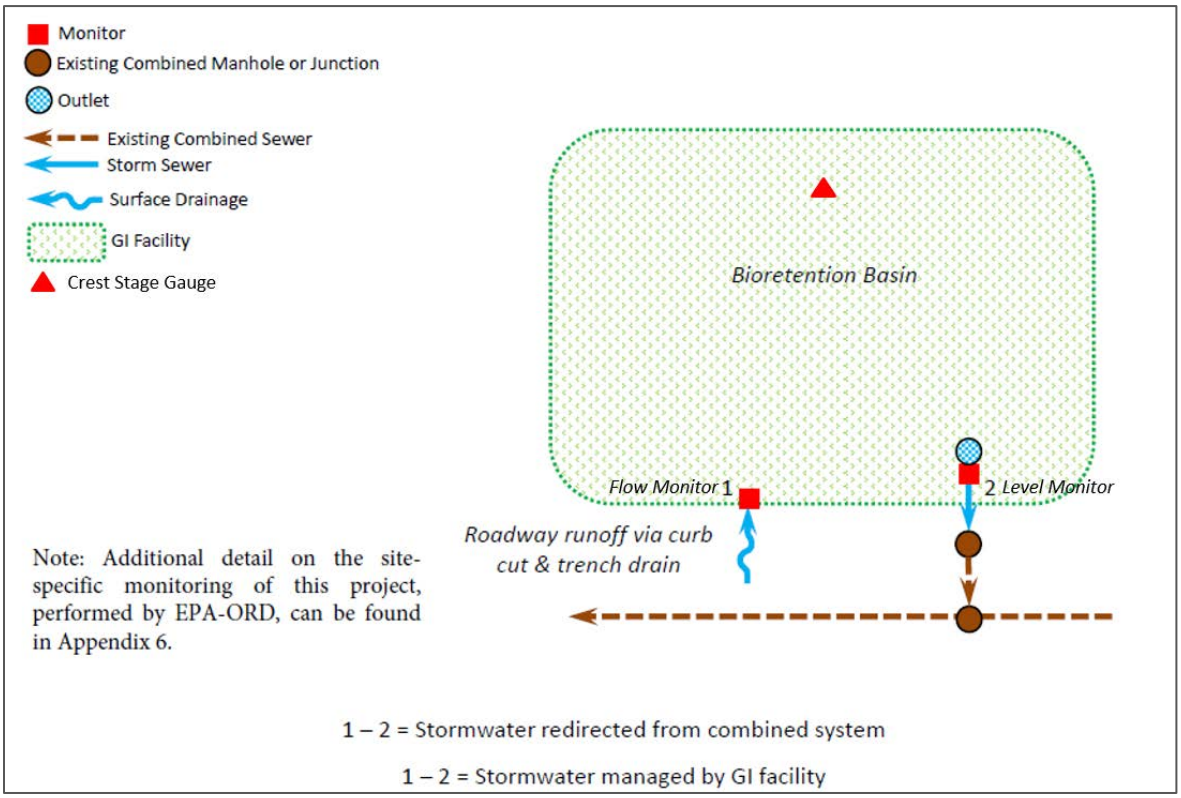
Source: Attachment 1 of NEORSD Semi-Annual Progress Report No. 7

Figure 3-5. Buckeye GI - E 102nd Basin Monitoring Plan



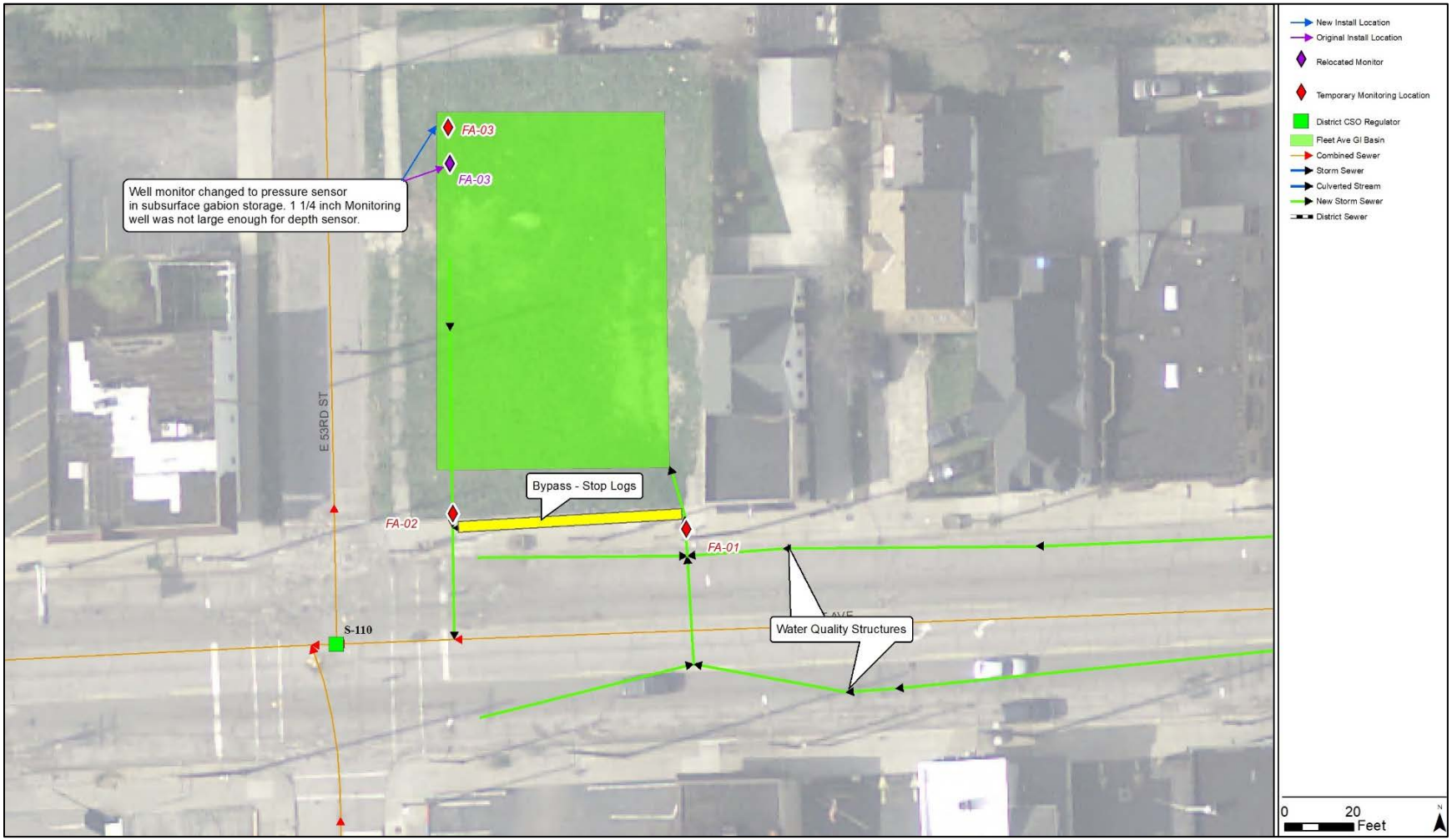
Source: Buckeye GI Site-Specific FMP

Figure 3-6. Green Ambassador Slavic Village Demonstration GI Monitoring Plan



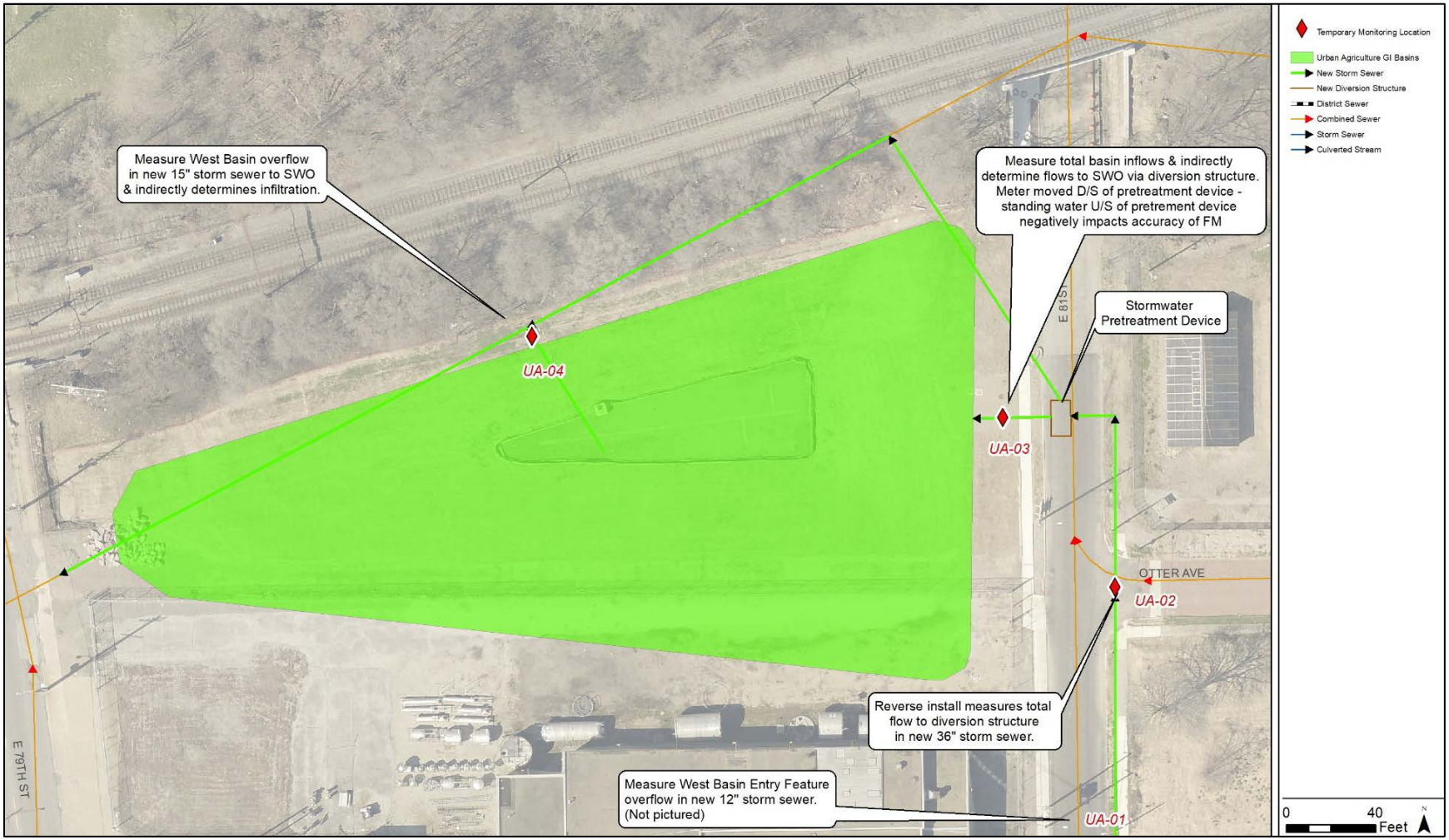
Source: GI monitoring,75th St, Slavic Village area of Cleveland OH Report

Figure 3-7. Fleet Ave GI Monitoring Plan



Source: Fleet Ave GI Site-Specific FMP

Figure 3-8. Green Ambassador Urban Agriculture GI – West Basin Monitoring Plan



Source: Green Ambassador Urban Agriculture GI Site-Specific FMP

3.3 Site-Specific GI PCMP Results

The core objective of site-specific monitoring was to assess the performance for the various GI technology types (i.e., bioretention, infiltration, etc.) that were built as part of the District's CD Appendix 3 GI program. The use of the site-specific data was two-fold. First, the monitoring data was analyzed and reported as previously mentioned in **Table 3-2** above. Secondly, the data was used to assess modeled representations of the individual GI projects.

The site-specific monitoring data provided information on the actual performance of the particular GI control type over a one-year period. Once the record drawings were made available from the GI project implementation, appropriate modifications were made to update sewer network changes to reflect the new improvements and facilities built as well as updates to the hydrologic catchments tributary to these new improvements. For example, the Fairhill/MLK GI project included storm sewer separation to remove stormwater runoff from the combined area. The model representation in the baseline model was updated to include the new stormwater network and removed the runoff from the tributary area from the previous combine system. The post construction monitoring data was then used to refine the hydraulic and hydrologic parameters and validate the model simulated performance of the system.

For projects where only one GI feature was monitored, results from same or similar GI technology type that were monitored under the various site-specific GI PCMPs were then extrapolated to develop an appropriate model representation for all the GI projects specified in the GI PCMP. These updated representations were incorporated into the District's master CD conditions models for the sewershed performance of the system with the GI controls in place as discussed in **Section 4.0**. Highlights of specific model updates and refinements are discussed in **Table 3-3** by GI project area.

The collected data from each PCMP was used to validate and update the modeled representation of the fully constructed GI facilities in the District's baseline (BL) and CD conditions models. Once the updates were completed, the revised models were prepped to be used to support the sewershed-specific analysis as specified in Appendix 3 of the CD as discussed further in **Section 5**.

Table 3-3. Appendix 3 GI Model Updates

Appendix 3 GI Project	CSO District	Downstream Permitted CSO	GI Technology Type	Model Update Highlights
E 140th Consolidation and Relief Sewer GI	Easterly	211/232	Detention	• Only one (Page Basin) of three basins installed was monitored • Due to proximity, similar pre-construction soil type, and similar GI design, updates to Page Basin replicated for Scioto Ave and 2nd Ave Basins • Model representation was updated to redirect tributary storm subcatchments and sewers to the GI basins • Infiltration rate developed for Page basin was also applied to Scioto Ave and 2nd Ave basins • Page Basin is tributary to CSO 232 rather than CSO 211 as originally specified in GI PCMP
Green Ambassador Fairhill-MLK GI	Easterly	073	Bioretention	• Overall facility monitored • Discharges for the upper and lower basins were adjusted based off collected flow monitoring data • Modeled representation of the basin underdrains for the upper and lower basins were modified to use head discharge curve to better address relationship between basin depth and basin outflow
University Circle GI	Easterly	224	Infiltration	• GI project resulted in de minimis reduction in CSO with respect to the accuracy of the model • Technology unique to only this GI project • Model representation limited to removal of subcatchment runoff tributary to UCGI project
Buckeye GI(1)	Easterly	073	Detention	• Only E 102nd St Basin monitored • Depression storage was used to simulate basin storage • Additional refinement assumed during large events that storm flow overpasses catch-basins and into downstream basins; based on upstream basins inlets had modified curb cuts with concrete aprons at catch-basins compared to downstream traditional catch-basin types; overall improved simulations • Head discharge relationship was applied to E 99th St basin outlet

Appendix 3 GI Project	CSO District	Downstream Permitted CSO	GI Technology Type	Model Update Highlights
Union Green GI[(1)]	Southerly	036	Detention	• Facility was not required to be monitored as part of site-specific work • Outlet fitted with flap gate which was unique to this project • Model representation was updated to redirect tributary storm subcatchments to the GI basin before flowing back to the combined system
Green Ambassador Slavic Village Demonstration GI	Southerly	036	Bioretention	• GI project resulted in de minimis reduction in CSO with respect to the accuracy of the model • Design characteristics unique to site • GI project was ultimately not represented in the model
Fleet Ave GI	Southerly	036	Infiltration	• Overall facility monitored • Infiltration coefficient was found to directly impact peak depth and flow routed back to combined system • Infiltration coefficient was increased from the design infiltration rate during validation efforts to better align with measured performance • Overall GI capture produces better results than initial design performance
Green Ambassador Urban Agriculture GI	Southerly	040	Bioretention	• Only West side of GI project monitored • Used pretreatment unit manufacturer's head discharge curves • Basin underdrain discharge were updated to use a head discharge curve similar to GAFM project to better address relationship between basin depth and basin outflow
Woodland Central GI	Southerly	040	Detention	• Facility was not required to be monitored as part of Site-Specific GI PCMP • Characteristics unique to site; including impervious liner, no storm baseflow, outlet conveyed to drop structure • Model representation was updated to redirect tributary storm subcatchments to the GI basins

4.0 GI PCMP Sewershed-Specific Monitoring Program

The GI PCMP outlined the elements for the sewershed-specific monitoring program to satisfy the Appendix 3, paragraph 6b requirement. The purpose of the sewershed-specific FMP was to collect monitoring data following the construction and start of operation of all GI projects identified in the District's GI PCMP. The monitoring data was used to evaluate the performance and effectiveness of the GI as simulated by the master models on a sewershed scale. Sewershed as defined by the GI PCMP is the drainage area of one or more regulator structures impacted by a GI project(s) and tributary to a single permitted CSO outfall. The sewershed-specific monitoring included the collection of flow monitoring data within the combined sewer system downstream of the GI implemented in the Easterly and Southerly CSO Districts. The results of the sewershed monitoring programs are summarized in this section.

4.1 Sewershed-Specific Program Status

The sewershed-specific monitoring was performed in two phases for a minimum of 12-months each due to the construction schedules of the E140CRS and Doan Valley Tunnel (DVT) projects. Phase 1 addressed the sewershed monitoring for the Southerly CSO District, whereas Phase 2 addressed the sewershed monitoring for the Easterly CSO District. Each phase began following the full implementation and operation of the GI associated with each CSO District. The Southerly GI PCMP sewershed-specific began on September 23, 2019, and the Easterly program began on August 5, 2020. **Table 4-1** presents status for both sewershed-specific FMPs completed to meet Appendix 3 requirements.

Table 4-1. Sewershed-Specific GI PCMPs Statuses

Sewershed-Specific Monitoring Program	CSO District	Start Date	Finish Date	Monitoring Period	Comments
Easterly District CSOs – CSOs 073, 211, 232, 242	Easterly	8/5/2020	8/4/2021	12 months	Addressed the E 140CRS GI, GAFM, UCGI and BGI projects
Southerly District CSOs – 036, 040	Southerly	9/23/2019	9/22/2020	12 months	Addressed the UGI, FGI, SVGI, GAUA, and WCGI projects

In particular, the Easterly sewershed-specific GI PCMP was planned to begin after completion of the gray infrastructure components of the CM 6 DST and E140CRS projects immediately downstream of the E 140CRS GI basins. The gray infrastructure components of these projects impact the performance of the collection system in conjunction with the GI projects in the Easterly District. Furthermore, because of delays to the gray components within CM 6, the GI post-construction monitoring was delayed. Although, this delay impacted the submission deadline date for the GI performance report by July 7, 2021, there was

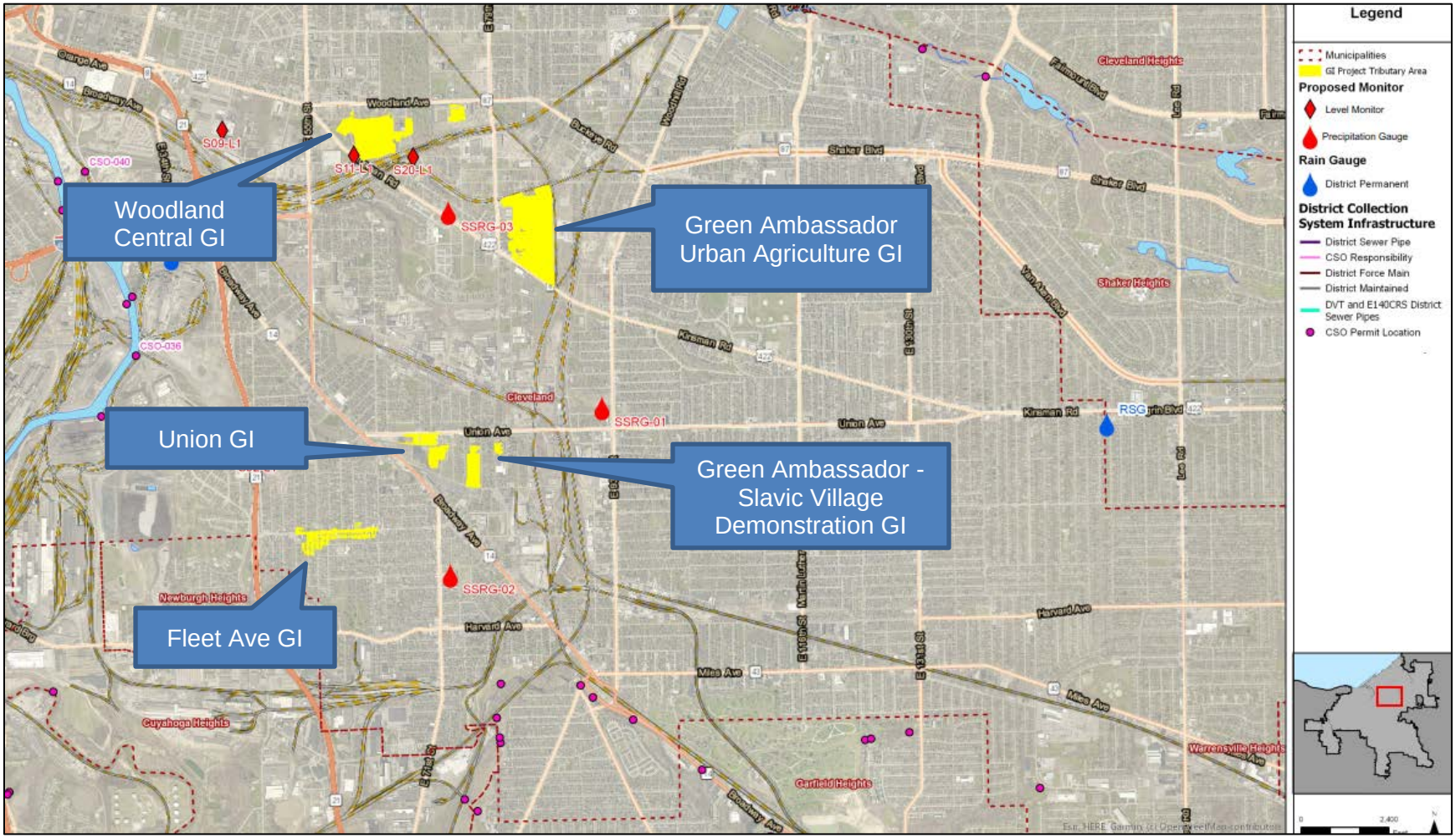
no delay to completion of infrastructure as originally planned and required. The District subsequently requested and received a non-material modification to Appendix 3 of the CD to extend the reporting deadline for the GI Performance Report from July 7, 2021 to January 3, 2022.

4.2 Monitoring and Data Collection

Sewershed-specific monitoring occurred at locations within the collection system downstream of where the flows were being removed and/or detained by the GI that best allowed for quantification of GI performance on a sewershed scale. Accessibility and safety were considered in siting the monitoring locations. In many cases the monitors were at or near CSO regulator structures directly impacted by upstream GI. These regulators relieve wet weather flows that exceed the capacity of combined sewer system by diverting excess flows to the environment at the NPDES-permitted CSO outfalls identified in **Table 4-1**. The CSOs in many cases have multiple tributary regulators, and where applicable, the monitoring equipment was positioned in and around these structures to adequately quantify the impact of upstream GI in terms of CSO control performance.

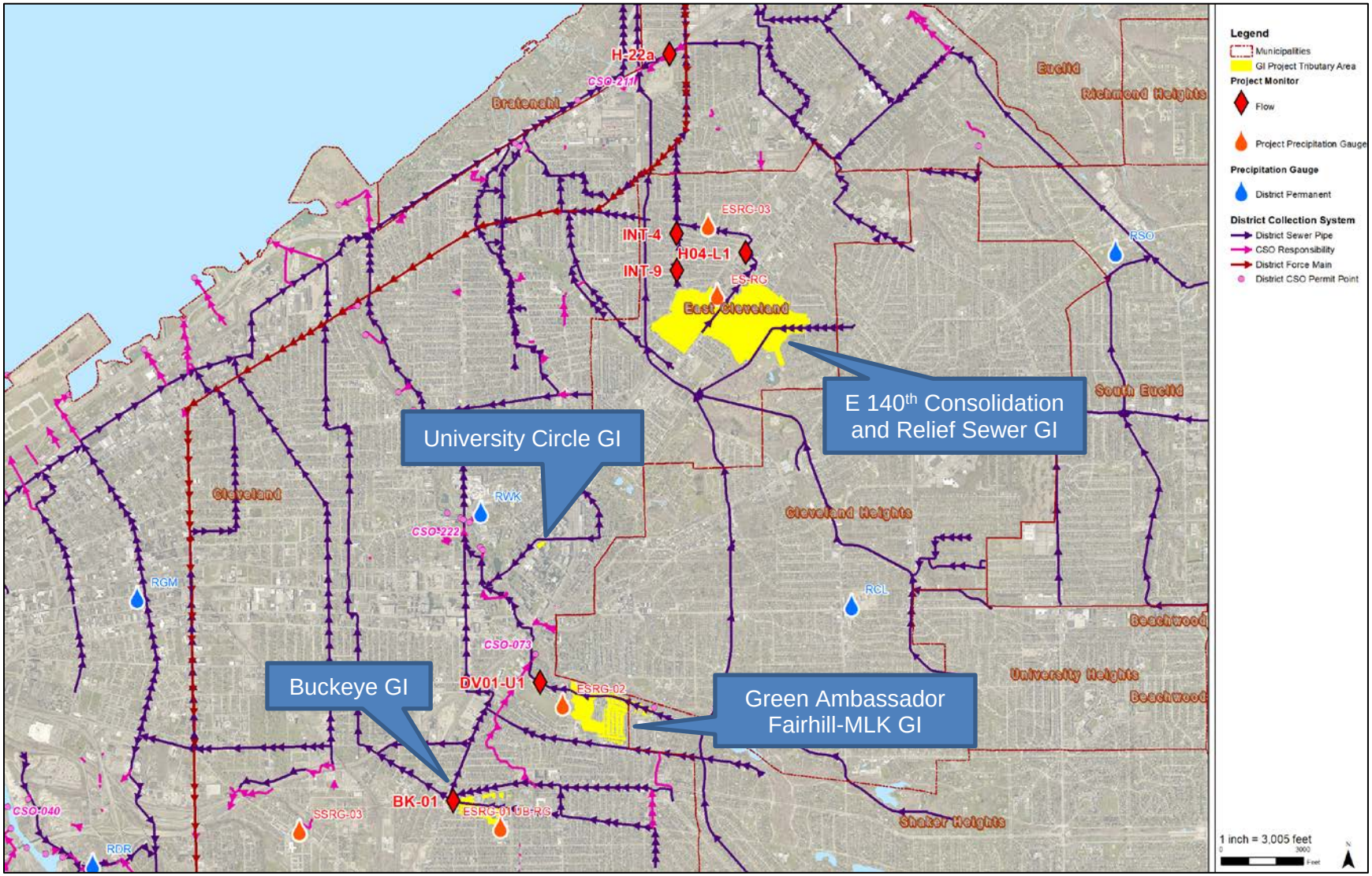
Flow monitoring and precipitation data were collected and analyzed in accordance with the District's flow monitoring standards and protocols as specified in the GI PCMP. During the course of the site-specific monitoring program, the District standards and protocols were refined and updated since the GI PCMP acceptance in July 2015 and used accordingly. Each FMP ran for a total of 12 months using a combination of flow monitors, level sensors, and precipitation gauges. For each site-specific location, the overall GI PCMP [ref. 3] specified the locations for monitors and precipitation gauges. The monitoring sites did not always coincide with the original sites included in the GI PCMP but were adjusted, as necessary based on the field observed hydraulic conditions, accessibility, and/or safety concerns. **Figures 4-1** and **4-2** shows the locations of the final sewershed-specific monitors relative to the GI projects themselves. Details on changes are presented in the individual sewershed-specific flow monitoring reports for Southerly and Easterly in **Appendix B-1** and **B-2**, respectively. Data collected from these monitors and gauges were used to assess the sewershed performance as discussed in **Section 5.0**.

Figure 4-1. Southerly GI PCMP Sewershed-Specific Overview



Source: Southerly GI Sewershed-Specific FMP

Figure 4-2. Easterly Sewershed-Specific GI PCMP Overview



Source: Easterly GI Sewershed-Specific FMP

4.3 Sewershed-Specific Monitoring

The main objective of sewershed-specific monitoring was to collect sufficient data with the specified Appendix 3 GI projects in place and operational to validate the District's master models as part of the overall model-based performance assessment of the system under TY conditions. The sewershed-specific monitoring data provided information on the actual performance at strategic points in each CSO District, downstream of the GI but upstream of the permitted CSO outfall points over a one-year period to capture seasonal variances.

At this point, the District's master baseline and CD conditions models have been updated to reflect existing conditions updates captured during the GI project designs and validated model representations for the constructed GI projects, resulting from the GI PCMP site-specific effort discussed in **Section 3.0**. Specific details on the Southerly and Easterly sewershed-specific GI PCMPs are discussed below.

4.3.1 Southerly Sewershed-Specific Monitoring

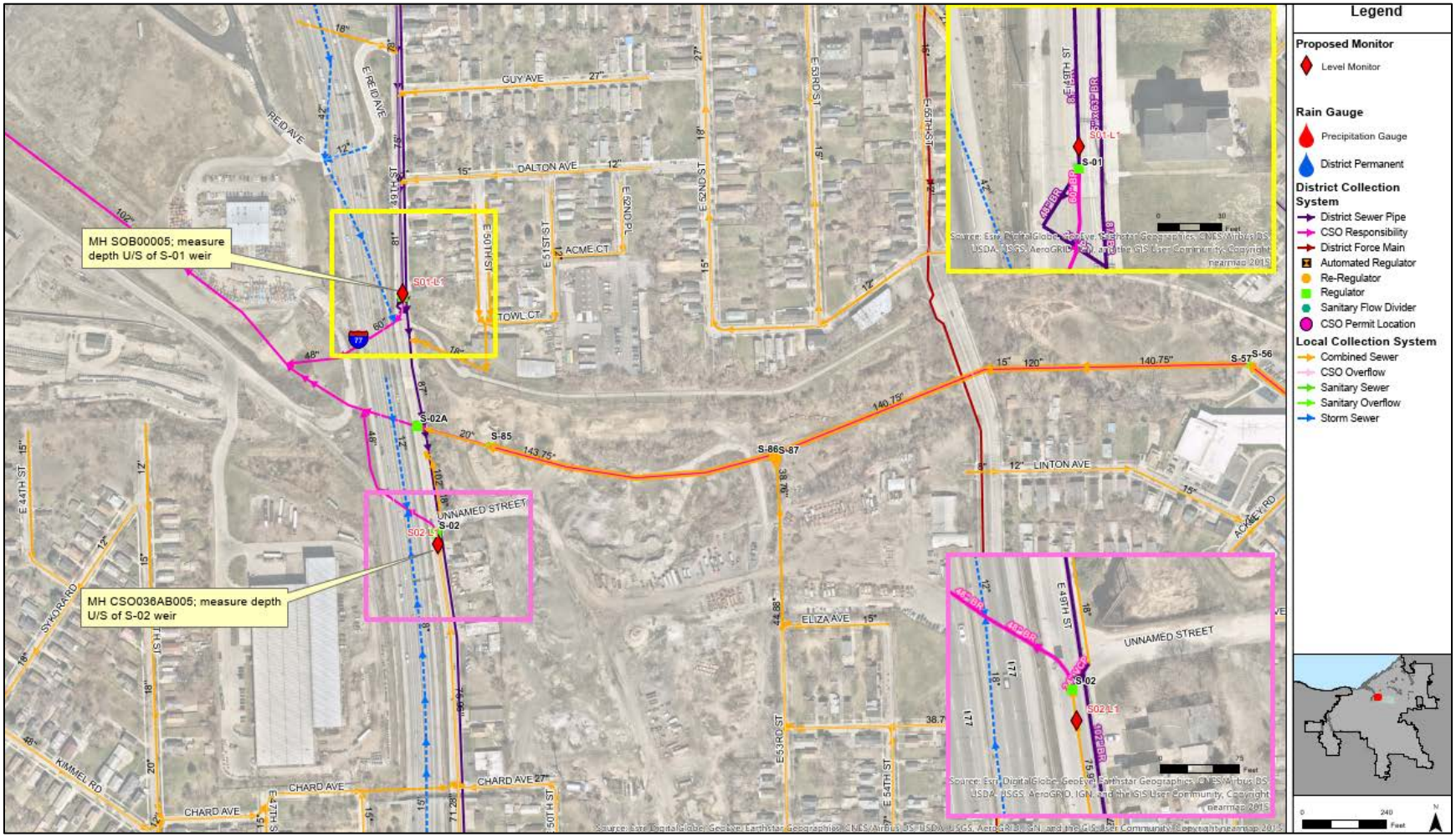
The Southerly sewershed-specific FMP consisted of five (5) level sensors. **Table 4-2** provides a summary of all the monitors installed, identifies the monitor type and the purpose of each monitor which includes structure, targeted CSO outfall, and associated upstream GI project. **Figures 4-3** through **4-6** provide zoomed-in views of each monitored location.

Table 4-2. Southerly Sewershed-Specific Monitors

Monitor ID	Monitor Type	Structure	Targeted CSO	Upstream GI CM
S01-L1	Level Sensor	Manhole u/s of regulator S-01	036	SVGI
S02-L1	Level Sensor	Regulator S-02	036	FGI
S09-L1	Level Sensor	Regulator S-09	040	WCGI
S11-L1	Level Sensor	Manhole u/s of regulator S-11	040	WCGI
S20-L1	Level Sensor	Manhole u/s of regulator S-20	040	GAUA

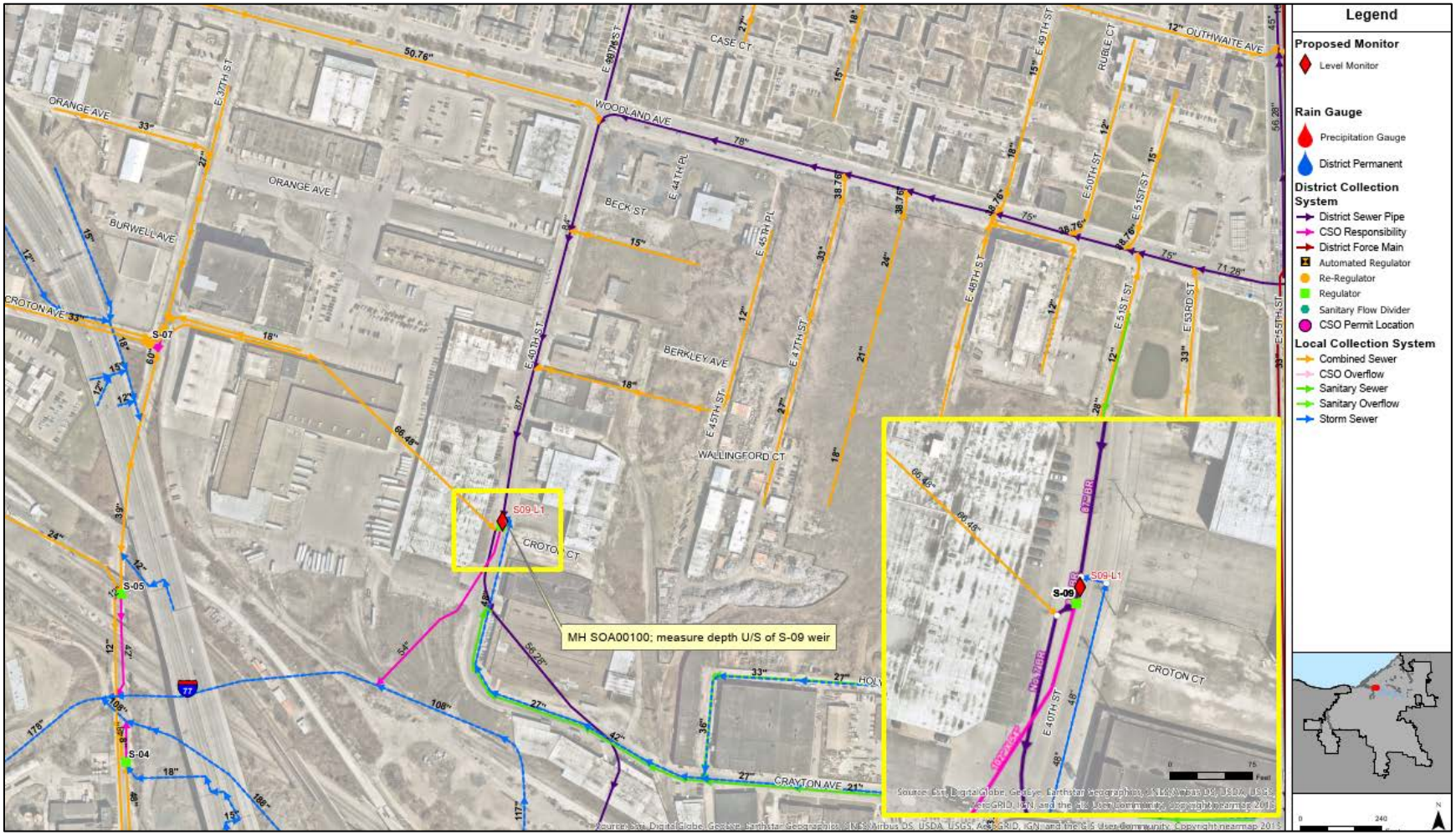
A total of 133 events were recorded by the precipitation gauges and were defined, using the EPA SSOAP Toolbox software, by the 12-hour inter-event duration. Forty-Two (42) of the events were considered snowfall/snowmelt events, according to the National Climatic Data Center's (NCDC) Cleveland-Hopkins International Airport climate station. Further details on the program can be found in the Southerly sewershed-specific monitoring report in **Appendix B-1**.

Figure 4-3. CSO 036 Sewershed-Specific Monitoring at S-01 and S-02



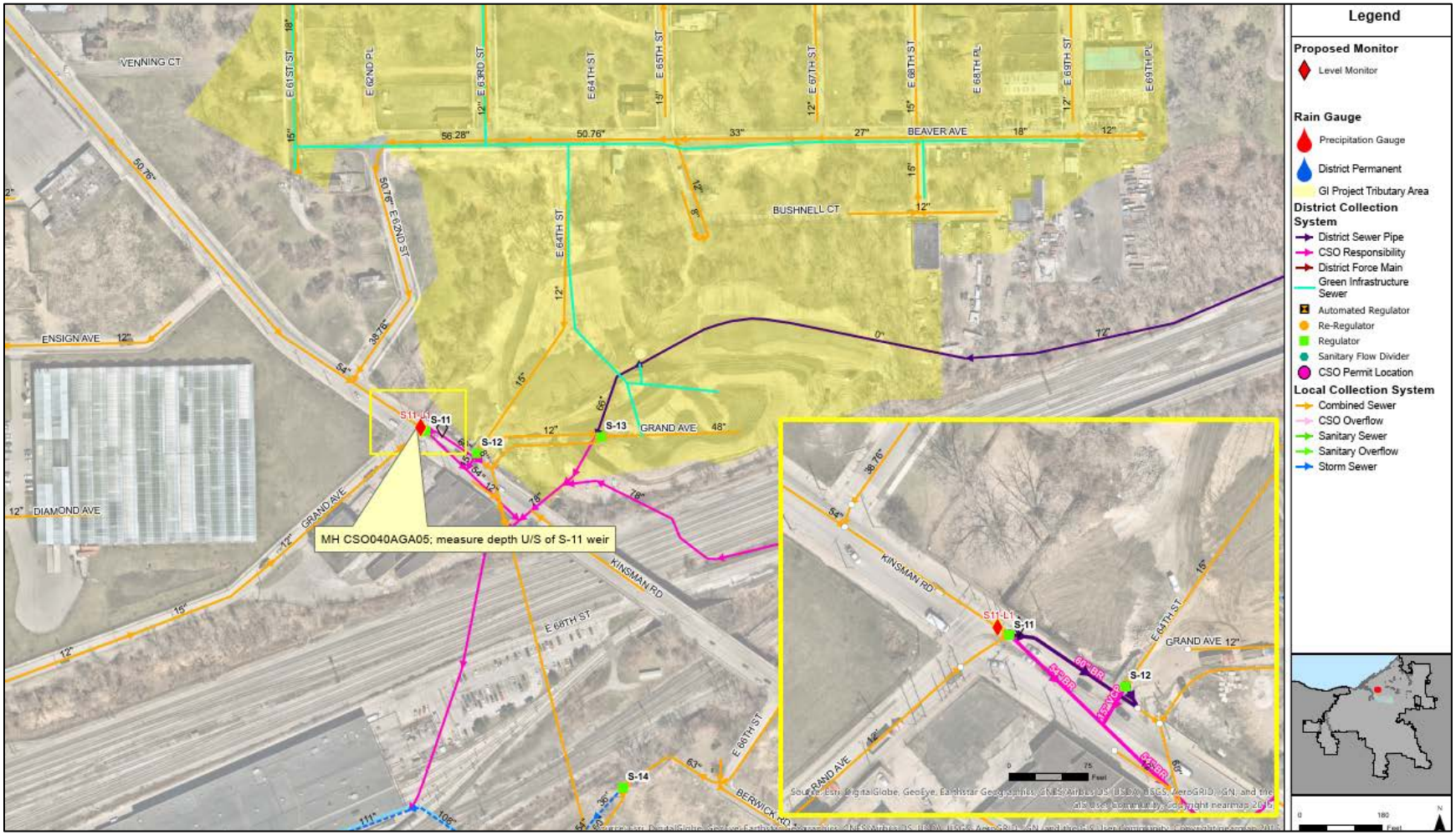
Source: Southerly GI Sewershed-Specific FMP

Figure 4-4. CSO 040 Sewershed-Specific Monitoring at S-09



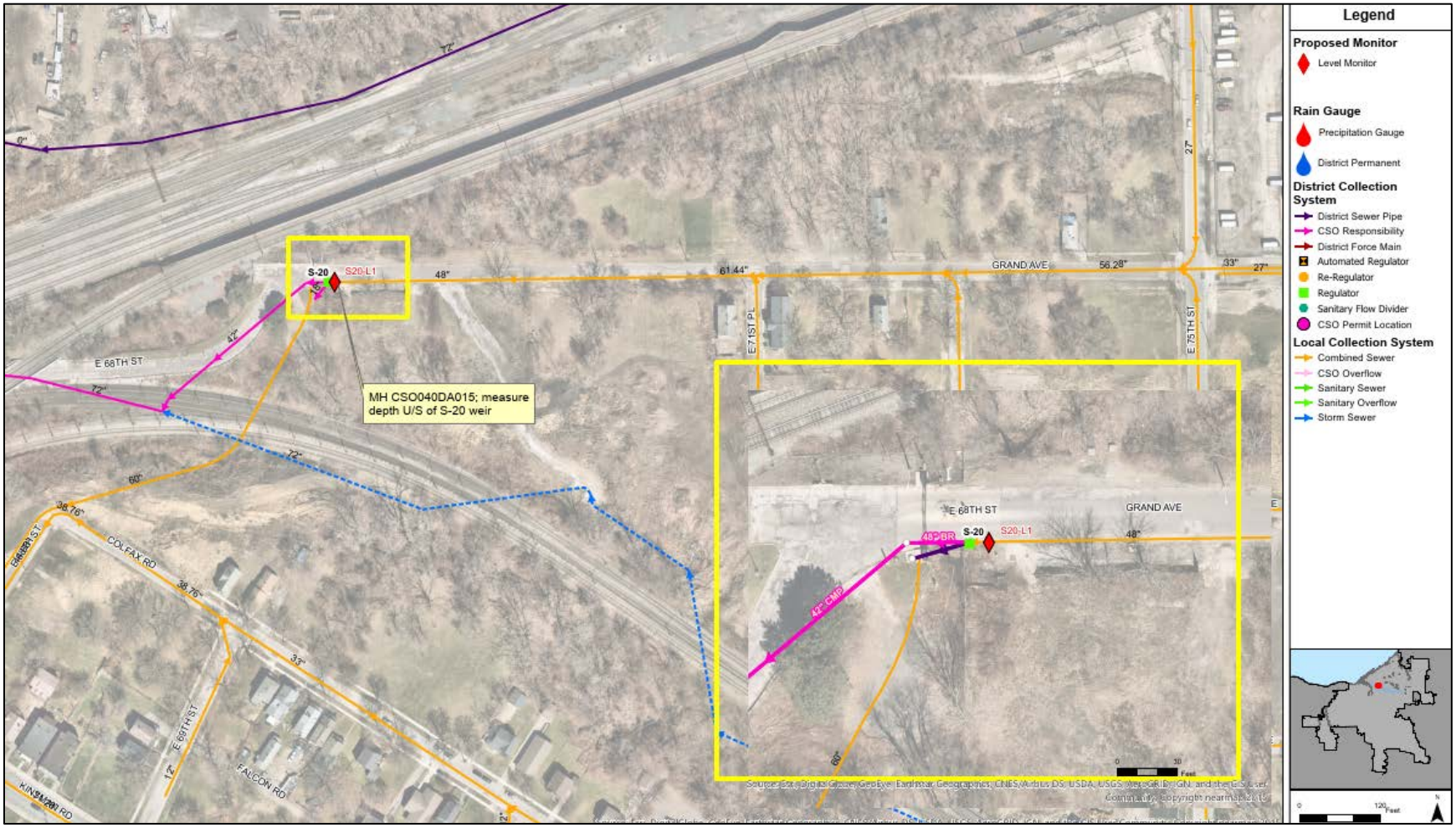
Source: Southerly GI Sewershed-Specific FMP

Figure 4-5. CSO 040 Sewershed-Specific Monitoring at S-11



Source: Southerly GI Sewershed-Specific FMP

Figure 4-6. CSO 040 Sewershed-Specific Monitoring at S-20



Source: Southerly GI Sewershed-Specific FMP

4.3.2 Easterly GI PCMP Sewershed-Specific Results

The Easterly sewershed-specific FMP consisted of four (4) flow monitors and two (2) level sensors. **Table 4-3** provides a summary of all the monitors installed, identifies the monitor type and the purpose of each monitor which includes structure, targeted CSO outfall, and associated upstream GI project. **Figures 4-7** through **4-10** provide zoomed-in views of each monitored location.

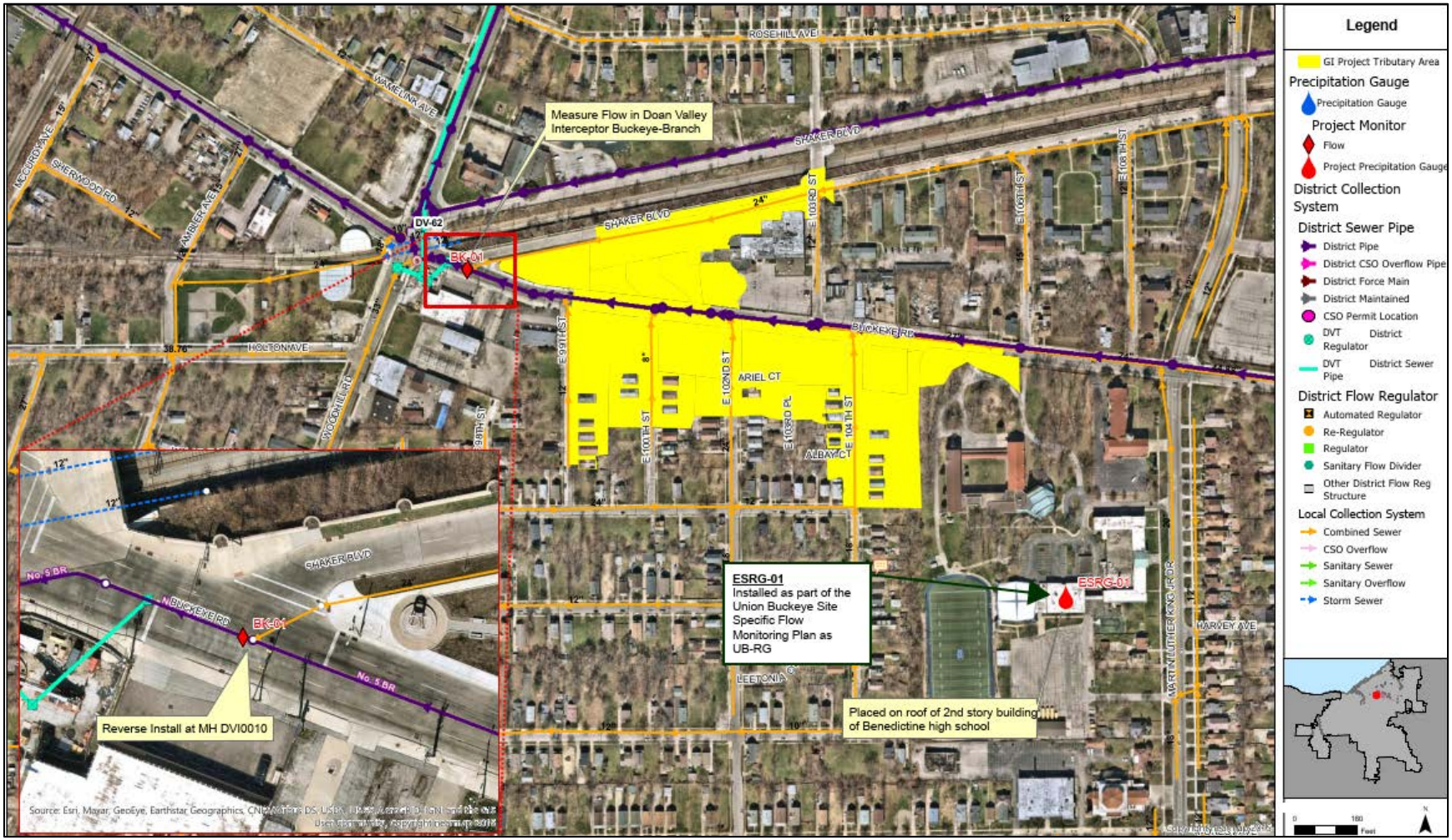
The Easterly sewershed-specific FMP started later than the Southerly FMP as some of Easterly GI projects were upstream and tributary to gray infrastructure components of the E140CRS and DVT projects that were in an active phase of construction. The E140CRS gray components were not fully operational until September 2020. The DVT was substantially completed and operational, but construction activities were still being performed within new regulators at the time of the FMP, and therefore limited potential monitoring locations for this sewershed-specific effort. Beginning the Easterly sewershed-specific GI PCMP following the completion of these gray infrastructure construction phase provided a more accurate assessment of overall performance of the GI project with gray infrastructure in place. Flow monitors were installed on District interceptors downstream of associated GI projects as an alternative approach for validating modeled GI performance.

Table 4-3. Easterly Sewershed-Specific GI PCMP Monitors

Monitor ID	Monitor Type	Structure	Targeted CSO	Upstream GI Project
BK-01	Flow Monitor	Manhole d/s of GI project	073	BGI
DV01-U1	Flow Monitor	Manhole u/s of regulator DV-01	073	GAFM
H04-L1	Level Sensor	Regulator H04-L1	211	E140CRS GI
INT-4	Flow Monitor	Manhole previously monitored supporting calibration	232	E140CRS GI
INT-9	Flow Monitor	Manhole previously monitored supporting calibration	211	E140CRS GI
H22A-L1	Level Sensor	Regulator H-22A	211	E140CRS GI

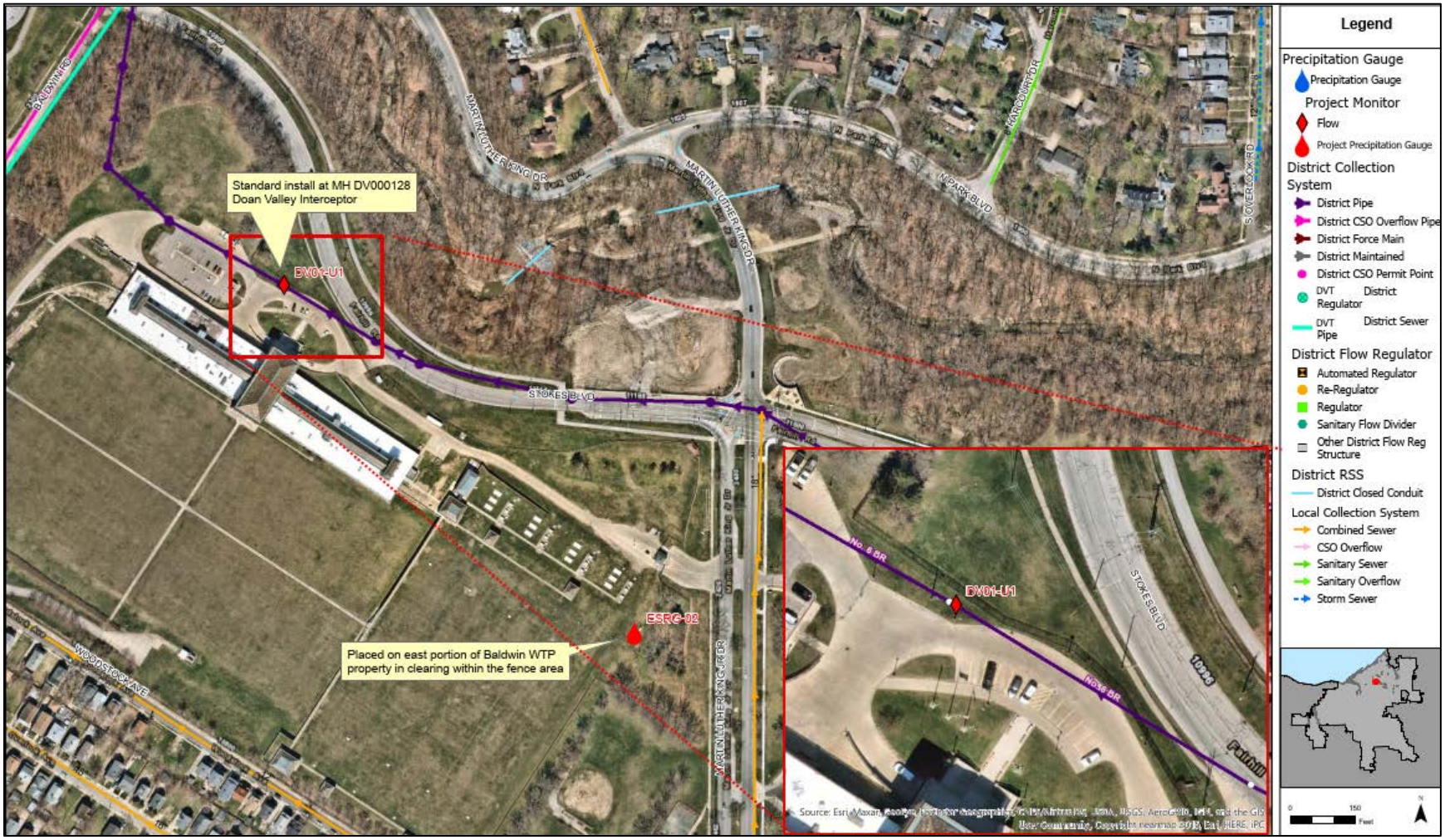
A total of 138 events were recorded by the precipitation gauges and were defined, using the EPA SSOAP Toolbox software, by the 12-hr inter-event duration. Fifty (50) of the events were considered snowfall/snowmelt events, according to the National Climatic Data Center's (NCDC) Cleveland-Hopkins International Airport climate station. Further details on the program can be found in the Easterly sewershed-specific monitoring report in **Appendix B-2**.

Figure 4-7. CSO 073 Sewershed-Specific Monitoring at BK-01



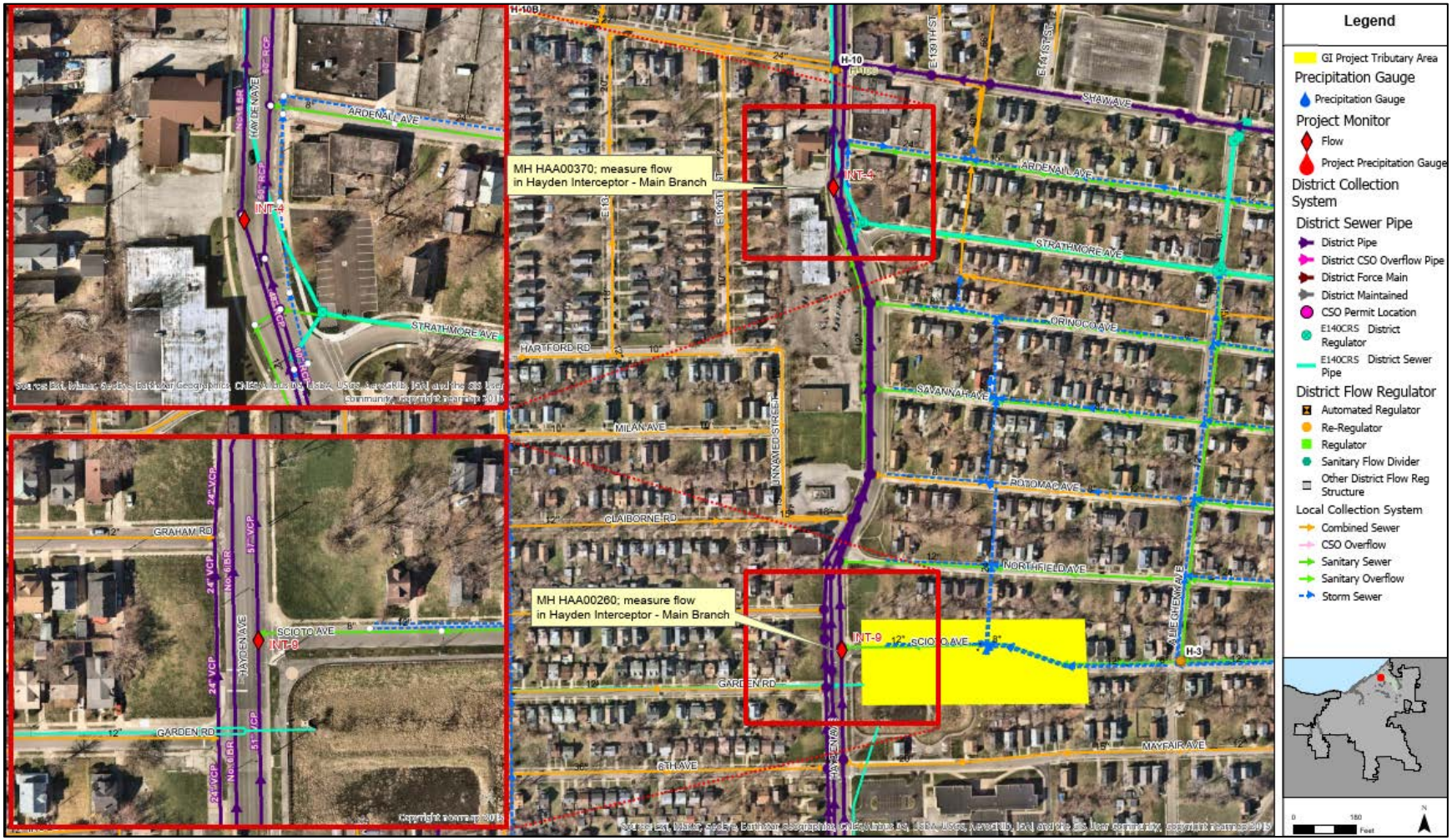
Source: Easterly GI Sewershed-Specific FMP

Figure 4-8. CSO 073 Sewershed-Specific Monitoring at DV01-U1



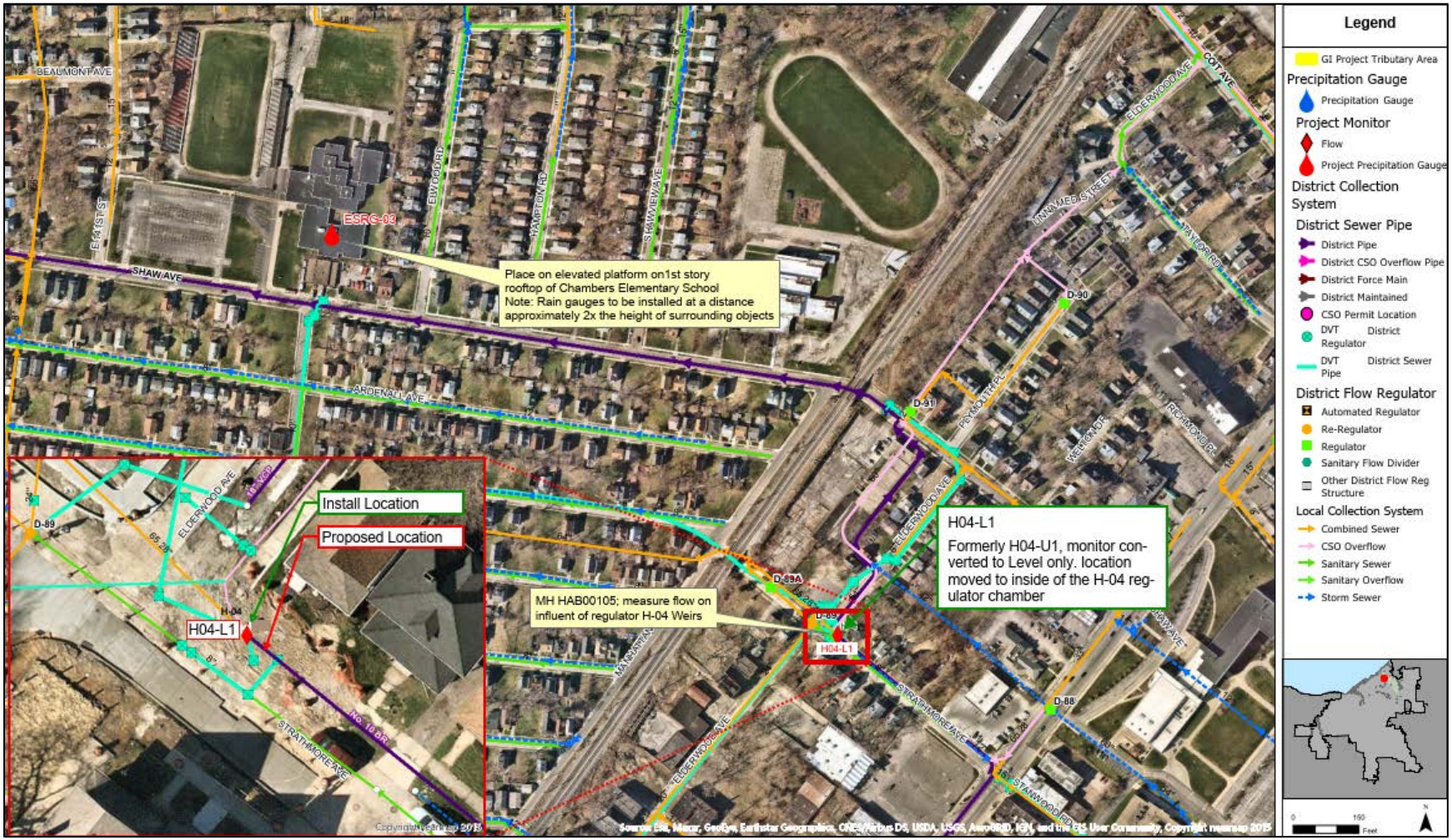
Source: Easterly GI Sewershed-Specific FMP

Figure 4-9. CSO 211 and 232 Sewershed-Specific Monitoring at INT-4 and INT-9



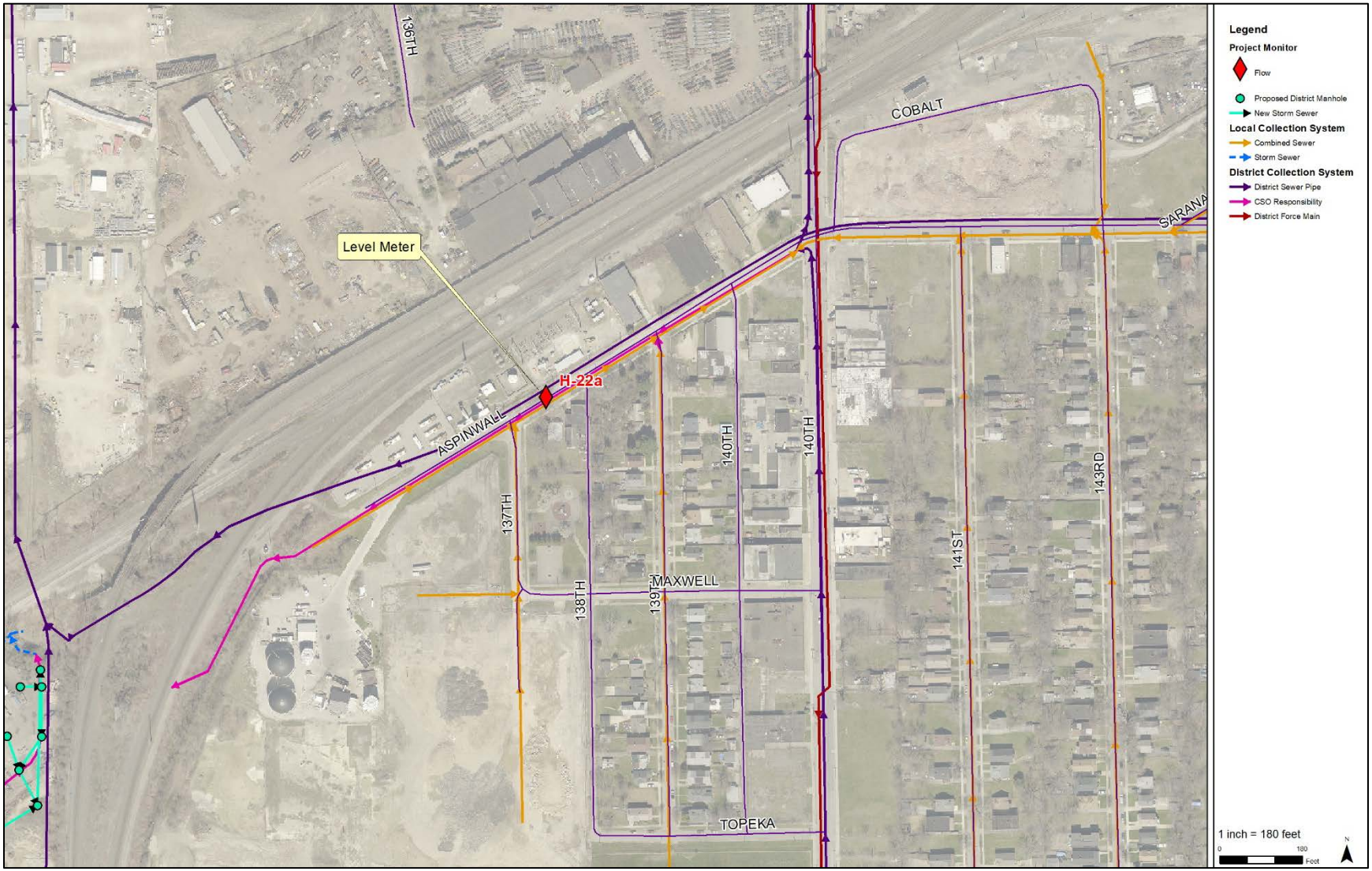
Source: Easterly GI Sewershed-Specific FMP

Figure 4-10. CSO 211 Sewershed-Specific Monitoring at H04-L1



Source: Easterly GI Sewershed-Specific FMP

Figure 4-11. CSO 211 Sewershed-Specific Monitoring at H22A-L1



5.0 Performance Assessment

In accordance with Appendix 2 of the District's CD, a model-based approach was followed to demonstrate the targeted CSO performance of reducing at least 44 MG in CSO volume in the TY above that required of the Appendix 1 gray infrastructure controls. Appendix 3 requires GI project construction completion by July 7, 2019, and demonstration of effectiveness as documented by this assessment report by January 3, 2022.

5.1 Model-Based Approach to GI CSO Volume Reduction

The model-based approach included the following steps:

1. Evaluate master model performance using the data collected from the Sewershed-Specific programs discussed in **Section 4.0** to validate model;
2. Update model and calibration, as necessary; and
3. Conduct performance evaluation based on TY simulations to demonstrate CSO reduction achieved through implementation of GI.

5.1.1 Performance Evaluation Based on Monitoring Data

Data collected during the GI PCMP sewershed-specific FMP were used to validate the CSO performance of the District's Easterly and Southerly master baseline conditions models. These models represent current conditions of the collection system which includes Appendix 1: gray infrastructure constructed prior to and during PCMP and the constructed Appendix 3 GI projects. The master baseline conditions models used to support the model validation were the ESBG202105MM and SOBG201910MM models. The model and simulation results presented herein were generated using the Innovyze InfoWorks ICM modeling software based on a continuous simulation of the sewershed-specific PCMP FMP recorded precipitation.

Precipitation data recorded during the sewershed-specific FMPs were used to ground truth the radar reflectivity data. The Gauge Adjusted Radar Rainfall (GARR) data was developed in 1 km^2 grids by Vieux & Associates to account for the spatial distribution of precipitation over the sewershed areas during the FMP periods. The GARR data was simulated in the collection system models to generate model predicted CSO performance and compared to monitored performance as part of the model validation effort.

Monitored CSO performance was calculated using the level data collected at the 11 monitors installed during the sewershed-specific FMPs. Validation consisted in comparing the monitored system

performance based on the collected data to the model-predicted performance. **Table 5-1** provides a summary of the 11 monitored locations and purpose in the validation effort. Six (6) monitors were installed in CSO regulators to measure and compare overflow performance between monitor and model. Five (5) monitors were installed on District interceptors downstream of associated GI projects as alternative locations for monitoring to support validating modeled GI performance due to ongoing construction activities associated with the E140CRS and DVT projects.

Table 5-1. Southerly and Easterly Sewershed-Specific Monitors Use to Support Model Validation

Monitor ID	Monitor Type	Targeted CSO	Upstream GI Project	Purpose
S01-L1(1)	Level Sensor	036	SVGI	Installed at regulator S-01 to monitor CSO performance
S02-L1	Level Sensor	036	FGI	Installed at regulator S-02 to monitor CSO performance
S09-L1(1)	Level Sensor	040	WCGI	Installed at regulator S-09 to monitor CSO performance
S11-L1(1)	Level Sensor	040	WCGI	Installed at of regulator S-11 to monitor CSO performance
S20-L1(1)	Level Sensor	040	GAUA	Installed at regulator S-20 to monitor CSO performance
BK-01(2)	Flow Monitor	073	BGI	Installed in previous calibration location downstream of GI project
DV01-U1(2)	Flow Monitor	073	GAFM	Installed in previous calibration location downstream of GI project
H04-L1(3)	Level Sensor	211	E140CRS GI	Installed at flow divider H-04 to monitor system performance at previous calibration location
INT-4(3)	Flow Monitor	232	E140CRS GI	Installed in previous calibration location downstream of GI project
INT-9(3)	Flow Monitor	211	E140CRS GI	Installed in previous calibration location downstream of GI project
H22A-L1(4)	Level Sensor	211	E140CRS GI	Installed at regulator H-22A to monitor CSO performance

1. *Monitoring in CSO regulator was not possible due to accessibility/safety concerns and/or poor hydraulic conditions for collecting quality data.*
2. *Monitoring at CSO regulator was not possible due to ongoing construction activities related to DVT project.*
3. *Monitoring at CSO regulator was not possible due to ongoing construction activities related to E140CRS project.*
4. *Data collected at H-22A was obtained from District-owned eDMR monitoring equipment.*

Table 5-2 summarizes the number of overflows predicted by the monitoring data and model at the six regulators that were monitored during the 12-month monitoring periods. The model showed close agreement with the monitored CSO performance in terms of overflow volume, peak flow rate, and duration for all overflows. Nearly all field observed activations were replicated in the model. **Appendix**

C provides a more detailed discussion of the model validation based on the collected sewershed-specific monitoring data.

Table 5-2. CSO Activations Predicted by Monitoring and Model at CSO Regulators

Monitored Locations	CSO Activations	
	Monitoring Data	Model
S01-L1	22	22
S02-L1	12	12
S09-L1	10	10
S11-L1	17	16
S20-L1	27	26
H22A-L1	7	11

5.1.2 Model Updates/Calibration

Model validation was completed in accordance with the District's Standards and Protocols for Hydrologic and Hydraulic Modeling of Combined Sewer Systems [ref. 5]. Initial assessment of the model performance based on the PCMP monitoring data indicated that adjustments were needed for the model representations of regulators that were monitored. Hydraulic refinements were made to update the regulator representation to improve the correlation with the observed data collected as part of the sewershed-specific FMPs.

The model simulation of the post construction monitoring period showed model-predicted activations were not less than the monitored CSO activations.

5.1.3 Performance Evaluation Based on TY Simulations

The final step in the model-based approach was to quantify the reduction in CSO volume above the required Appendix 1 gray infrastructure control measures attributed to implementing the GI. Refinements to the regulator representations developed during model validation were incorporated into the District's CD conditions master models which represent the full build-out of the Appendix 1 gray infrastructure Control Measures projected to be completed in 2035. CSO performance attributed to the GI was evaluated by developing two model scenarios of the District's 2035 CD conditions in which GI project representations were either removed/absent (Gray Only) or included per the full Appendix 1 and Appendix 3 GI planned condition (Gray + GI). CSO reduction achieved by GI was quantified as the difference in the system wide CSO volume estimated between the Gray Only and Gray+GI scenarios.

The master CD conditions models used to support the TY performance were the ESCG202105MM-20210907 and SOCG202108MM models. The model and simulation results presented herein were generated using the Innovyze InfoWorks ICM modeling software based on a continuous simulation of the District's TY.

Based on this approach, the overall reduction in CSO volume achieved through the implementation of the Appendix 3 GI projects is expected to be 8.6 MG in a TY above what is achieved by the Appendix 1 gray infrastructure. Overall, this reduction in CSO volume is less than the estimated volumes (15.8 MG) based on the individual site-by-site design efforts previously provided to EPA. **Table 5-3** provides a breakdown of CSO volume reduction per individual Appendix 3 GI project in the TY. **Table 5-4** shows the total District-wide CSO volumes with and without the GI projects included. A full breakdown of CSO volumes per individual permitted outfall for the Gray Only and Gray +GI scenarios can be found in **Appendix D**.

Table 5-3. Appendix 3 GI Projects CSO Reduction in the TY

Appendix 3 GI Project	Tributary CSO	CSO Reduction in TY (MG)
E 140th Consolidation and Relief Sewer GI	CSO 211 and 232	0
Green Ambassador Fairhill-MLK GI	CSO 073	1.6
University Circle GI	CSO 224	0.2
Buckeye GI	CSO 073	0.7
Union GI	CSO 036	0.1
Green Ambassador Slavic Village Demonstration GI	CSO 036	0
Fleet Ave GI	CSO 036	0.5
Green Ambassador Urban Agriculture GI	CSO 040	2.4
Woodland Central GI	CSO 040	3.1
	GI Reduction Total	8.6

Table 5-4. District Wide CSO Volumes

Model Scenario	CSO Volume (MG)						
	Easterly	Southerly	Big Creek	Mill Creek	Westerly	Total	Difference
Gray Only	93.2	70.9	61.8	21.78	23.7	271.4	-
Gray+GI	90.7	64.8	61.8	21.8	23.7	262.8	8.6

A few of the GI projects (E140CRS GI and GASV GI) show no CSO benefit in the TY. This is due to the higher level of control being achieved from the Appendix 1 gray infrastructure as a result of the planning level conservatism applied to the Description and Design Criteria as well as the District's goal to maximize CSO control through design. Due to this, the CSO reduction benefits from upstream Appendix 3 GI is less than originally estimated or in some cases does not correlate to CSO reduction above what is provided by the Appendix 1 gray infrastructure.

An example of this is the E140CRS GI project which is located in the upstream tributary area of CM-06: ECT/DST system. The project was estimated, based on final design and the most up to date hydraulic model at the time, to provide 5.8 MG in a TY of additional CSO reduction above that provided by the required gray infrastructure per Appendix 1. After subsequent flow monitoring and hydraulic modeling system evaluation, a majority of the associated CM-06 CSOs are demonstrated to be fully controlled in the TY (zero (0) activations) due to the CM-06 improvements alone. As a result, no additional CSO reduction can be achieved by upstream GI such as E140CRS GI.

The ECT/DST system provides 120.8 MG of effective storage volume for CSO control. The largest TY storm results in 65.5 MG of CSO volume allowing the TY to be fully controlled. Removing the E140CRS GI in the Gray Only scenario results in 69.7 MG of CSO volume in the ECT/DST system and no CSO activations (zero volume) in a TY. While the E140CRS GI frees up volume in the ECT/DST system (i.e., 4.2 MG), as designed it does not result in any additional CSO reduction in the TY above what is provided by the required gray infrastructure because the tunnel system is larger than what is necessary to control all TY storms. Additionally, system flows were found to be less than at the time of the CD negotiations through more accurate flow monitoring and model updates.

While not making a significant reduction in CSO in the TY, the District's Appendix 3 GI projects do provide significant community and environmental benefits beyond CSO control and are able to provide increased CSO control in larger storm events including an additional 6.4 MG in the 5-year, 6-hour event. **Tables 5-5** shows the estimated additional CSO control above that provided by the required Appendix 1 gray infrastructure in the 5-year, 6-hour design event.

Table 5-5. Appendix 3 GI CSO Reduction in 5-Year, 6-Hour Design Event

Appendix 3 GI Project	Tributary CSO	CSO Reduction in 5-yr, 6-hr Storm (MG)
E 140th Consolidation and Relief Sewer GI	CSO 211 and 232	0.8
Green Ambassador Fairhill-MLK GI	CSO 073	1.2
University Circle GI	CSO 224	0.1
Buckeye GI	CSO 073	0.6
Union GI	CSO 036	0.1
Green Ambassador Slavic Village Demonstration GI	CSO 036	0
Fleet Ave GI	CSO 036	0.3
Green Ambassador Urban Agriculture GI	CSO 040	1.4
Woodland Central GI	CSO 040	1.9
	GI Reduction Total	6.4

5.2 GI Design and Construction Cost Documentation

As part of Appendix 3 a minimum expenditure of $42 M for the design and construction of the GI projects is required. As illustrated in **Table 5-6**, the collective design and construction cost of the nine (9) GI projects was approximately $53 M (2011$$). Actual project cost documentation is provided in **Appendix E**.

Table 5-6. Summary of Appendix 3 GI Design and Construction Costs

Appendix 3 GI Project	Actual Costs		Costs in 2011$$(1)	
	Design Costs	Construction Costs	Design Costs	Construction Costs
E 140th Consolidation and Relief Sewer GI	$3,847,319.82	$21,324,839.83	$3,297,630.41	$17,302,684.67
Green Ambassador Fairhill/MLK GI	$958,917.40	$5,548,956.36	$808,428.27	$4,678,122.61
University Circle GI	$78,296.32	$190,597.04	$74,259.87	$190,607.75
Union GI & Buckeye GI	$2,103,312.52	$5,120,437.58	$1,736,006.52	$4,282,718.49
Green Ambassador Slavic Village Demonstration GI	$20,590.59	$176,393.12	$18,661.12	$159,249.54
Fleet Ave GI	$24,137.29	$1,809,726.22	$23,675.73	$1,544,785.75
Green Ambassador Urban Agriculture GI	$688,440.20	$5,536,180.83	$558,633.85	$4,670,550.77
Woodland Central GI	$2,908,095.70	$13,301,868.89	$2,419,009.88	$11,218,229.17
Totals	$10,629,109.84	$53,008,999.87	$8,936,305.64	$44,046,948.76
		TOTAL in 2011$$	$52,983,254.40	

(1) Cost in 2011 dollars, ENR CCI 10165.86 (Oct. 2011).

5.3 Summary of Findings

Based on the data collected, analyzed, and presented in the preceding sections of this report, the GI implemented by the District does not comply with the 44 MG requirement of Appendix 3 of the CD and corrective action is required. A corrective action proposal has been developed as a separate report. The District spent $53 M on design and construction costs for the nine (9) GI projects and therefore met the required $42 M minimum expenditure requirement of Appendix 3.

6.0 Quality Assurance/Quality Control

Quality assurance and control procedures were specified in the GI PCMP [ref. 2]. The District has established procedures for data collection and management (*Flow and Rainfall Monitoring for Engineering and Construction Projects Standards and Protocols, NEORSD*) [ref. 4] and for model development and updates (*Hydrologic and Hydraulic Modeling for Combined Sewer Systems Standards and Protocols, NEORSD*) [ref. 5]. Both these documents were developed for purposes of CD performance compliance activities. Since the start of the GI PCMP, both these documents have been

updated and refined to adapt to technology changes and best in class procedures that establish consistent and performance standards for maintaining integrity of collected data and master model management.

7.0 References

1. Civil Action No.1:10CV2895-DCN, Consent Decree, Case: 1:10-cv-02895-DCN Doc #: 23 Filed: 07/07/11 1 of 63.
2. Green Infrastructure Plan, Northeast Ohio Regional Sewer District, April 23, 2012.
3. Green Infrastructure Post-Construction Monitoring Programs – Combined Sewer Overflow (CSO) Long-Term Control Plan Consent Decree. NEORSD. July 2013, Revised July 2015.
4. Flow and Rainfall Monitoring for Engineering and Construction Projects – Standards and Protocols (Version 2.1). Northeast Ohio Regional Sewer District. June 10, 2019.
5. Hydrologic and Hydraulic Modeling for Sewer Systems – Standards and Protocols (Version 4.0). Northeast Ohio Regional Sewer District. July 10, 2020.