Appendix A

Pilot Program Details

A.1 Pilot Program Goals and Objectives

Six goals have been identified for the pilot program. Goals 1 through 3 are more general and relate to the relationship between the pilot program and the proof of concept phase. Goals 4 through 6 relate to the intended conclusions from the pilot program.

Goal 1: Demonstrate the feasibility of green stormwater infrastructure

- Objective 1a: Coordinate efforts with Consent Order and Agreement requirements for Early Action Areas, comprehensive monitoring plan, tributary water quality models, and tidal waters water quality models.
- Objective 1b: Provide data to support modeling and monitoring that implemented green stormwater infrastructure reduces combined sewer overflows.
- Objective 1c: Provide data to support modeling and monitoring that implemented green stormwater infrastructure improves receiving water quality.
- Objective 1d: Assess community acceptance of green stormwater infrastructure.

Goal 2: Assess green stormwater infrastructure opportunity

- Objective 2a: Implement green stormwater infrastructure on a range of suitable property types.
- Objective 2b: Implement green stormwater infrastructure using a variety processes for design and construction
- Objective 2c: Identify challenges and solutions for achieving greened acres on the most promising property types.
- Objective 2d: Provide information to update estimates of total greened acres that can be accomplished through the *Green City, Clean Waters* program based on greened acres implemented in first five years, total opportunity for greened acres, and challenges/solutions determined from 2a and 2b.

Goal 3: Assess green stormwater infrastructure cost effectiveness

- Objective 3a: Identify costs for planning, design, inspection, construction, and maintenance for a range of green stormwater infrastructure paying close attention to the distinction of costs as they relate to green stormwater infrastructure types and locations. Develop cost summaries both in terms of cost per area and volume managed and cost per area of green stormwater infrastructure.

Goal 4: Confirm green stormwater infrastructure functions

- Objective 4a: Demonstrate green stormwater infrastructure meets or exceeds design standards.
- Objective 4b: Identify primary causes of successes and failures.

Goal 5: Define maintenance requirements

- Objective 5a: Identify maintenance needs (e.g., sediment removal, weeding,).

- Objective 5b: Estimate maintenance demands (e.g., people, equipment, time, frequency).
- Objective 5d: Identify maintenance cost.

Goal 6: Support design standard development

- Objective 6a: Utilize pilot project designs to assemble design standards.
- Objective 6b: Communicate lessons learned for design standard revision.

A.2 Pilot Program Implementation Strategies

The pilot program development and implementation consists of the following tasks:

Task 1: Create a matrix of variables and projects

Create a list of pilot program variables, which are conditions that could affect the ability of green stormwater infrastructure to be implemented, its ability to function as designed, or its ability to maintain its functionality over time. For each variable, establish a target number of projects that should be constructed and for adequate assessment. Create a matrix of variables, add existing sites to the matrix, and check off all variables appropriate for each project. The matrix should be maintained and updated throughout the proof of concept period as new projects are completed.

Task 2: Select potential projects and new sites to fill in gaps (location, physical setting, policy and partnerships)

Use the matrix and target number of projects to help direct the project queuing process and project scheduling to design and build the required projects to complete the pilot program. Find projects that help meet the target number of projects for each variable.

Task 3: Develop site visit checklists and perform site visits to fill in with all observable variables for potential sites

For each potential site identified in Task 2, prepare site visit checklists and perform desktop analysis and carry out site visits to determine which variables apply to the site (e.g., location variables).

Task 4: Decide on pilot design to fill in gaps in pilot program (system, materials)

Once the purpose of the pilot project has been established (i.e., which variables are being tested), develop a conceptual design that will direct the design consultant to design a pilot project that meets the piloting objectives. The design must provide guidance on inspection and monitoring of the site so that adequate data will be collected to assess the variables being tested.

Task 5: Develop a monitoring plan for each pilot project

Develop a monitoring plan tailored to each site to collect the data to assess green stormwater infrastructure performance and to address the questions of applied pilot variables. The monitoring plan should include identification of data to be collected, frequency of data collection, and development of a database for subsequent analysis. The monitoring plan should include directions on subsequent data analysis and specify what outcomes are expected from the data analysis. Monitoring data should be collected and stored over the period specified in the plan.

Task 6: Develop a maintenance plan for each pilot project

Develop a maintenance plan tailored to each site to maintain the site and to establish reasonable maintenance requirements for similar sites. The maintenance program during the proof of concept phase will be geared toward establishing minimal acceptable maintenance procedures and frequencies, and must result in specific recommendations for frequency, type, and procedures at the end of the pilot period.

Task 7: Develop surveys and/or questionnaires and gather community/owner responses

For pilot projects with high visibility, for variables that require input based on surveys and questionnaires, or to test the feasibility of projects in a variety of neighborhood settings, a survey should be carried out to test community/owner response to specified pilot projects. The survey should establish a set of questions to organize and standardize data collection and to meet public participation requirements.

Task 8: Calculate a water budget for a variety of storms for each project

For each green stormwater infrastructure pilot project that is monitored for water levels, infiltration, and other losses such as evapotranspiration and slow release, a storm by storm and annual water budget should be calculated. The intent is to assess the ability of the green stormwater infrastructure project to control the first inch or more of runoff, to manage its assigned loading ratio, and to provide data and information to the modeling group to update the models used in the assessment of the overall program in meeting volume reduction requirements.

Task 9: Compile design, inspection, construction, maintenance, and monitoring costs

During the course of the pilot program, develop a system to carefully track design, inspection, construction, maintenance, and monitoring costs.

Task 10: Collect and report pilot program findings and conclusions

Produce a final report for the pilot program. The report should show the full range of pilot project variables and report on success and failures. The report should result in:

- Summary of green stormwater infrastructure performance results
- Updated costs and assessments of the cost effectiveness of each category or type of project
- Suggestions for project locations
- Suggestions for implementation strategies
- Cost effective and standardized designs
- Recommendations for maintenance
- Recommendations for effective partnerships
- Recommendations for changes to the overall *Green City, Clean Waters* program based on revised estimates of green stormwater infrastructure effectiveness

A.3 Pilot Program Variable List

The following is the list of every pilot variable to be assessed in the pilot program along with brief descriptions:

Variable	Description
Pilot Locations	
School Yards / Schools	Project implemented on school grounds or constructed adjacent to the school while working in partnership with the school administration
Recreation Centers	Project implemented on recreation center grounds or constructed adjacent to the recreation center while working in partnership with Philadelphia Parks and Recreation
"Open Space" Park Sites	
Mowable	Open spaces or parks with vegetated green stormwater infrastructure that needs to be routinely mowed
Non-mowable	Open spaces or parks with vegetated green stormwater infrastructure that is allowed to grow freely with only minimal plant maintenance such as weeding and pruning
Surface	Open spaces or parks with green stormwater infrastructure that is on the surface, such as a rain garden or swale
Subsurface	Open spaces or parks with green stormwater infrastructure completely in the subsurface, such as a subsurface infiltration trench
Traffic Triangles	Green stormwater infrastructure located within a traffic triangle to manage adjacent street and sidewalk area
Gateways	Green stormwater infrastructure located along a highly visible main entranceway to a certain neighborhood

Alleys	
Public	The managed alley is public right-of-way
Private	The alley is privately owned
With Rooftop Disconnect	Green stormwater infrastructure within the alley manages adjacent rooftops with downspout disconnections
Without Rooftop Disconnect	Green stormwater infrastructure within the alley does not manage adjacent rooftops
Centralized Facility	Green stormwater infrastructure structure that manages a large drainage area from multiple streets
Stormwater + Art Site	Art installations are implemented in addition to the green stormwater infrastructure in order to increase aesthetics and awareness
Spraygrounds	Managed stormwater can be stored and used for grass irrigation
Athletic Fields	Green stormwater infrastructure located within an athletic field footprint
Vacant Underground Facilities	Unused underground facilities that can be retrofitted to manage stormwater
Medians	Green stormwater infrastructure located within established medians on wide roads
Commercial Corridors	Green stormwater infrastructure located along streets with a high density of commercial businesses such as shops, restaurants, and bars to increase visibility and awareness
Bridge Runoff	Green stormwater infrastructure located near or under a bridge to manage bridge runoff
Streets	
Bumpouts	Project includes bumpouts within the street to capture street and sidewalk runoff
Crosswalks	Green stormwater infrastructure located at the crosswalk or within the crosswalk
Tree Trenches	Project includes tree trenches within the sidewalk to capture street and sidewalk runoff
Planters	Project includes planters within the sidewalk to capture street and sidewalk runoff
Porous	Project includes porous pavement within the street or sidewalk
Rain Garden	Project includes a rain garden within or adjacent to a sidewalk to manage street and sidewalk runoff
Infiltration/Storage Trench	Project includes subsurface infiltration/storage trenches within the sidewalk to manage street and sidewalk runoff
Sidewalk Swale	Project includes a swale within the sidewalk to manage street and sidewalk runoff

Various Ownership Types	
Public Right-of-way	Green stormwater infrastructure located within the public right-of-way while also managing runoff from streets and sidewalks
Public Parcels	Green stormwater infrastructure located within a public parcel, such as a park or open space
Other Public Property	Green stormwater infrastructure located within property owned by other public entities, such as the Philadelphia School District
Private	Green stormwater infrastructure located within private property with runoff from public land directed to the facility
Parking Lots	
Surface Systems	Surface green stormwater infrastructure such as rain gardens located within a parking lot
Subsurface Systems	Subsurface green stormwater infrastructure such as porous pavement or an infiltration trench located within a parking lot
Vacant Lands/ Land Acquisition	Vacant parcels acquired by the Water Department to implement green stormwater infrastructure
Commercial	Commercial properties such as strip malls or other businesses with large impervious areas
Physical Settings	
Piedmont Province	Project located within the Piedmont physiographic province. Soil properties and infiltration to be compared with the Coastal Plain Province.
Coastal Plain Province	Project located within the Coastal Plain physiographic province. Soil properties and infiltration to be compared with the Piedmont Province.
Soil Infiltration Capacity	
High tested infiltration rate (>5 in/hr)	The initial average tested infiltration rate, prior to green stormwater infrastructure construction, is high, greater than 5 in/hr
Low tested infiltration rate (<0.5 in/hr)	The initial average tested infiltration rate, prior to green stormwater infrastructure construction, is lower than the typical minimum infiltration rate of 0.5 in/hr
Slope Conditions	
Steep (>3%)	The drainage area includes steep slope conditions of greater than 3%
Pilot Systems	
Curbless Street	The drainage area includes curbless streets
Stormwater Treepit Designs	Green stormwater infrastructure includes stormwater treepits that manage stormwater by infiltration through the soil profile to subsurface gravel storage
Rain Gardens	
With Stone	The rain garden utilizes gravel storage under the soil profile
Without Stone	The rain garden does not have stone storage under the soil profile

With Sumped Inlet Pretreatment	Runoff is first captured by sumped inlets before draining to the rain garden ponding area
With Swale Pretreatment	Runoff is conveyed via a vegetated swale before reaching the rain garden ponding area
With Forebay Pretreatment	The rain garden utilizes a forebay for sediment removal
Without Pretreatment	The rain garden does not have any pretreatment
Planters	
With Stone	The planter utilizes stone storage under the soil profile
Without Stone	The planter does not have stone storage under the soil profile
With Sumped Inlet Pretreatment	Runoff is first captured by sumped inlets before draining to the planter ponding area
Without Pretreatment	The planter does not have any pretreatment
Sidewalk Swales	Green stormwater infrastructure is a swale within the sidewalk
Pipeless Trenches	The subsurface gravel trench does not include perforated distribution pipes or underdrains
New Inlets	
Single Stormwater Tree	Runoff is captured by single stormwater trees, rather than inlets draining directly to subsurface storage
Permapave Inlets	Sumped inlets with pervious concrete bottoms
Dual Trap Inlets	Inlets with two outflow pipes. The lower drains to the green stormwater infrastructure facility and the higher acts as an overflow directly connected to the combined sewer
Trench Drains	Trench drains used as the inlet itself or used to convey stormwater captured by curb cut inlets
Blue Roof	A rooftop stormwater detention system without vegetation
Roof Leader Treatments	
Disconnection Options	A variety of downspout and roof leader disconnection techniques to be tested
Leader to planter	Roof leader drains to a planter
Leader to rain garden	Roof leader drains to a rain garden
Leader to tree pit	Roof leader drains to a tree pit
Leader to tree trench	Roof leader drains to a tree trench
Pumped Systems	Green stormwater infrastructure utilizes pumped systems for controlled discharge back to the combined sewer
Reuse Systems	Stormwater reuse system such as cisterns and rain barrels for irrigation or grey water use
Injection Wells	Deep infiltration wells with a small area footprint

Regrading Street Crown/ Median Treatments	Complete street regrading to maximize drainage area to green stormwater infrastructure
Loading Ratio	
High Loading Ratio (>15)	High loading ratio. (Impervious drainage area)/(Green stormwater infrastructure area) > 15
Mid-Range Loading Ratio (10-15)	Mid-range loading ratio. 10 < (Impervious drainage area)/(Green stormwater infrastructure area) < 15
Low Loading Ratio (<10)	Low loading ratio. (Impervious drainage area)/(Green stormwater infrastructure area) < 10
Bumpouts	Bumpout systems are incorporated into the green stormwater infrastructure
Pilot Materials	
Porous Materials	
Porous Pavers	Porous pavers are used
Asphalt	Porous asphalt is used
Concrete	Pervious concrete is used
Playsurface	Porous rubber playsurface pavement is used
Other	One of various alternative porous pavement products is used
Storage Types	
Stone	Gravel is used for stormwater storage
Arched Systems	Arched systems such as StormTech chambers are used for increased storage
Structural Vaults	Concrete structural vaults are used for detention and slow release storage
Crate Systems	Crate systems with high void ratios (95-97%) are used for increased storage
Pretreatment Technologies	
Vortechs Separator	A hydrodynamic separator pretreatment system for solids removal
Forebays	Forebays can prevent excess solids from entering a rain garden area
Sumped Inlet Systems With Filter	Inlets with a sump and trap as well as a filter insert to capture larger debris and solids
Sumped Inlet Systems Without Filter	Inlets with a sump and trap only, without a filter insert
Swales	Vegetated swales can remove pollutants while also reducing stormwater velocity
Soil Types	
Structural Soils	For tree trenches/tree pits. Can be compacted to meet engineering requirements for paved surfaces while possessing qualities that allow roots to grow more freely

Native Soils	Native soils are used for vegetated green stormwater infrastructure rather than imported soils
Amended Native Soils	Native soils are amended to give them properties more suitable for plant health and stormwater management
Engineered Imported Soils	Specifically engineered bioretention soils and planting soils are used for vegetated green stormwater infrastructure
Modular Planters	
Freno System	The Freno System consists of precast modular concrete slabs meant for constructing planters
Fencing	Fencing is used to protect planting surfaces
Policy/Partnerships	
LEED / Sustainable Sites Initiative	Partnership with construction projects to include green stormwater infrastructure to support LEED certification
Public Agency	Partnership with public agencies such as Philadelphia Parks and Recreation, Mayor's Office of Sustainability, Philadelphia Streets Department, Department of Public Property, etc.
Non-Government Organizations	Partnership with non-government organizations such as the Pennsylvania Horticultural Society
Civic Groups	Partnership with neighborhood groups such as Ogontz Avenue Revitalization Corporation, Northern Liberties Neighbors Association, Allegheny West Model Neighborhood Partners, Tacony Civic Association, etc.
Center City District, University City District	Partnership with the Center City District or University City District
Other Policy/ Partnership	Partnership with any other type of organization
Implementation Strategies	
Complete Street Concepts	Total streetscape improvements that include new green stormwater infrastructure
Storm Flood Relief	Green stormwater infrastructure implemented after construction of storm flood relief pipes as the street is reconstructed
Standard Detail Roll-Out	Implementation of green stormwater infrastructure facilities with a standard detail design to reduce total design costs
Physical networks	Implementation of a network of interconnected green stormwater infrastructure facilities that together manage a larger drainage area
SMEDs	Stormwater Management Enhancement Districts (SMEDs) are areas where a potential exists for concentrated contiguous and interconnected use of green stormwater infrastructure controls that may offer greater efficiencies than if those same controls were implemented in a non-coordinated manner
Following Public-Works	Green stormwater infrastructure implemented after public works construction projects where pavement removal and evacuation will have already taken place

Green Campuses	Green stormwater infrastructure implemented on local college campuses such as the University of Pennsylvania, Drexel University, Temple University, etc.
Community Acceptance	
Subsurface Conditions	
Groundwater Mounding	Green stormwater infrastructure design incorporates piezometer wells for groundwater monitoring
Soil Stability (i.e. subsidence)	If soil subsidence occurs, investigations into the cause will take place to inform future design
Health and Safety	
Pedestrian Impacts	Green stormwater infrastructure potentially has impacts on pedestrians, such as when a rain garden or planter is constructed within the sidewalk right-of-way or a corner bumpout reduces the distance to cross the street
Bicyclist Impacts	Green stormwater infrastructure potentially has impacts on bicyclists, such as when a bumpout intrudes on an existing bike lane
Driver Impacts	Green stormwater infrastructure potentially has impacts on drivers, such as the traffic calming effects of bumpouts
Vectors	Green stormwater infrastructure potentially has vector issues, such as increased mosquito populations due to standing water

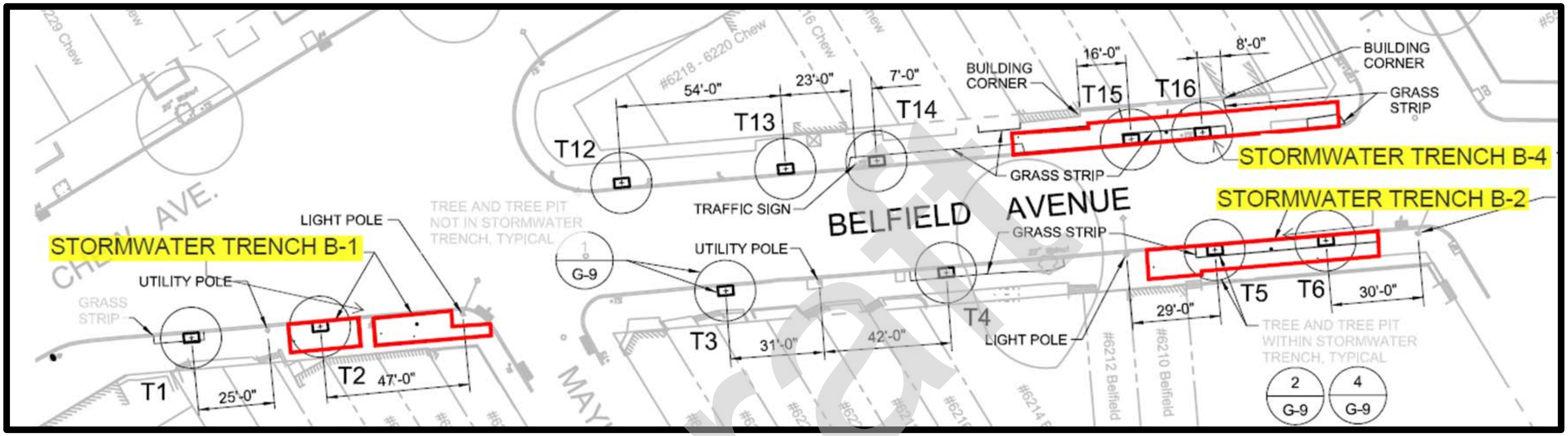
Appendix B

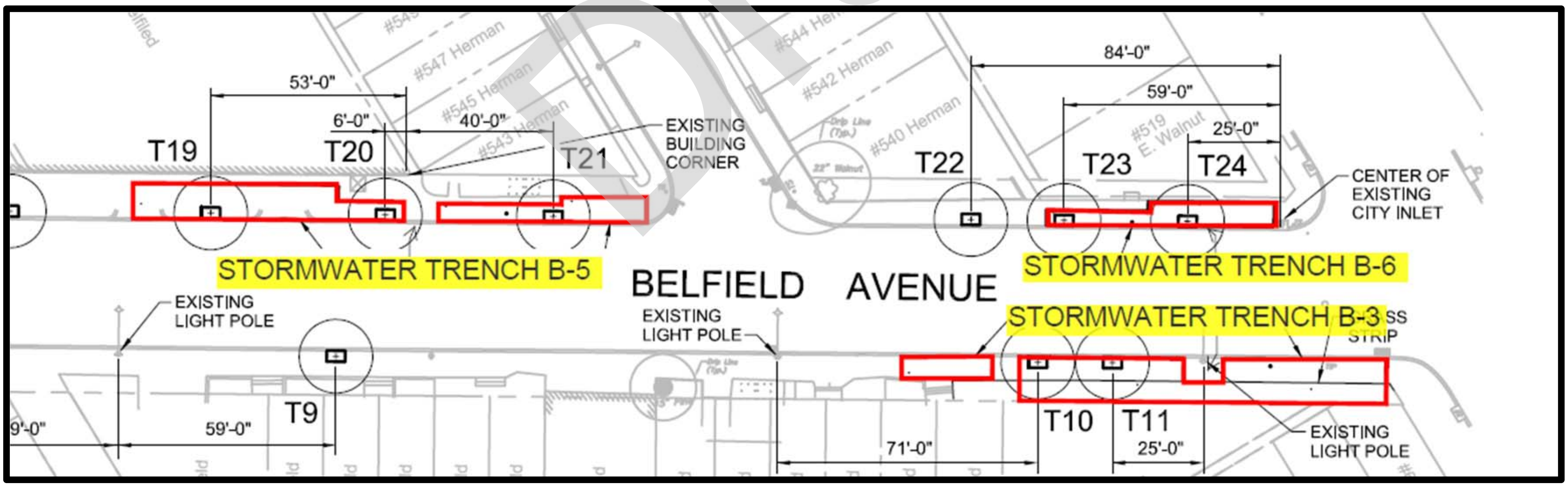
Green Stormwater Infrastructure Monitoring Schematic Examples

Details of the monitoring capabilities for each project are available in the design drawings, and are necessary to develop monitoring plans. Important information to be collected for monitoring plans includes inlet locations, SMP footprint, peak water elevations within the SMP, monitoring well locations, and monitoring well details. This information is clipped from the plans and organized into simple and concise monitoring schematics for each SMP to be monitored. Seven examples are included for a variety of SMP types that will be implemented as part of the *Green City, Clean Waters* program. In each example, important details of the plan are highlighted; most significantly, the location of monitoring equipment used to collect water level data is specified. The types of SMPs and projects that are included are:

- Tree trench – (50004) Belfield Avenue from Chew Avenue to Walnut Lane
- Bumpout/tree trench – (50001) Chew Playground, Washington Avenue and 19th Street
- Planter/infiltration trench – (50006) Columbus Square
- Planter – (50009) Bureau of Laboratory Services
- Bumpout – (50009) Queen Lane
- Porous pavement and infiltration trench – (50023) Herron Playground
- Rain garden – (50041) Cobbs Creek Parkway and Springfield Avenue Traffic Island

Tree Trench Example
(50004) Belfield Ave from Chew Ave to Walnut Ln

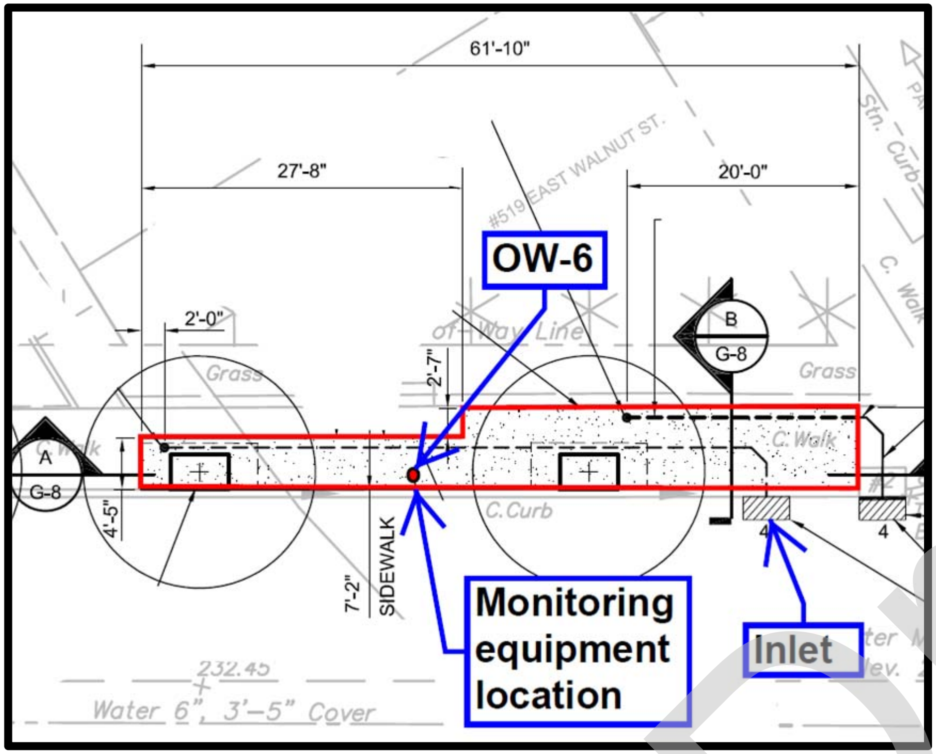


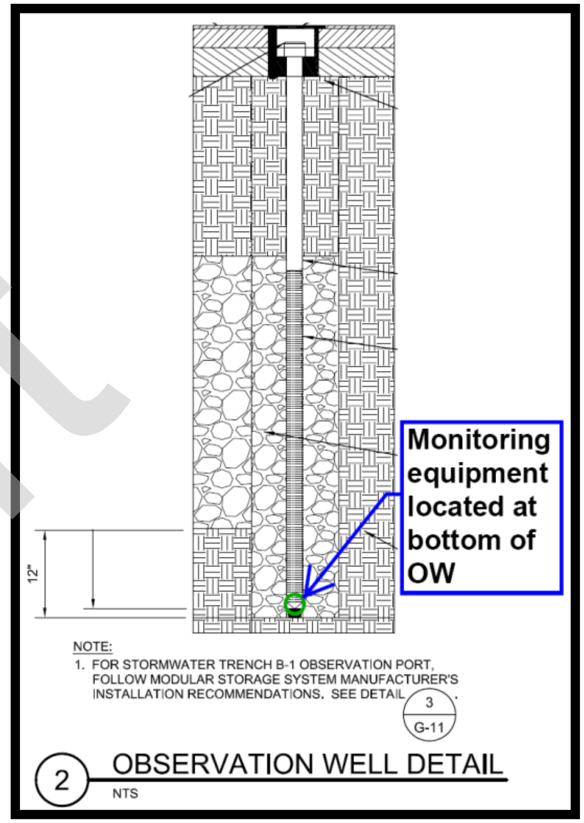


Reference: Sheet G-2 from construction drawings

(50004) Belfield Ave from Chew Ave to Walnut Ln

Stormwater Trench B-6





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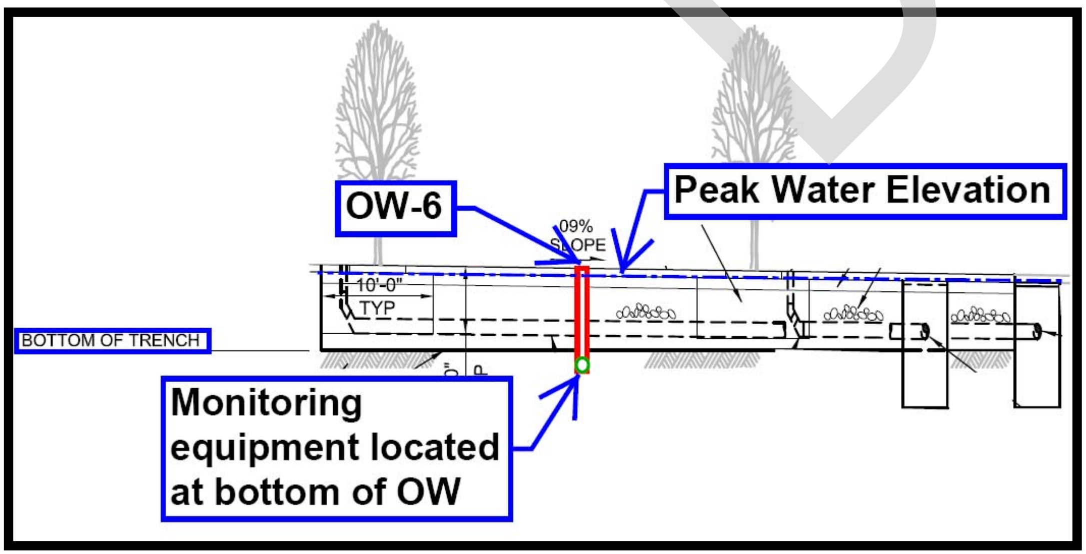
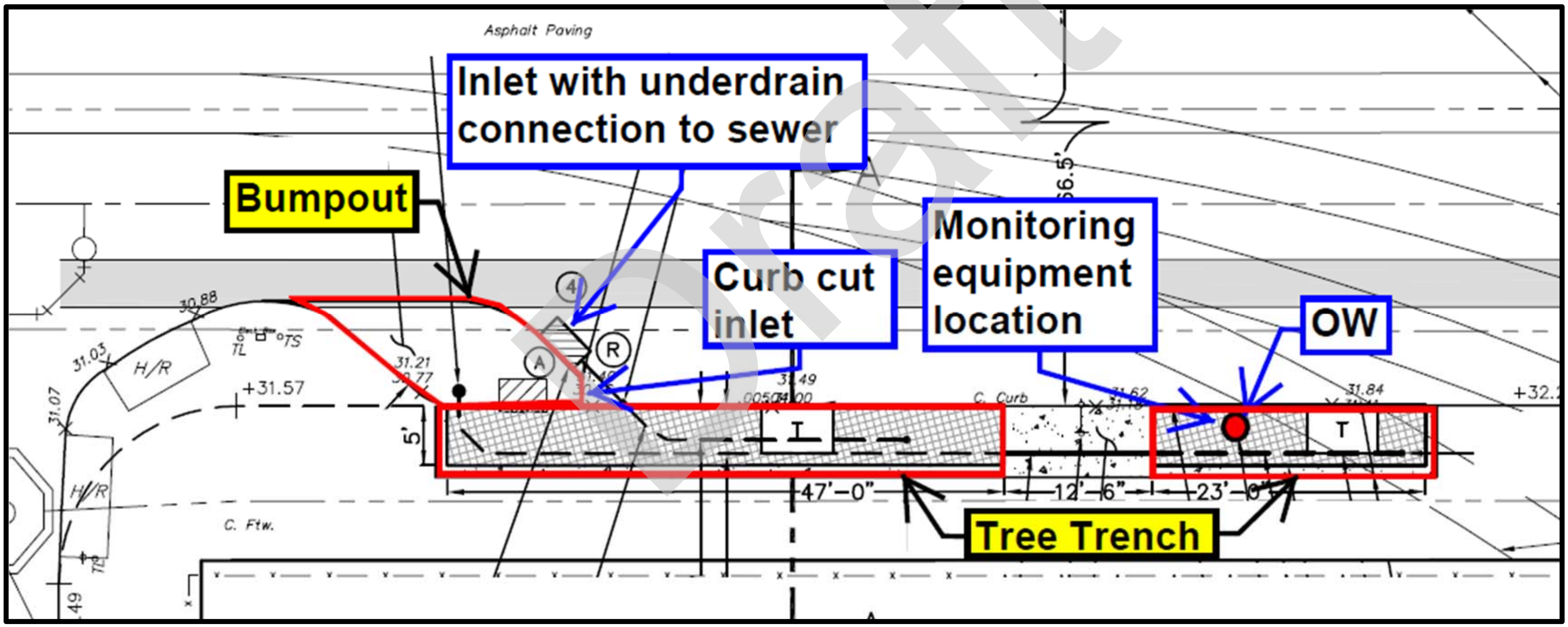


Reference: Sheet G-8 from construction drawings

Bumpout/Tree Trench Example
(50001) Chew Playground

Washington Ave. & 19th St.



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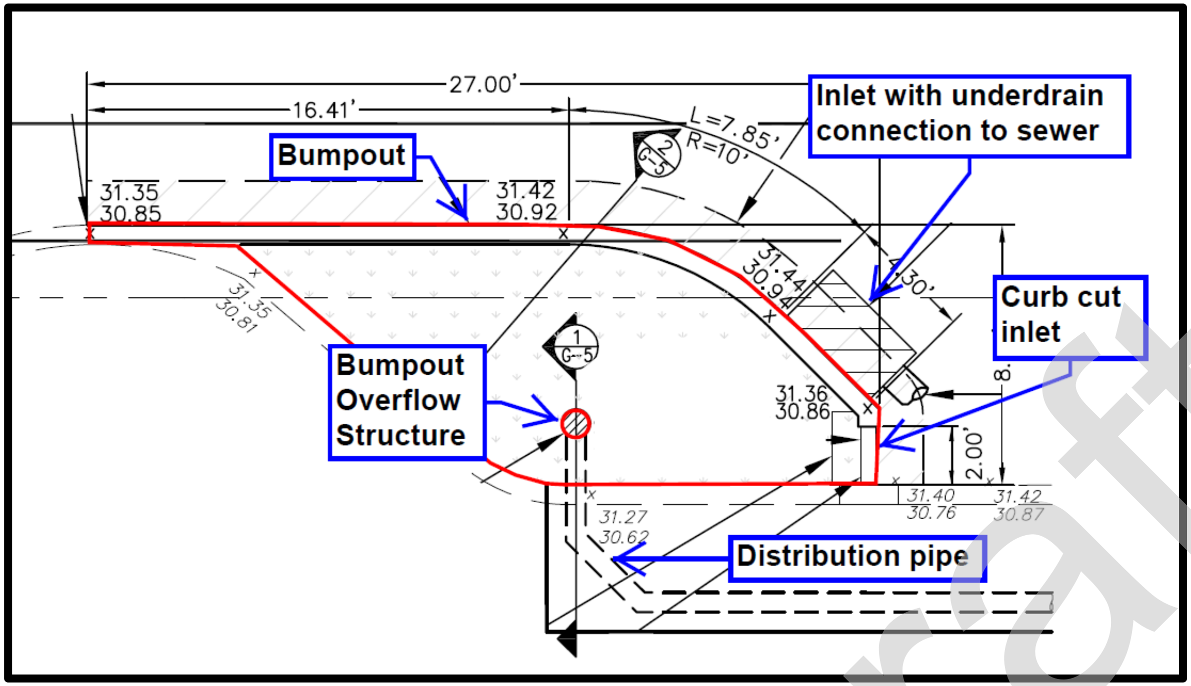
(50001) Chew Playground



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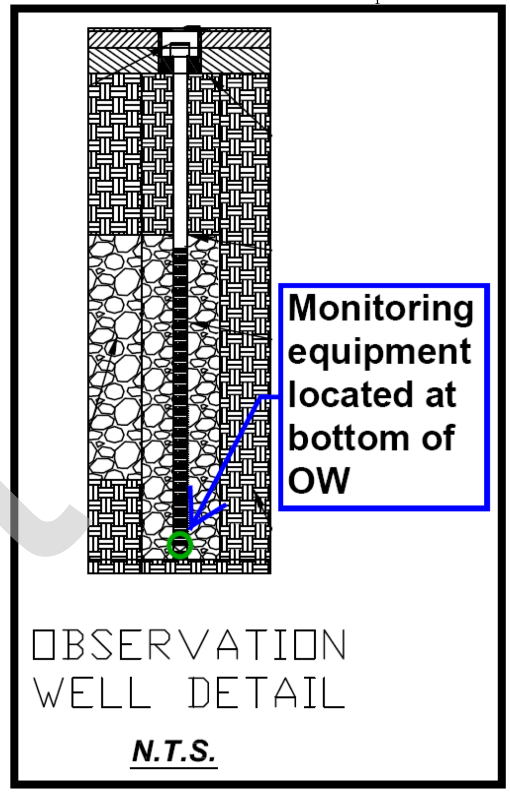

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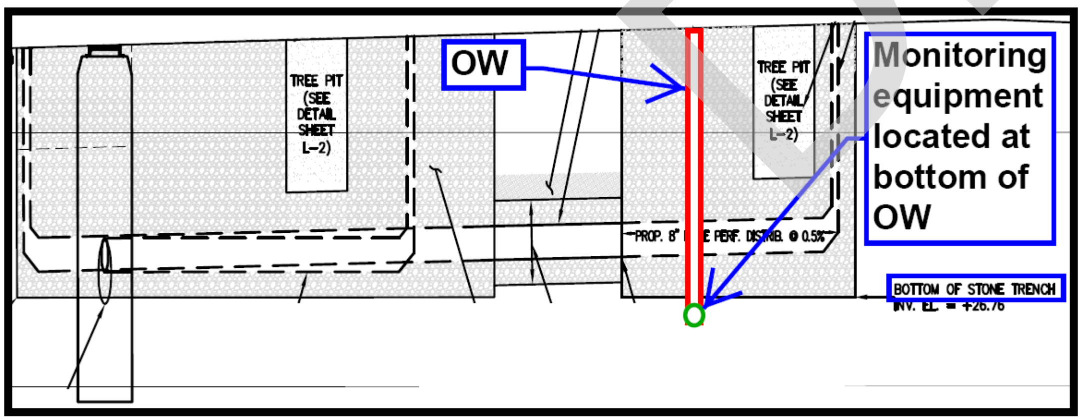

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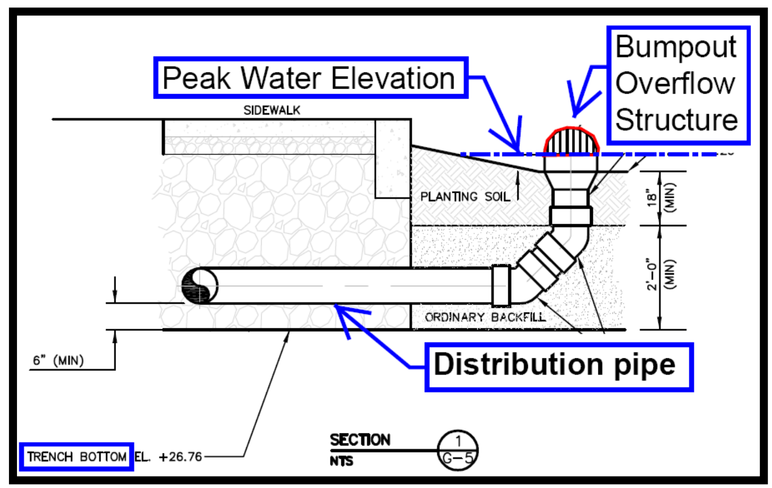
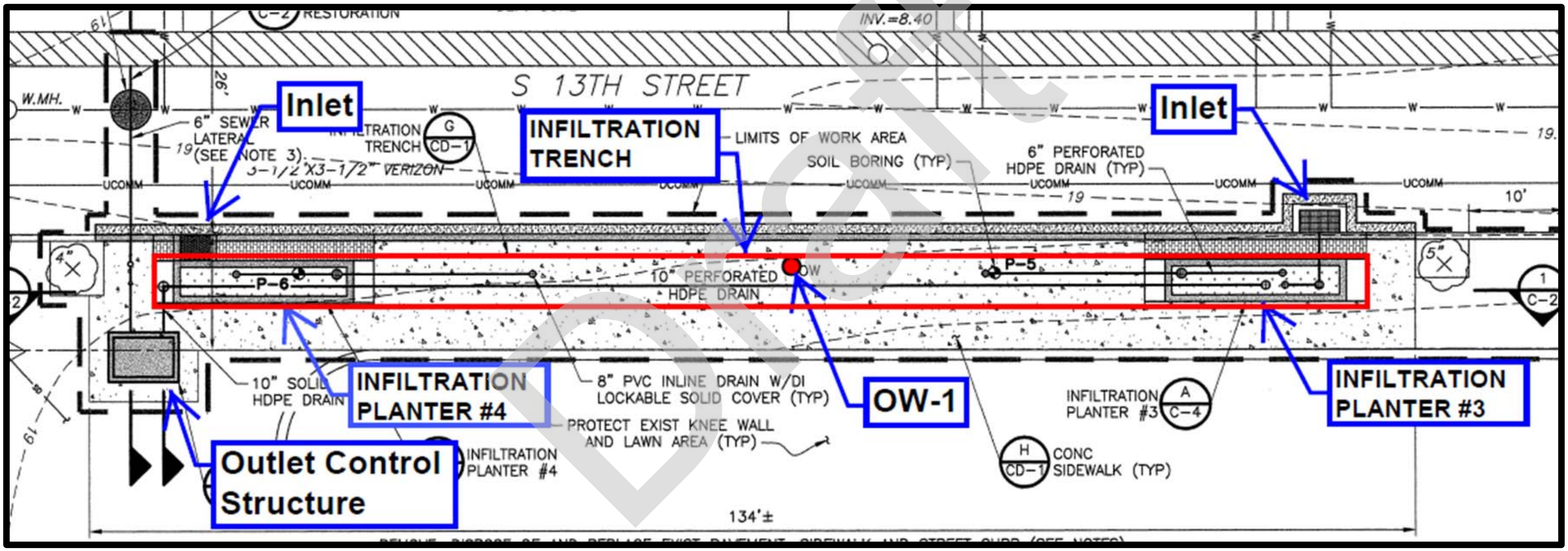


Reference: Sheet G-5 from construction drawings

Planters/Infiltration Trench Example
(50006) Columbus Square



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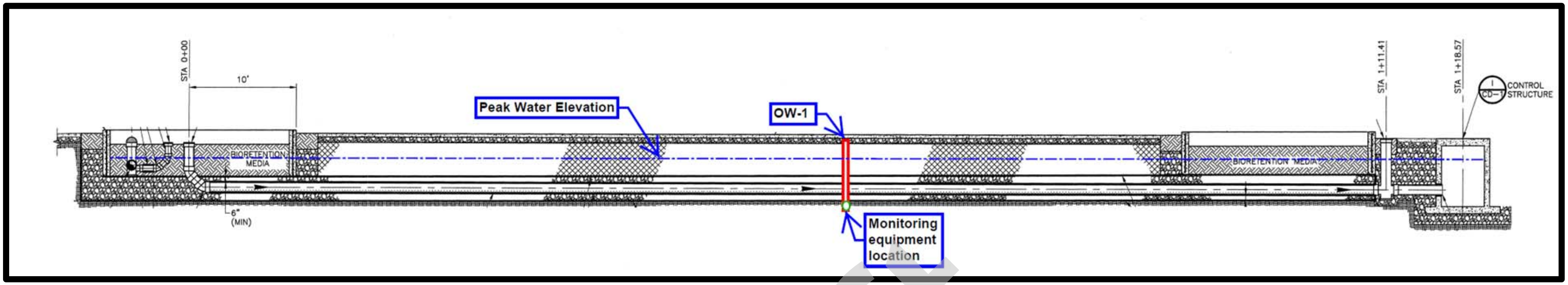

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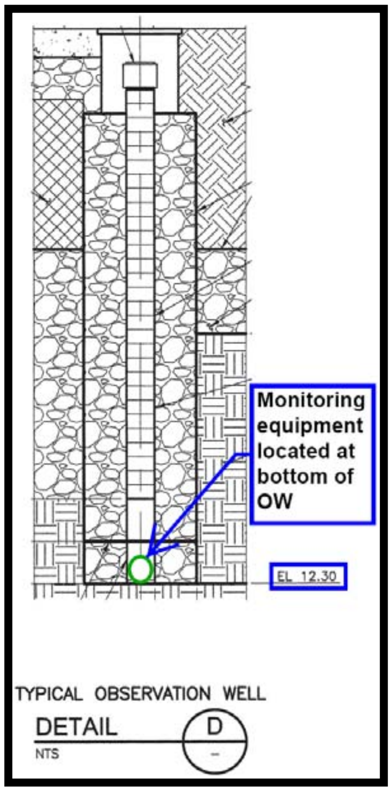

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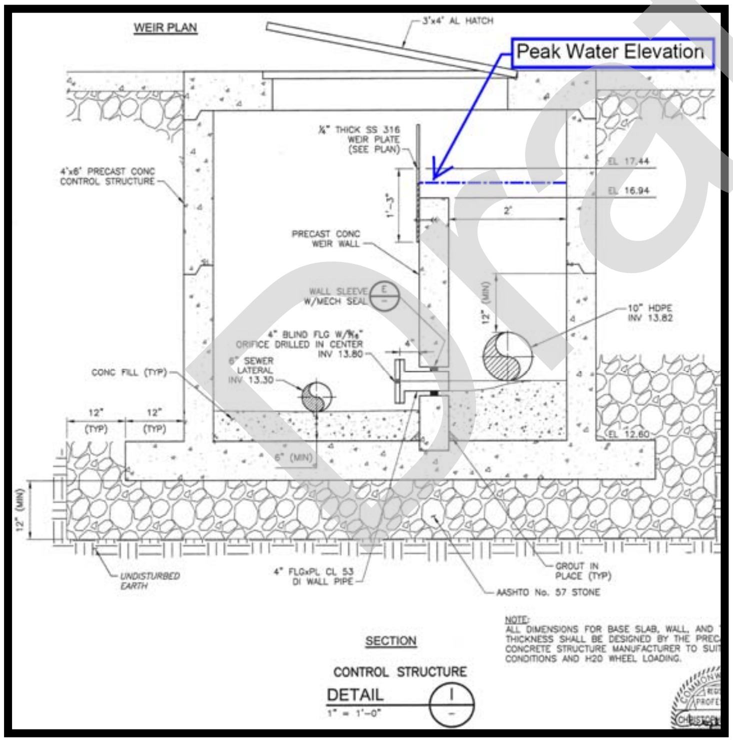

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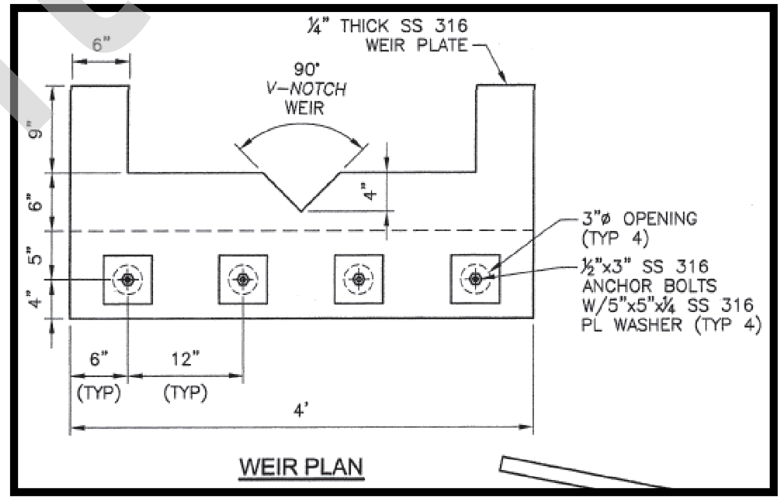
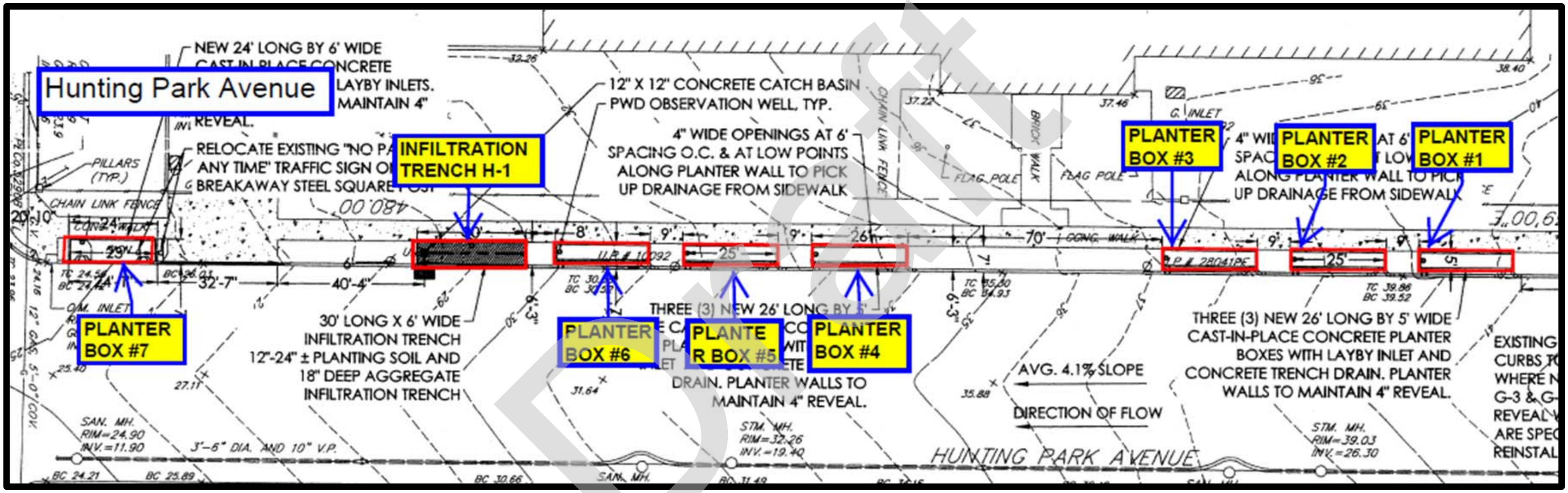


Reference: Sheet CD-1 from construction drawings

Planters Example
(50009) Bureau of Laboratory Services



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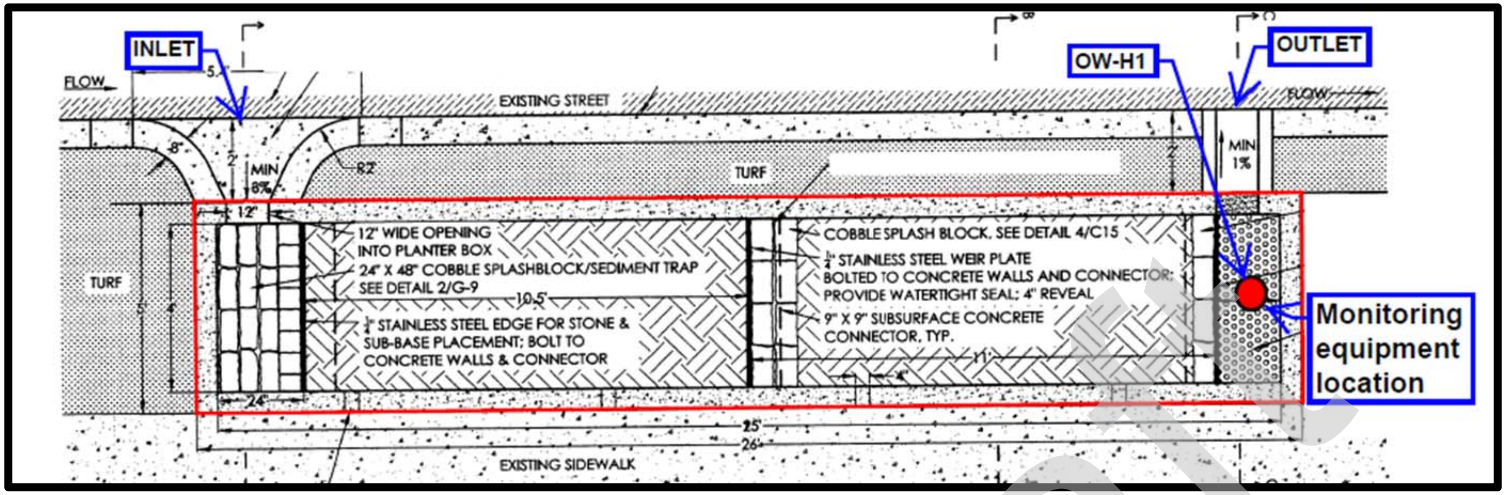
(50009) Bureau of Laboratory Services

Hunting Park Avenue – Planter #1



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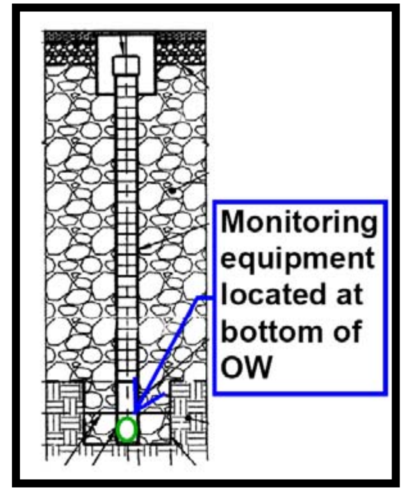

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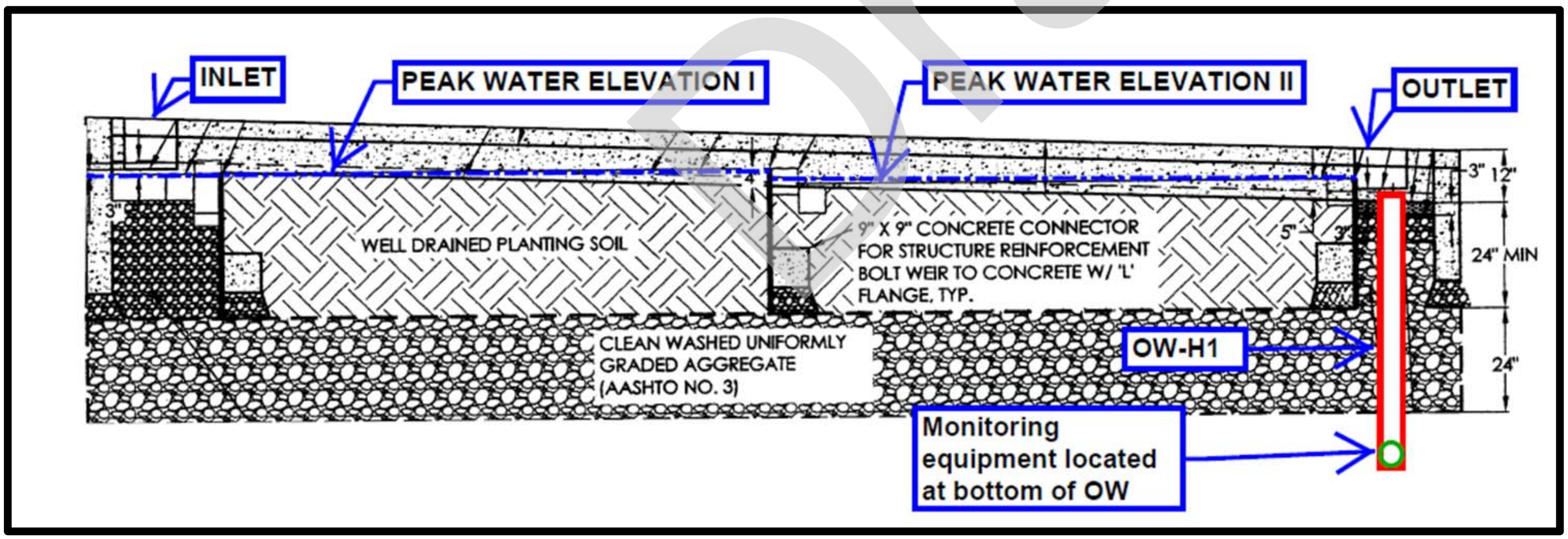
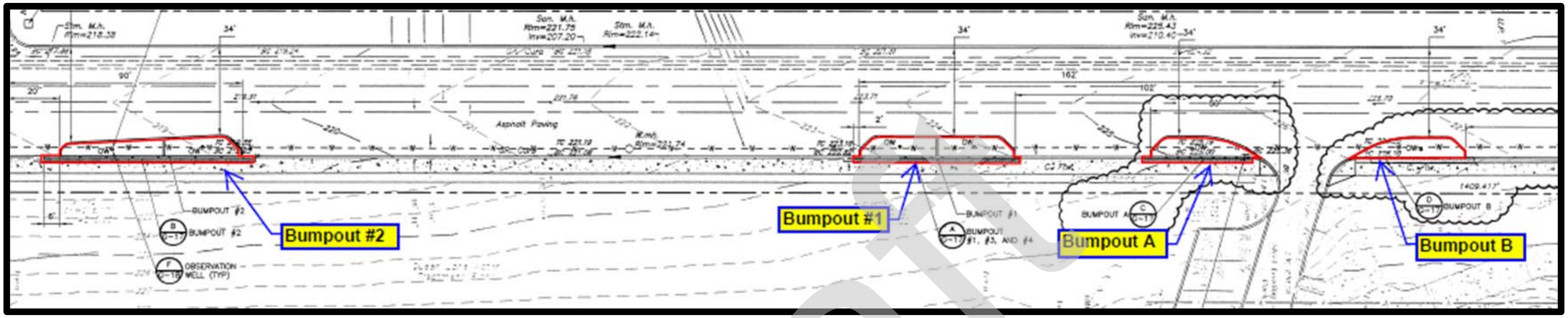
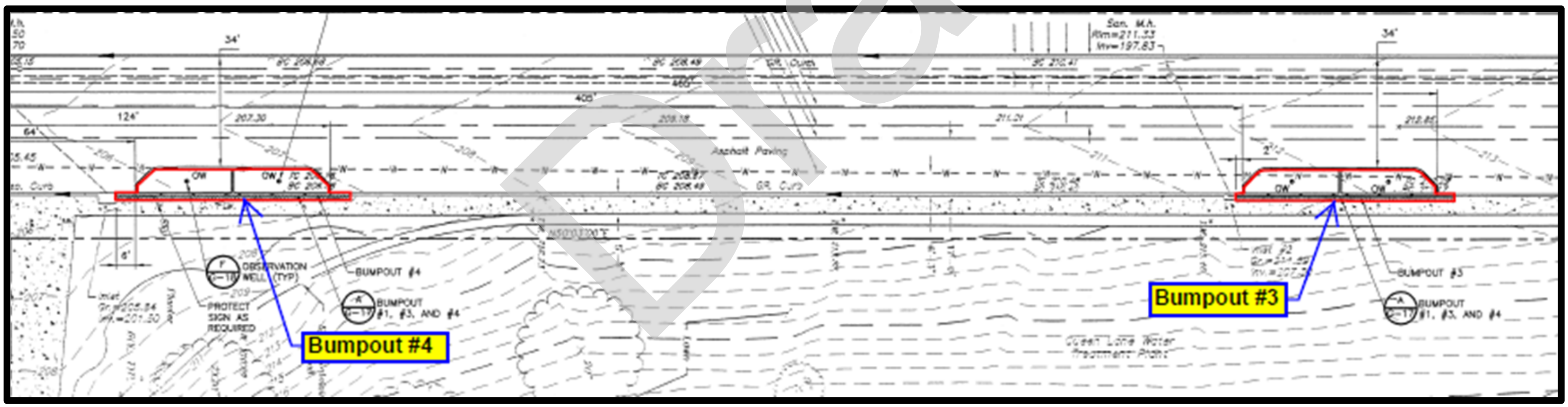


Reference: Sheet G-9 from construction drawings

Bumpout Example
(50009) Queen Lane

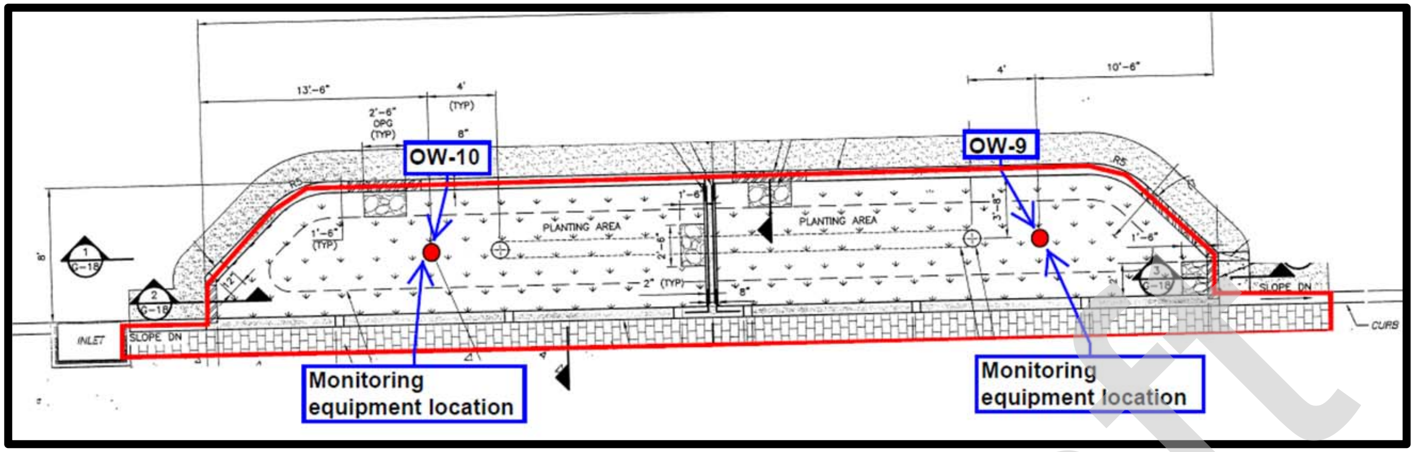




Reference: Sheet G-15 from construction drawings

(50009) Queen Lane

Bumpout #4



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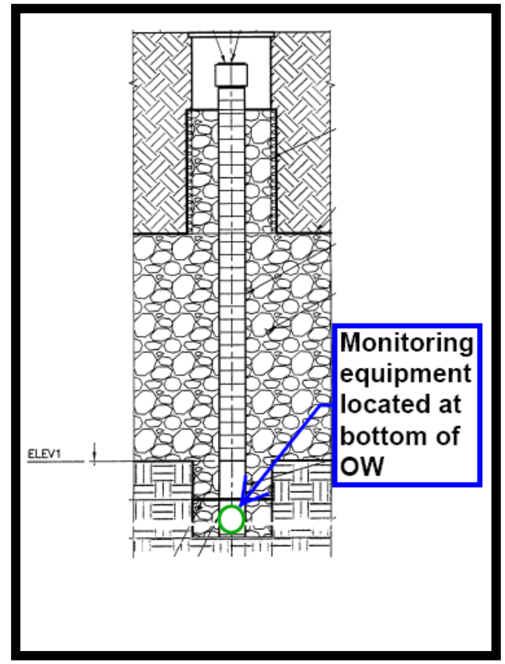
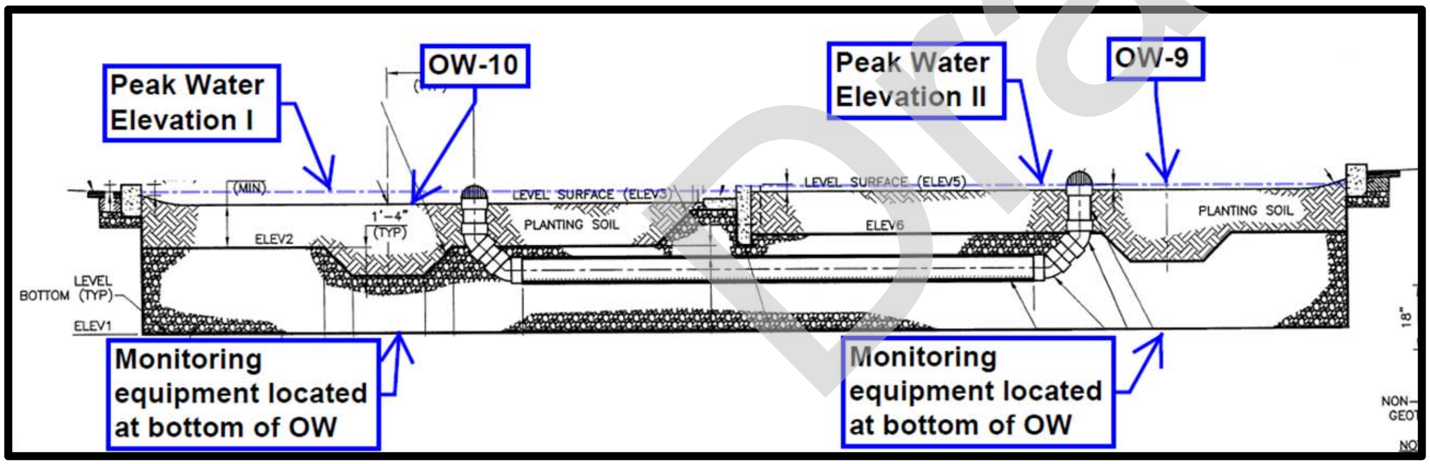
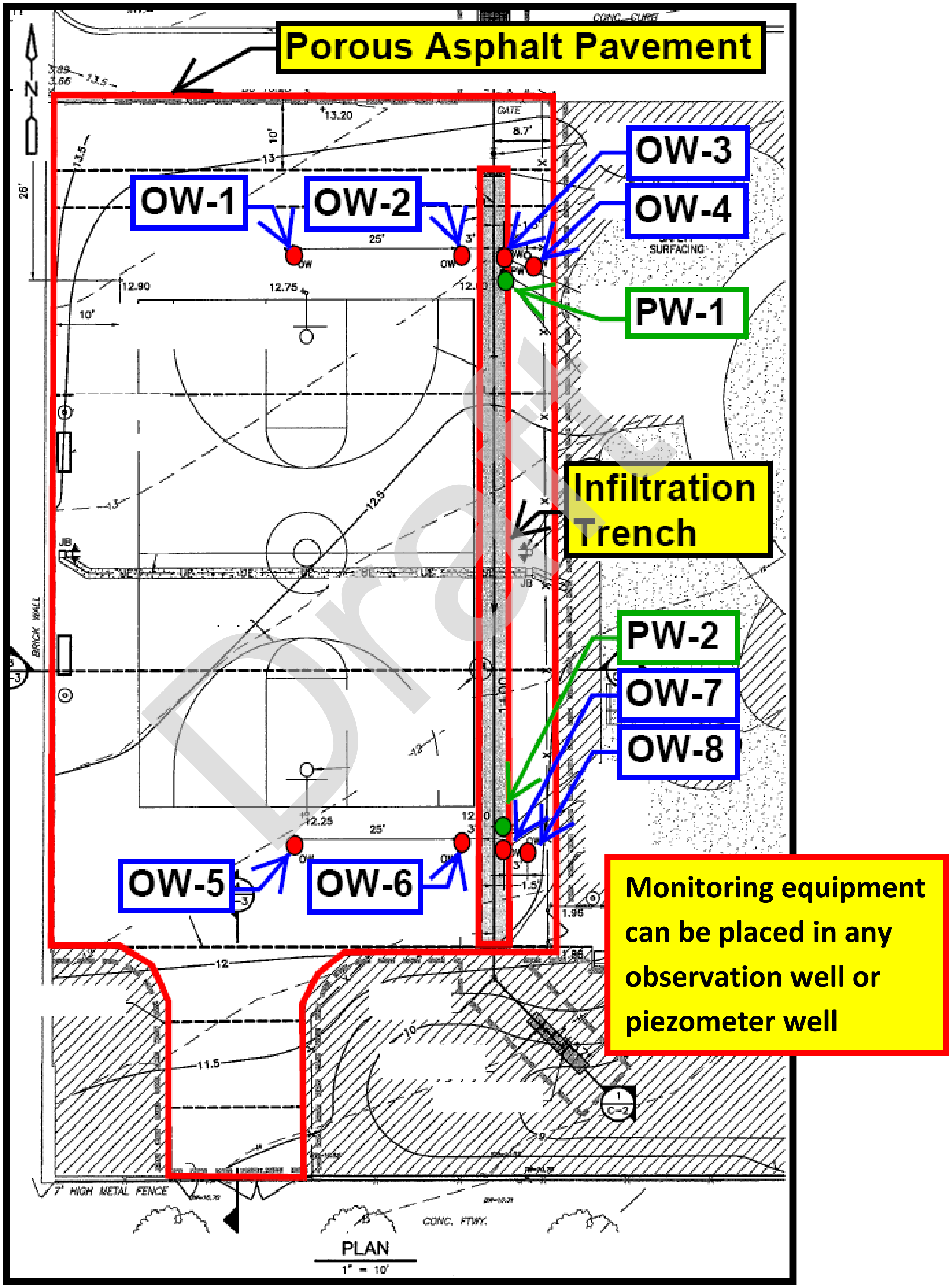




Note: The position of the observation well is to be located within the limits of the level surface as determined in the field by the Engineer.

Reference: Sheet G-18 from construction drawings

Porous Pavement and Infiltration Trench Example (50023) Herron Playground



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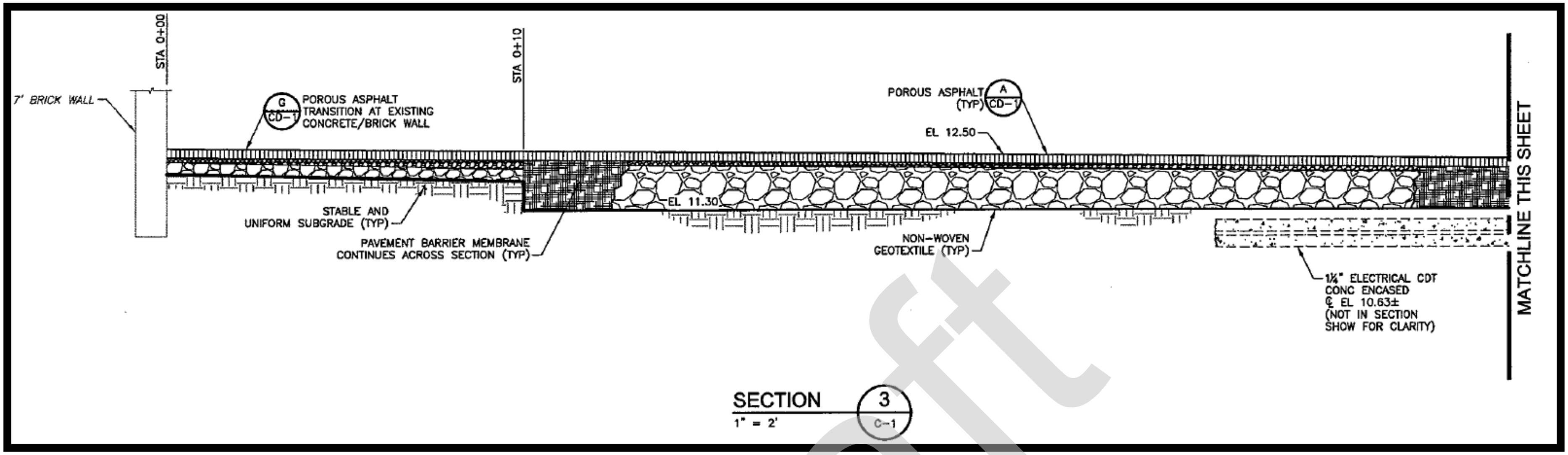
(50023) Herron Playground



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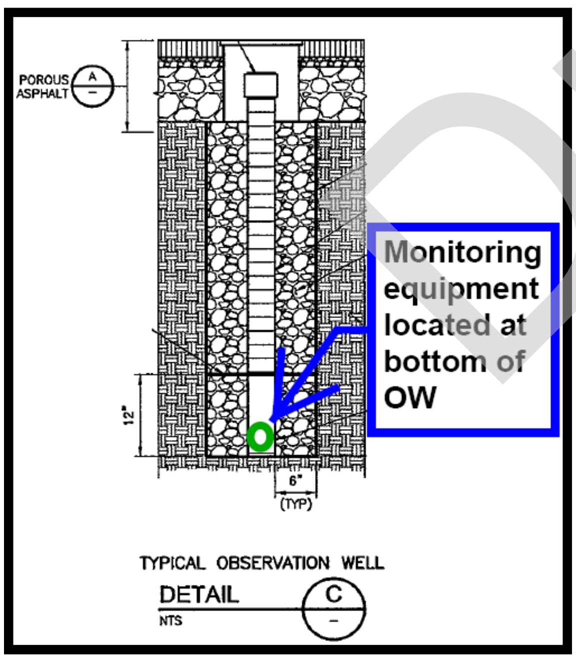
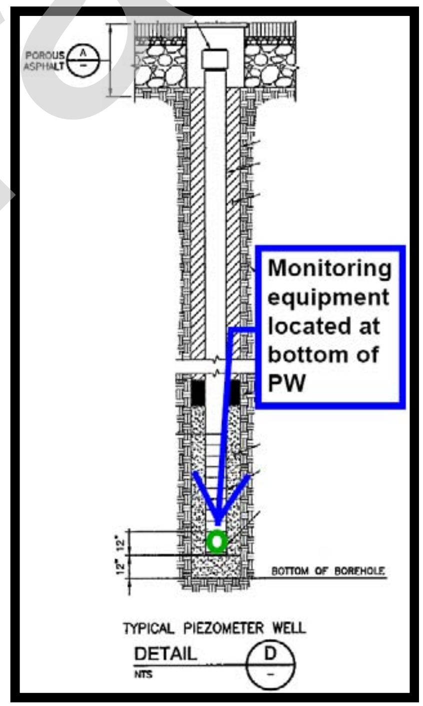
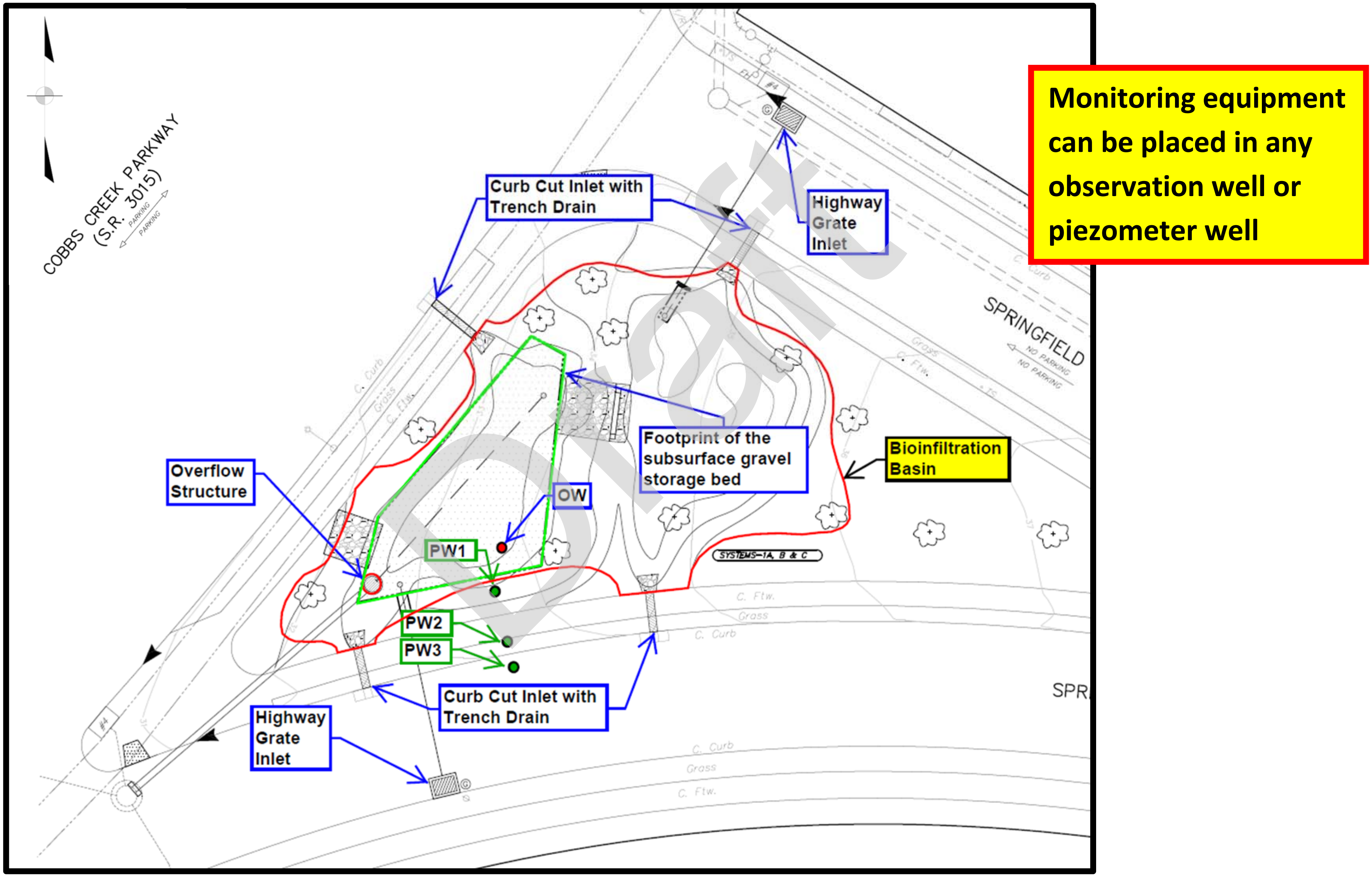




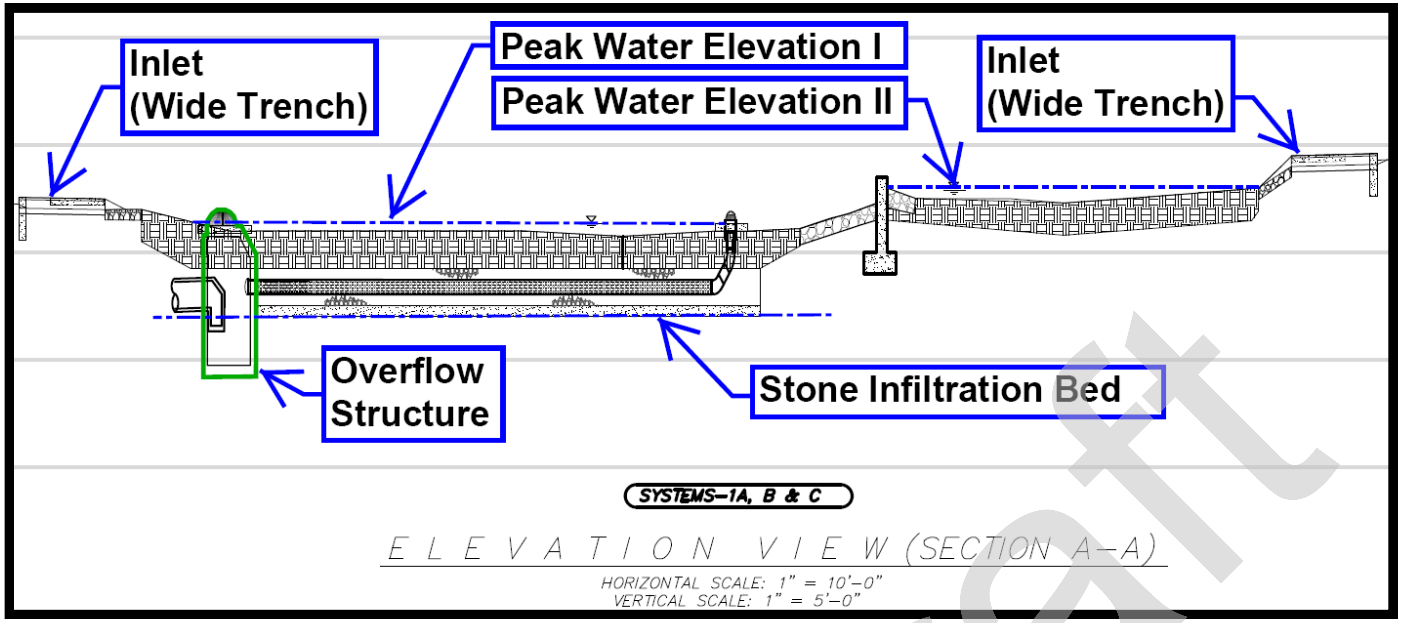
Reference: Sheet CD-1 from construction drawings

Rain Garden Example
(50041) Cobbs Creek Pkwy & Springfield Ave Traffic Island

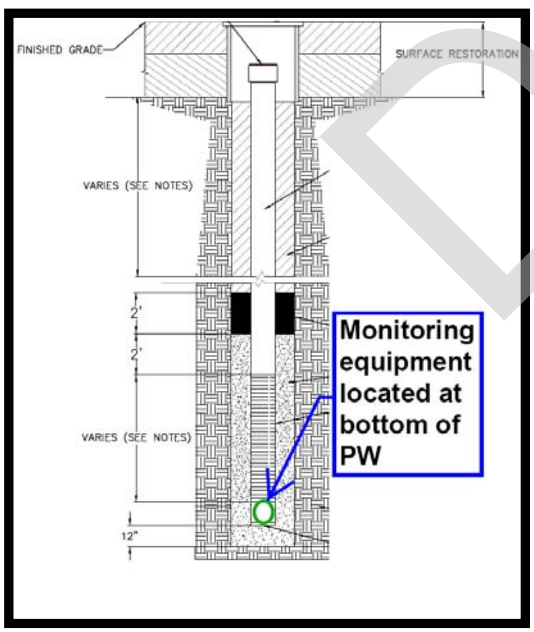


Reference: Sheet G-2 from construction drawings

(50041) Cobbs Creek Pkwy & Springfield Ave Traffic Island

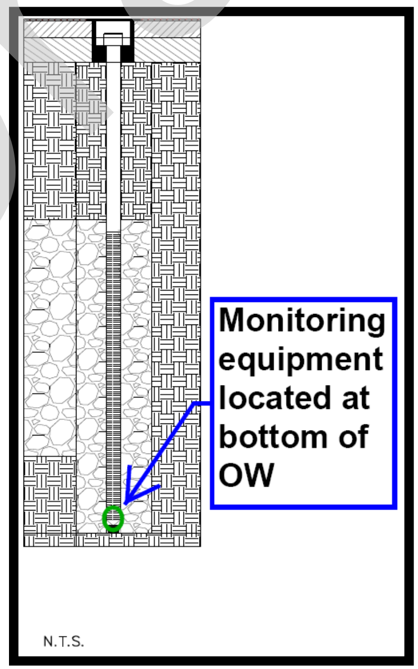


Reference: Sheet G-2 from construction drawings



PIEZOMETER WELL DETAIL

N.T.S.



OBSERVATION WELL DETAIL

N.T.S.

Reference: Sheet G-22 from construction drawings

Appendix C

The Water Department's Standard Operating Procedures for Continuous Water Level Monitoring of Green Stormwater Infrastructure Practices

Appendix C Table of Contents

1.0 Introduction

This section describes the Philadelphia Water Department (PWD) procedures for continuous monitoring and water level measurements in observation wells and other monitoring devices located within Green Stormwater Infrastructure (GSI) Stormwater Management Practices (SMPs). This document will be updated frequently as monitoring and data analysis methods are refined during the first five years of implementation of the *Green City, Clean Waters* program. The most up-to-date version of this document is available on the PWD Office of Wwatersheds server at the following path:

\\pwdoows1\Watershed Sciences\GSI Monitoring\SOPs\SOP_Continuous_Water_Level_Monitoring_MM_DD_YYYY.doc

2.0 Water Level Monitoring Procedures

2.1 Office Tasks and Preparation

1.) Synchronize laptop and camera clocks with official U.S. time (http://www.time.gov/timezone.cgi?Eastern/d/-5)
2.) Check batteries in all equipment, verify SD storage card is in camera
3.) Prepare field forms by exporting information from GSI Monitoring Database
    a. Database name: GSI_Monitoring.mdb
    b. Database location: \\pwdoows1\Watershed Sciences\GSI Monitoring\Monitoring Database\
    c. Determine Project Name and Project ID for each site to be visited.
    d. For each SMP, determine the monitoring device ID(s)
    e. Determine the vertical reference elevation for each monitoring device (*e.g.*, well cap, top of PVC well pipe, etc.).
    f. Determine the source of barometric pressure correction
    g. PWD contact name and local contact name if present in the database
    h. Determine nearest rain gage.
    i. Determine whether there has been significant (> 0.05 in) rainfall within the past 24hrs.
4.) Plan a route and print maps/directions if necessary

2.2 Water Level Monitoring Field Procedures

1.) Locate the site and monitoring device(s), inspect the site for any unusual conditions and establish appropriate safety measures such as cones or pedestrian barriers.
2.) Remove cap from observation well or otherwise gain access to the monitoring location such as control structure, etc.

3.) Take a manual water level reading just before removing the sensor (see section 2.4 Water Level Measurements with Electric Tape, below). Record the water level, time, units, and measurement device (*e.g.*, electric tape) on field form

4.) Remove the logger from the well and enter the date and time on the field form.

5.) Wipe the logger clean and inspect the pressure sensor port for any debris. Carefully clean the port with a bottle brush or pipe cleaner if necessary.

6.) Disconnect the logger body from its plastic cap and connect the optical USB shuttle, observing the correct alignment of flat threading on the logger.

7.) Start HOBOware Pro software.

8.) Connect optical USB shuttle to laptop USB port

9.) Verify device ID in lower left hand corner of interface.

10.) Check status (Device>Status), verify system time is accurate

11.) Download data (Device>Readout)

12.) When prompted that device is still logging data, select "stop logger"

13.) Save file [Sensor_ID]_ [YYYY-MM-DD]_[SMP_ID]_ [Monitoring Device ID]
e.g., 9951601_2012-09-27_690_OW-1.hobo

14.) Plot sensor data and events in HOBOware. Inspect the plot for expected patterns (remember these are uncorrected data subject to atmospheric pressure fluctuation).

15.) Export as CSV file, *e.g.*, 9951601_2012-09-27_690_OW-1.csv

16.) Use a flashlight to inspect, or sound the bottom of the well if possible to determine if there is debris accumulation.

17.) Re-launch the logger (Device>Launch) with 5 minute logging interval, recording absolute pressure and temperature. Name the deployment [Sensor_ID]_[SMP_ID]_ [Monitoring Device ID] *e.g.*, 9951601_690_OW-1. It is imperative that both sensors are recording at the same time interval. e.g. Both sensors recorded a data point for the time 12:00:00 AM, not one at 12:00:00 and the other at 12:01:30.

18.) Reinstall the sensor in the well by slowly lowering the sensor. Avoid any obstructions such as rebar that may be present within the well. The logger should be hanging freely (*i.e.*, not resting on the bottom of the well) and there should be no cable slack when the sensor is properly deployed. Record time on the field form

19.) Take a manual water level reading just after installing the sensor. Record the monitoring device ID, water level, time, units, and measurement device on field form

20.) Reinstall the well cap, ensuring well cap is vented to the atmosphere to allow for proper barometric pressure compensation.

2.3 Barometric Pressure Compensation Data Field Procedure

1.) Barometric pressure compensation monitoring is conducted using similar equipment, and monitoring procedures are similar to those described in section 2.2, above, with the exception that no water level readings are necessary for barometric pressure monitoring.

2.) Monitoring device ID for local barometric pressure compensation (*i.e.*, located at the same GSI project site will be "BARO", files should be saved with the following naming convention: [Sensor_ID]_ [YYYY-MM-DD]_[SMP_ID]_ [Monitoring Device ID]
e.g., 9951601_2012-09-27_690_BARO.hobo
e.g., 9951601_2012-09-27_690_BARO.csv

3.) Data processing tasks may be marginally easier if the barometric pressure sensor record is longer than the water level sensor data record(s). For this reason the field procedure can be staged such that the barometric pressure sensor deployment begins prior to the water level sensor(s) deployment and the barometric pressure sensor deployment ends after the water level sensor(s) deployment.

2.4 Water Level Measurements with Electric Tape

1.) Manual water level readings should be taken with the pressure transducer installed in the well. For new deployments, take a water level reading after deploying sensors initially. When visiting existing sites, record a level reading just before removing the sensor when reading out data from sensor deployments and immediately after redeploying the sensor for its next deployment.
2.) Refer to the monitoring device information to determine the vertical reference elevation for water level readings, (*e.g.*, well cap, top of PVC well pipe, etc.). The vertical reference elevation should be a level surface. Watch for uneven pavement or debris.
3.) Place a horizontal reference object (*e.g.*, ruler, solid metal bar) across the opening of the vertical reference. Bar should be placed perpendicular to curb line of nearest street if possible.
4.) Measure water level at the center of the opening (Figure C-1)
5.) Repeat the measurement, adjusting the sensitivity of the instrument as required, to determine the exact distance to the air/water interface in 1/100ths of a foot.
6.) Record the monitoring device ID, water level, time, units, and measurement device (*e.g.*, electric tape) on field form.

Figure C-1: Manual Water Level Measurement in Observation Well

2.5 Equipment Checklist

Equipment is organized in two separate lists. Sensitive electronic equipment and field forms should be stored separately from hand tools.

1.) "Clean Bag"

- Laptop with HOBOware software
- Optical USB shuttle and USB cable
- Clipboard and pencils
- Field forms
- Digital camera
- Information resources for residents

2.) "Tool Bag"

- Electric tape
- Ruler or solid metal bar for horizontal reference measuring point
- Tape measure
- Flashlight
- Key(s) for control structure, padlocks etc. needed to access facilities
- Ratchet and socket for well caps
- Hammer
- Small pry bar or chisel
- Screwdriver
- Well cap level reading bar
- Stainless steel cable
- Wire cutter/Crimping tool
- Carabiners
- Ferrules
- Work gloves
- Safety goggles
- Shop rags
- Bottle brush or pipe cleaners
- Hand sanitizer
- First Aid Kit

3.0 Data Processing

3.1 Overview

Water level data processing and quality assurance and control (QA/QC) procedures are based upon QA/QC procedures originally developed for temporary flow monitoring within sewer systems. Precipitation data QA/QC procedures are performed by the Hydrologic and Hydraulic (H&H) Modeling group. A conceptual diagram of the data processing procedures was developed to show the various sources of input data and data processing workflow (Figure C-2).

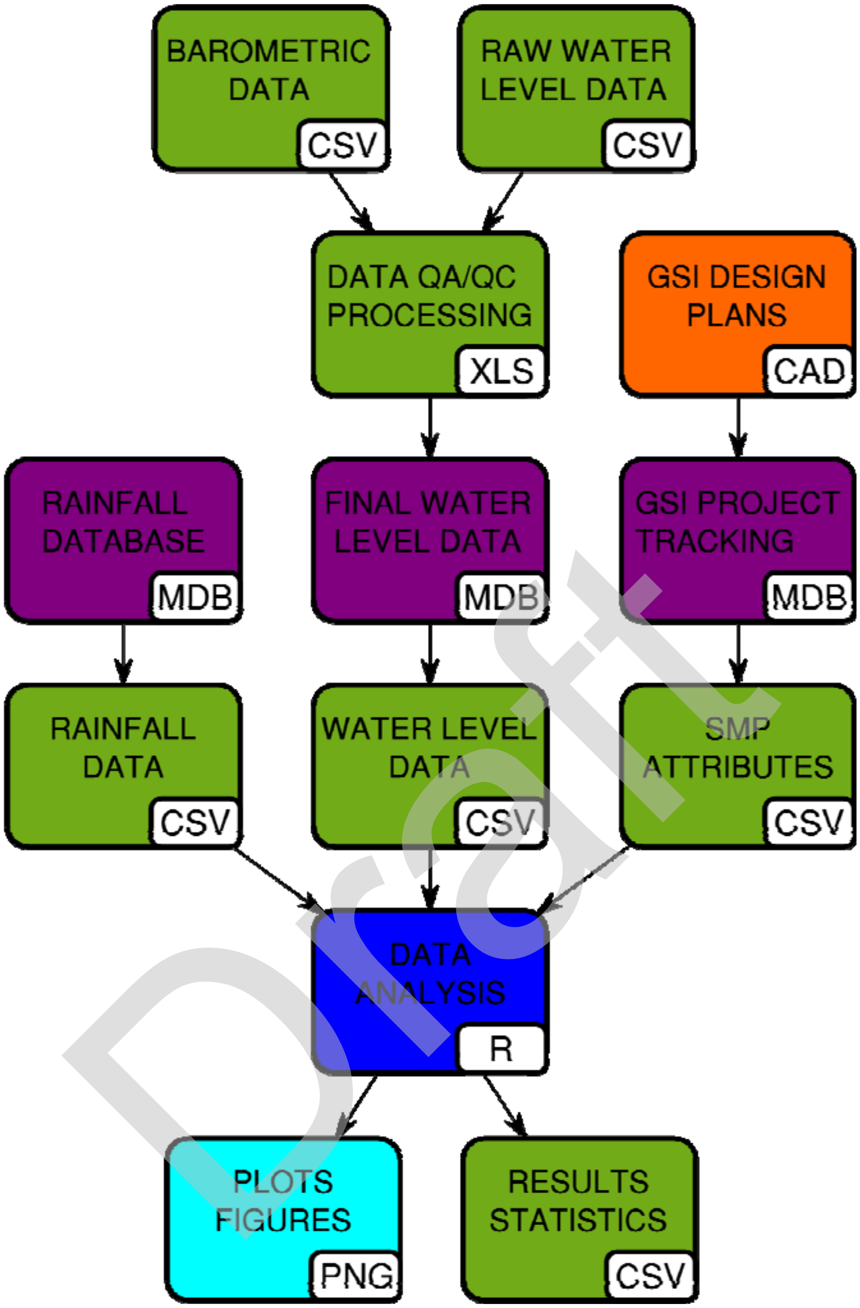


Figure C-2: Conceptual Diagram of Data Processing and Analysis Procedures for Continuous Water Level Monitoring in Green Stormwater Infrastructure Practices

3.2 Data Processing

3.2.1 Water Level Data Processing

1) Project Directory
   a) To create a new project directory navigate to the following file path and create a folder using the file naming convention shown below the file path.
   \\pwdoows1\Watershed Sciences\GSI Monitoring\Monitoring Database\GSI

Monitoring Sites
[ProjectID_SystemID] ex. (9_48)

b) Create two subfolders one each for Raw and Quality checked data named "Raw" and "QAQC" respectively.

2) Raw Data Import

a) Uncorrected water level and barometric pressure data are exported from the HOBOware software and stored as comma separated value (CSV) files using the following naming convention:
[SMP_ID]_[Sensor_ID]_[Monitoring Device ID]_ [YYYY-MM-DD].[extension]*e.g.*, 690_9951601_OW-1_2012-09-27.csv
e.g., 690_9951601_OW-1_2012-09-27.hobo
(see section 2.2 Water Level Monitoring Field Procedures for more information)

b) Save these files into the “Raw Data” folder for each SMP. Do not perform analysis within these files and then save! Keep these raw files as the original copies of the data. This will aid in troubleshooting with QA/QC procedures.

3) Time Step Check Procedures

a) Create a new time step check Excel workbook from the available template located in the following directory:
\\Pwdoows1\watershed sciences\GSI Monitoring\Monitoring Database\GSI_QAQC_Database_Templates. The time step check Excel workbook is used to compare and standardize the date and time for the barometric pressure sensor data and the water level sensor data.

b) GSI Monitoring data are usually recorded in 5-minute increments, which has been shown to be a good compromise between responsiveness to water level changes and the logistics of deployment length. If, as a result of evaluating the data, or in the opinion of H&H analysts, the measurement interval should be changed, the standard time column can be adjusted for different time steps by changing the values in the Excel formula. For example, (1/60)/24 is for 1-minute time steps, (5/60)/24 is for 5-minute time steps.
Note that errors or inconsistencies could be present within the data record(s) even if beginning and end times match. A simple scan of the data is probably sufficient to detect these errors.

c) Save the time step check workbook according to the following naming convention:
timestep_check_[SMP_ID]_[Sensor_ID]_ [Monitoring Device ID]_ [YYYYMMDD-YYYYMMDD]_[YYYY-MM-DD]_[initial].[extension]
e.g., time_check_690_9951601_OW-1_20120718-20120927_2012-10-12_EL.xls

4) QAQC Excel workbooks

a) Water level data is processed and analyzed on a quarterly basis. For a new site or new quarter, create a new water level data workbook from the QA/QC template. The water level data QA/QC sheet templates are located here: \\Pwdoows1\watershed sciences\GSI Monitoring\Monitoring Database\GSI_QAQC_Database_Templates**”.** Save the workbook in the appropriate folder by SMP or Project Name, while using the following naming convention:

b) [SMP_ID]_[Sensor_ID]_ [Monitoring Device ID]_[Q3-12]_QAQC_[YYYY-MM-DD]_[initial].[extension] *e.g.*, 690_9951601_OW-1_Q3-12_QAQC_2012-10-12_EL.xls

c) Barometric compensation data from the time step check excel worksheet can be pasted directly into the “Data” worksheet of the QA/QC workbook you just created. Only column D “Dtime Baro” and column E “Abs Pres Baro (psi)” need to be pasted into the QAQC sheet for barometric data (note that temperature data collected by the barometric pressure sensor are not used).

d) Water level data from the time step check Excel worksheet can be pasted directly into the “Data” worksheet of the QA/QC workbook. Only column E “Date Time, GMT-04:00”, column F “Abs Pres, psi” and column G “Temp, ºF” need to be pasted into the QAQC sheet for barometric data. The “Date Time, GMT-04:00” column should be rounded to the nearest “Standard Dtime” on the sheet (*e.g.*, if barometric data time starts at 14:47:23 and water level time starts at 14:46:10, paste all the data starting at 14:45:00). This will make future data manipulation easier. If the data loggers are launched correctly then the sensors Dtime and the standard Dtime should be equivalent.

e) Query the appropriate PWD Rainfall database to obtain 15 minute final data for the appropriate rain gage and then paste this data into the RainFall Data worksheet. When establishing a new site, consult with the H&H Modeling Group to determine if there are any data quality issues with the nearest rain gage. The best place to acquire 15 minute rainfall data is in the PWDRAIN2010 Access database located in the directory “\\pwdoows1\Modeling\Data\H&H Databases\PWD Raingauge”. Do not unzip to edit this file on the server! Create a copy of this database on your computer. With the database the table named final(2012) contains the appropriate 15 minute rainfall data. It should be noted that rain data will at times not synchronize with the continuous monitoring equipment which is kept on Eastern Standard Time. Analysts inspecting the data should take care to note when daylight savings time occurs for the year in question, and according to their best judgment temporally synchronize the data. When inserting rainfall data into spreadsheets use the "paste special" command to paste only the values in the rainfall data columns used by the charts.

f) The monthly plot worksheets should update automatically and display all the data after the values are pasted into the data tab. A rainfall plot and a water level plot will be created for each month. The x-axis of each plot is fixed to display the entire month. The y-axis may need to be adjusted to properly display the data. If various time steps are utilized among deployment then the plots will need to be adjusted to display the desired data.

g) Review the monthly water level plots for periods of erroneous data. Examples of erroneous data include travel data (*i.e.*, observations logged at times when the sensor was not properly installed in the well) data that was collected during the beginning of the monitoring period when the temperature sensor had not yet had time to come to thermal equilibrium with the water temperature in the well; negative water level data; water level spikes not associated with rainfall; Remove bad data records and record information about the period removed and why on the QA/QC “Removed Data” worksheet. When removing bad data, only delete the values in the “Corrected Water Depth (ft)” column in the “Data” tab.

h) Review the water level data for evidence of sensor drift. If adequate water level measurements are available and confirmed evidence of sensor drift, then minor monotonic sensor drift may be corrected by applying a time-weighted linear correction function. More serious instances of apparent sensor drift should be investigated more thoroughly before applying any corrections to the data.

i) Once all the data have been thoroughly checked, copy the data from the "Data" worksheet and then paste-special-values into the "Final_Import_Site" worksheet while keeping the headers. Then save the Excel QA/QC workbook and close.

3.2.2 Use of Alternative Sources of Barometric Pressure Correction Data

Due to unforeseen circumstances (*e.g.*, sensor failure, vandalism, loss or theft) it may be necessary to use alternative sources of barometric pressure correction to salvage water level observation data. When an alternative source of correction data is used, final data reports should contain information about the source of correction data, frequency of recording, distance from the GSI monitoring location, and an assessment of the degradation of water level accuracy that would be expected to result from using the alternative source rather than a local source of correction data. In practice, the PWD GSI monitoring program has already achieved a sufficient density of monitoring sites such that using correction data from the nearest neighboring deployment is usually the preferred alternate source of barometric pressure correction data.

If a source of barometric pressure data other than a local pressure transducer is used, barometric data may require interpolation in order to match the frequency of water level observations. For example, meteorological data from the National Oceanographic and Atmospheric Agency Climatological Observation Stations Network record barometric pressure at 1 hr intervals. Linear interpolation is the recommended method of interpolation.

3.2.3 Green Stormwater Infrastructure Monitoring Database

A Relational Database Management System (Microsoft Access) was created to store information about water level sensors, monitoring devices, deployments, and links to individual databases storing water level data (Table C-1). The Access application allows for relationships (*i.e.*, joins) between database fields in separate tables and for enforcement of referential integrity between these fields (Figure C-3). In addition to information specific to GSI monitoring, the database also contains "snapshots" of queries from a separate database application created by the GSI Implementation group to plan and track implementation of GSI projects. It is expected that this database will be improved over time, and this Standard Operating Procedure (SOP) document will be updated as needed to describe changes to the database structure.

3.2.3.1 Database Structure

Table C-1: Green Stormwater Infrastructure Monitoring Database Tables

Table Name	Description
t_Sensors	Level Sensors and Manufacturer Information
t_Mon_Loc	Monitoring Locations
t_Deploy	Deployment Information
t_Level_Obs	Water Level Data from Spot Measurements
t_SMP	SMP Information*
t_System	System Information*

* Exported from GSI Implementation Database

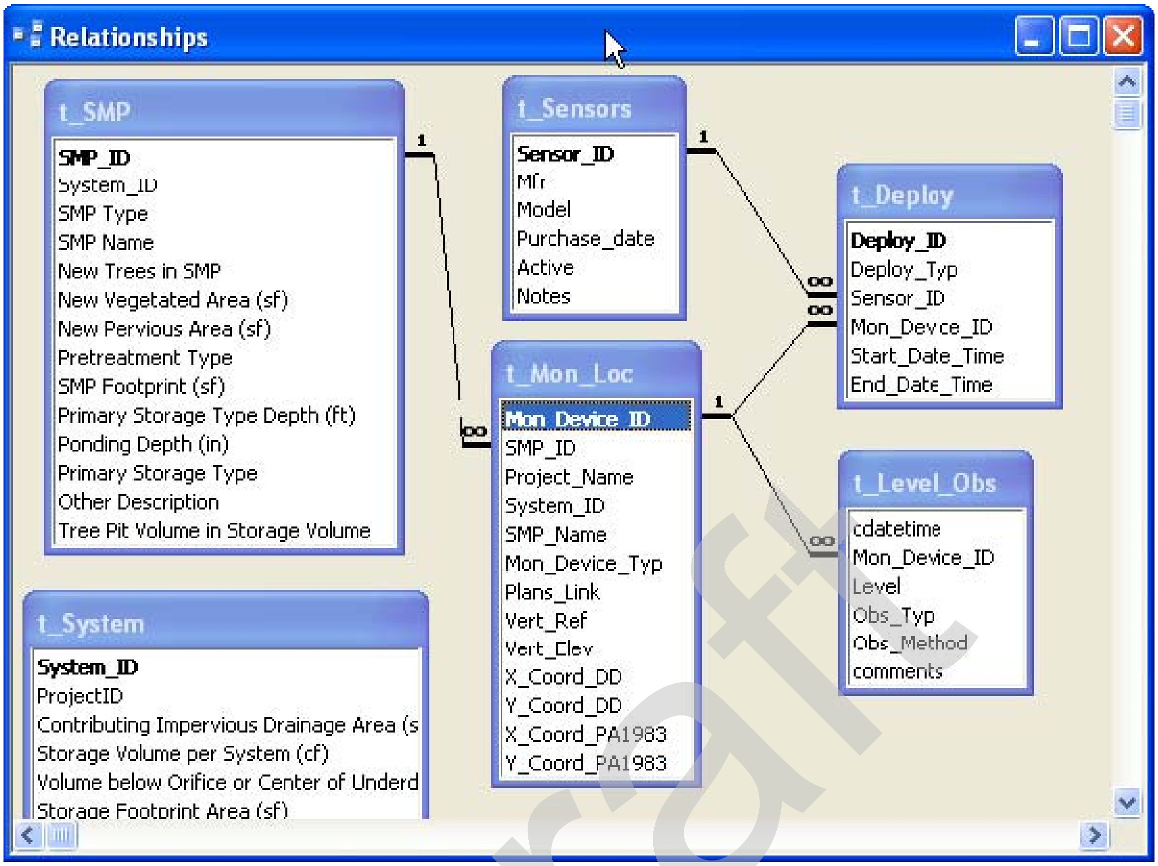


Figure C-3: Green Stormwater Infrastructure Monitoring Database Relationships

3.2.3.2 Importing Water Level Data to Database

Final corrected water level data for each deployment are saved as CSV files and imported into Access databases created for each site, which are linked from the master GSI Monitoring database. Data are currently updated using the File>Get External Data>Import from File facility within Access. It is expected that the process of updating these database will be improved over time, and this SOP document will be updated as needed to describe changes to the database structure.

3.2.3.3 Running the Infiltration Calculation R Program

The program files and procedures are located in the following directory:

\\Pwdoows1\watershed sciences\GSI Monitoring\Infiltration Calculation Program

4.0 Data Analysis and Interpretation

4.1 Overview

Pressure transducers are used to monitor the water surface elevation within GSI practices. A significant amount of information relating to the performance and maintenance of GSI can be inferred by analyzing the water surface elevation data along with precipitation estimates from a nearby rain gage. A three month pressure transducer deployment within a PWD GSI project located on Montgomery Ave from Blair St to Frankford Ave. is used herein as an example to illustrate monitoring and data analysis concepts. The deployment began on 8/26/2011 and ended 11/23/2011, recording data from 16 discrete wet weather events (Figure C-4). Data were processed with Microsoft Excel and R as described in section 3, Data Processing.

This information is provisional as a complete year of data is typically preferred before making any assumptions about a hydrologic process. A full year of data gives a clearer picture of seasonal changes in soil properties as well as providing a larger sample population from which to draw significant conclusions. It is beyond the scope of this SOP document to describe all possible conditions that could be interpreted from these analyses. PWD will continue to update this document with additional case studies as additional data are collected.

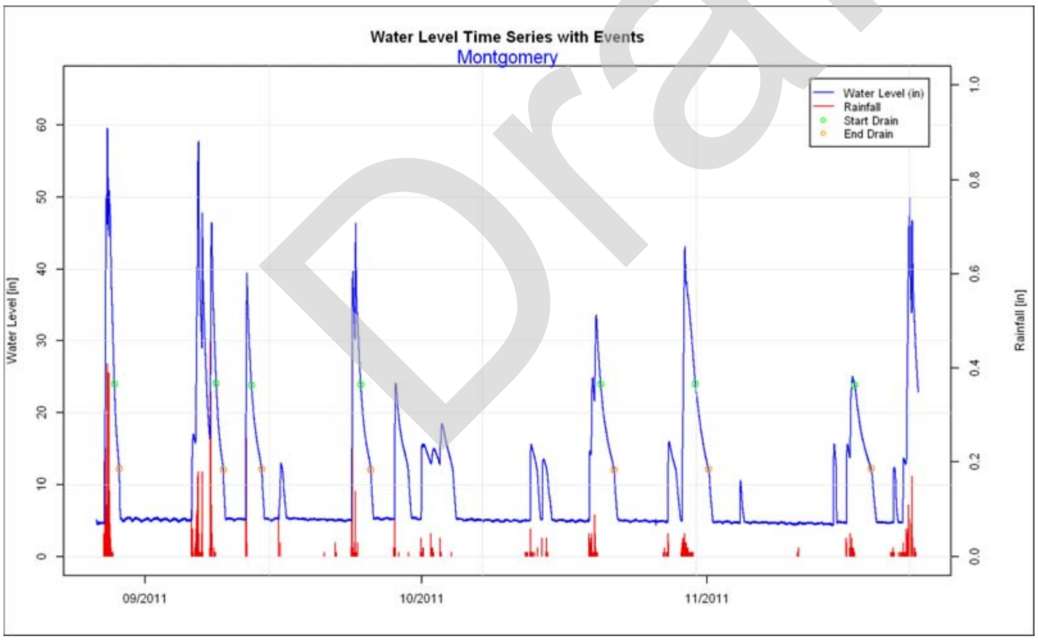


Figure C-4: Water Level and Precipitation Data for Sensor Deployment in Montgomery Ave. Stormwater Management Practices

4.2 Qualitative Analysis of Storm Hydrograph Plots

As described above in section 3, data processing, it is important to plot water level and rainfall data to verify that expected patterns are present. Generally, water level within the SMP should increase rapidly due to stormwater runoff. The recession rate, or decrease in storage volume should be more rapid when there is greater hydraulic head driving infiltration and/or flow through the slow release orifice, if present. Discrete rain events are best suited to this type of qualitative analysis, so the record should be reviewed for representative storms. Data from the Montgomery Ave. SMP deployment were found to generally conform to this expected pattern (Figure C-5). In general, unusual results may be observed for storm events in which rainfall was not distributed evenly, and poorer agreement should generally be expected the farther the rain gage is from the SMP. Variability in the recession rate should be expected seasonally depending on temperature, and to some degree, between storms, due to antecedent soil moisture conditions and other factors.

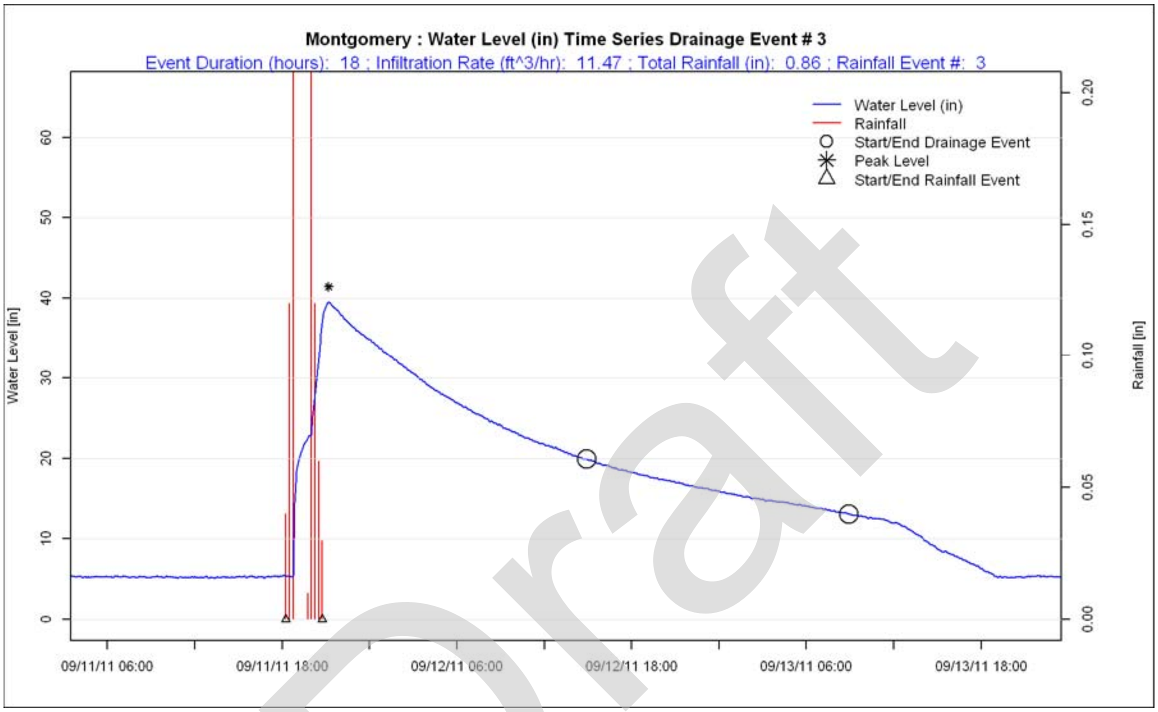


Figure C-5: Water Level and Rainfall Data from Montgomery Ave. Stormwater Management Practices, Storm Event 9/11/2011

Qualitative analysis can potentially identify construction defects, as well as transient or chronic conditions such as clogging. For example, if an SMP fails to fill up despite adequate stormwater runoff indicated in the rainfall record, it may be the case that inlets or distribution pipes are clogged or some other condition is causing stormwater runoff to bypass the system. Unusual inflections in the receding limb of the hydrograph could indicate leaks in the system and provide information about at what elevation within the system the leak is located. Conclusions should only be drawn based on a sufficient number of storms, as anomalous data should be expected given the factors mentioned above. Unusual conditions observed in water level data analysis should be investigated in cooperation with the GSI Implementation and GSI Maintenance groups.

4.3 Quantitative Hydrologic and Hydraulic Analysis

Beyond the simple qualitative analysis described above, quantitative analysis can be performed using assumptions about SMP dimensions and contributing drainage area. Seldom will putative findings arise from this type of monitoring. However it may become clear that one of the underlying assumptions is wrong. Interpretation of these data requires sound application of engineering principles.

4.3.1 Basic Calculations and Assumptions

In order to analyze the data thoroughly using only continuous water surface elevation, additional information about the site is required. Local precipitation estimates from a nearby rain gage, site drainage area, and a level to volume relationship for the SMP storage are required. The water surface elevation at each time step is a measure of volume stored. The difference between any two time steps is the change in volume. The following mass balance equation can be applied to determine infiltration rate and ET. By analyzing data while precipitation is not occurring the runoff term can be assumed to be zero.

$$\mathbf{\Delta Volume = (Runoff\ )_{IN} - (Infiltration + ET\ + Slow\ Drain\ Orifice\ Flow)_{OUT}}$$

The flow through a slow drain orifice, if present, can be accounted for with the orifice equation. The depth sensor directly measures h, while an assumption must be made about the orifice equation. The Montgomery Ave SMP site was found to have moderate infiltration potential, so a slow drain orifice was not included. In the original design, an underdrain pipe with solid cap was specified, terminating in the grey inlet connected to the combined sewer system. In this configuration, the solid cap can be subsequently drilled to provide slow release if necessary to meet draindown time requirements. The site was modified from the original design to have an overdrain, rather than an underdrain. The overdrain is directed to a raingarden located on an adjacent parcel.

$$\mathbf{V_{orifice} = C * Area * sqrt(g * h) * (\Delta t)}$$

The Montgomery Ave site was matched with rain gage 15 in the PWD rain gage network. This gage is located 1800ft to the southwest (Figure C-6). In this particular monitor configuration the sensor was placed within the water table. The bottom of storage provided by GSI is at elevation 10", so sensor readings below this elevation are not indicative of storage volume and are thus not used.

In order to evaluate inlet capture efficiency and verify SMP dimensions and drainage area assumptions, the total depth of rain is measured at a rain gage and the total depth of runoff (in inches) is estimated from the peak depth of storage observed within the SMP during an event. This analysis assumes that no significant infiltration is occurring during precipitation. For a rain event that occurred 9/7/2011, the Montgomery Ave. SMP filled to a depth of approximately 45 inches, which is approximately equivalent to 1.9 inches of runoff (Figure C-7). The rainfall total for this event was recorded as 1.93 inches. As the SMP contributing drainage area is highly impervious with little chance for infiltration or interception, this result appears to validate SMP dimensions and drainage area assumptions and suggests that water is being captured by the inlets and moving through the system as designed. The double mass analysis in section 4.3.2, below, demonstrates how this relationship may be tracked cumulatively throughout the deployment.

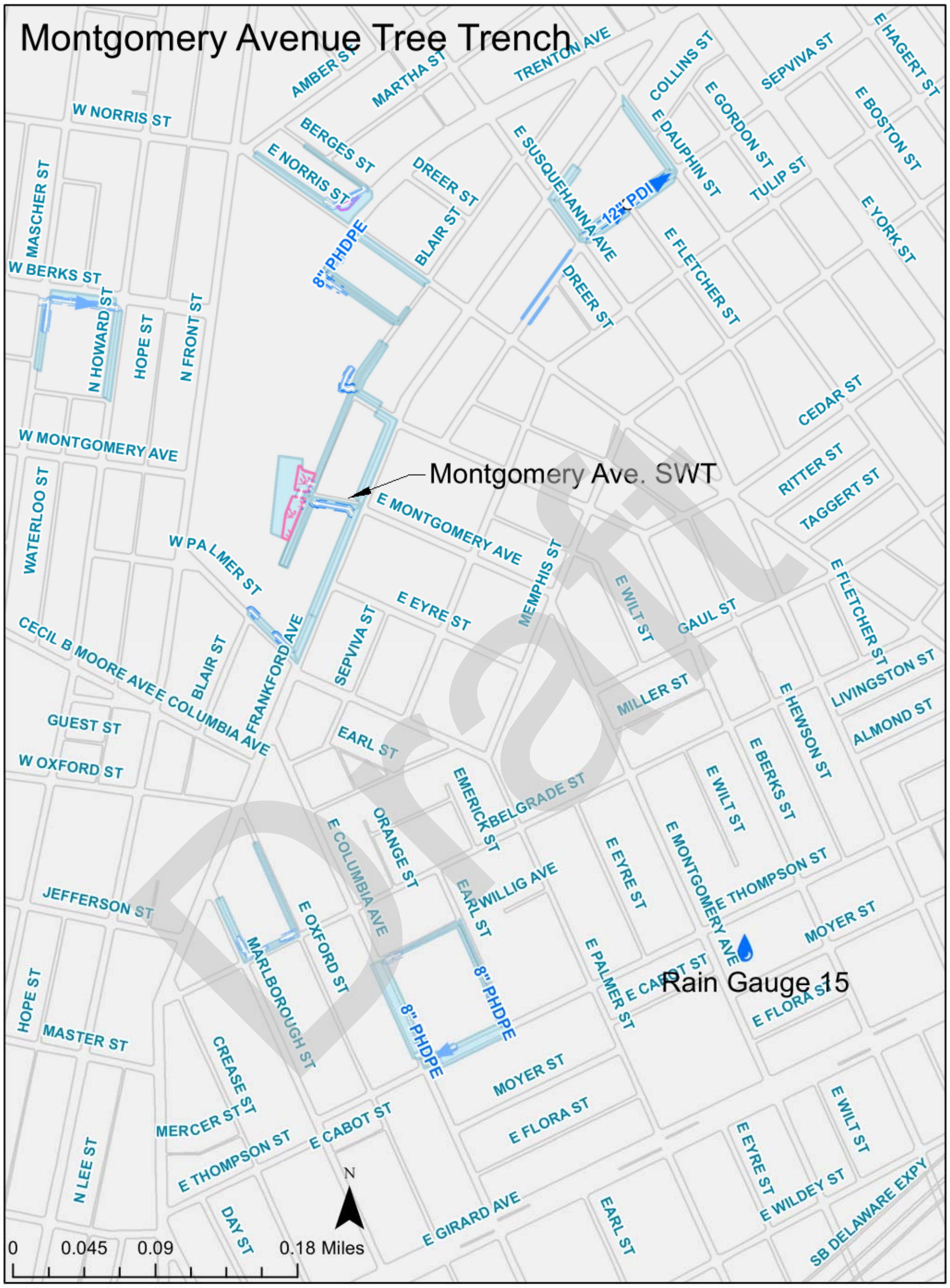


Figure C-6: Montgomery Ave Stormwater Management Practice and the Water Department rain gage #15 location

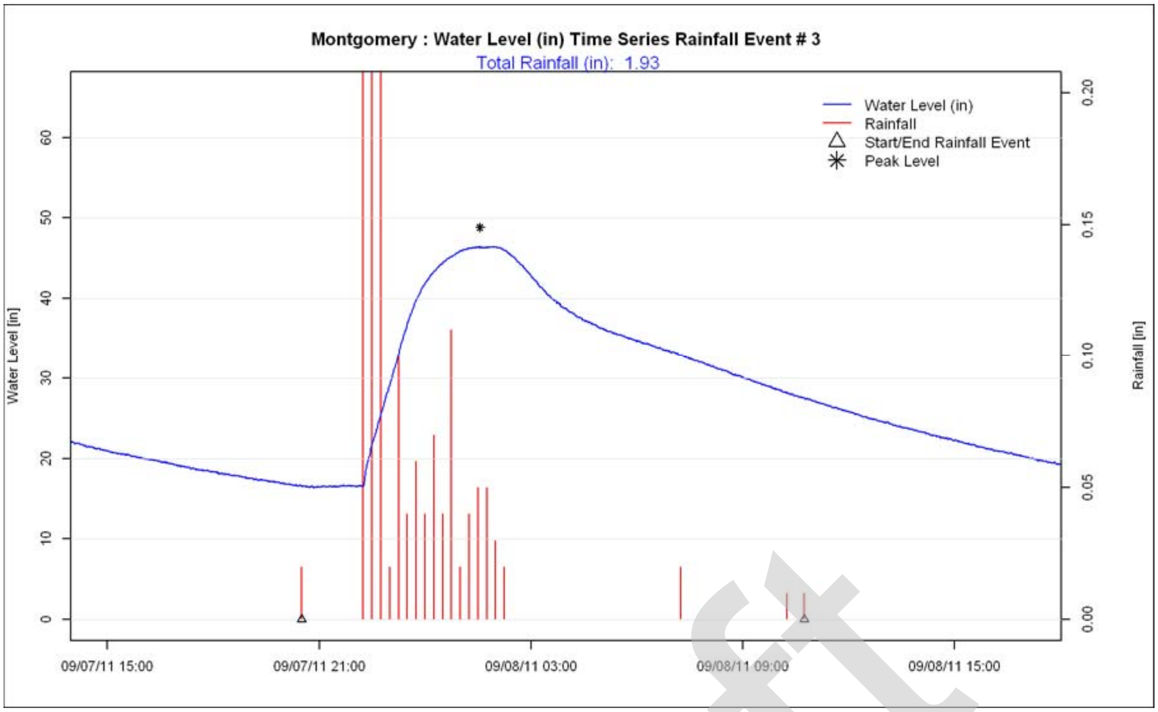


Figure C-7: Water Level and Rainfall Data from Montgomery Ave. Stormwater Management Practices, Storm Event 9/7/2011

4.3.2 Double Mass Analysis

Double mass analysis is a commonly used technique in hydrologic analysis. It is useful in determining whether or not conditions are changing relative to previous observations. The technique is employed here to track stormwater runoff capture (storage volume as determined by water level within the SMP vs. runoff volume as calculated from rainfall data), which is in practice a measure of inlet efficiency. However, it should be noted that changes to the underlying assumptions about site conditions could also cause divergence from the 1:1 trend. For example, if the contributing drainage area increased (*e.g.*, due to disconnection of nearby roof leaders) the site would appear to be capturing more runoff than predicted by rainfall data. Conversely, if drainage area decreased (e.g., due to repaving activity that changes the surface profile of a contributing street) the site would appear to be under-capturing stormwater runoff.

Precipitation measured at rain gages are point estimates of precipitation and may contain some level of error. The error can be compounded with distance between GSI and rain gage, rain gage maintenance, and by how spatially varied each precipitation event is. For these reasons, a significantly large data set is required for double mass analysis.

The slope of the best fit line through the regression can be taken as a measure of the inlet efficiency. A slope of 1 indicates the inlet is capturing 100% of the runoff. If the slope of the line decreases over time, the site most likely has issues with inlet maintenance. This analysis provides design feedback on inlet selection and inlet maintenance frequency.

Over three months, Montgomery has shown a close relationship between peak stored runoff within GSI and precipitation (Figure C-8). This suggests the inlets were designed well and there are currently no maintenance issues at the site.

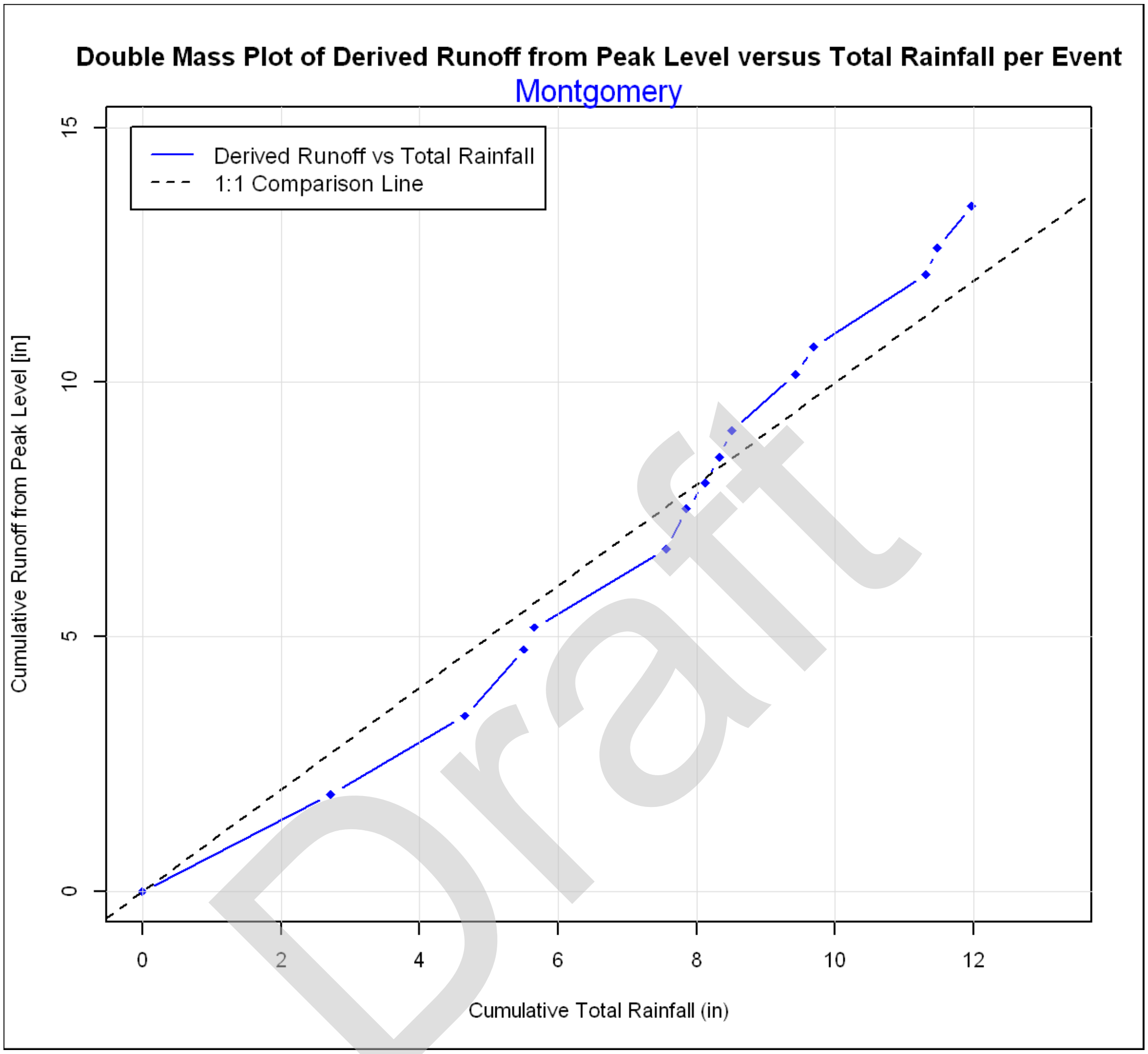


Figure C-8: Double Mass Analysis of Peak Derived Runoff vs. Precipitation for 16 Storm Events at Montgomery Ave. Stormwater Management Practices

4.3.3 Estimate of Infiltration Rate

Estimates of infiltration rate are important for assessing the performance of GSI in reducing the frequency and volume of overflows from the Combined Sewer System. Infiltration determines the rate at which storage volume becomes available following a precipitation event. The lower the infiltration rate, the more time the storage volume within GSI is unavailable for the next precipitation event. This relationship is explored further in section 4.3.4 Cumulative Frequency Distribution of Water Surface Elevation.

Ideally, an understanding of the saturated hydraulic conductivity of the soils would be compared over time; however this cannot be determined from knowledge of the water surface elevation and precipitation alone. In order to measure the saturated hydraulic conductivity, the soils must first be saturated, which does not occur for each precipitation event. Additionally, the hydraulic head across the system must be known. While the hydraulic head in the GSI system is known, the wetting front of the soils beneath the GSI is not known from this instrument configuration. For these reasons, rather than estimating saturated hydraulic conductivity, only the infiltration rate is estimated.

In an attempt to limit uncertainty between measured infiltration rates, the data has been analyzed for only events that meet certain predetermined criteria. Only data for events with falling water surface elevation from 24 in. to 13 in. with no precipitation occurring was analyzed for the Montgomery Ave. SMP initial 3 month deployment (Figure C-9). This restriction helps to ensure that for all events analyzed the system was relatively saturated in that it filled to at least 24 inches. Choosing a maximum elevation value that is too high will result in few events being identified from the data record. The hydraulic head driving infiltration was assumed to be consistent within this depth range for all events. If the storage volume measurement interval is changed, then the entire period of record should be subsequently re-analyzed to keep the assumption that hydraulic head is consistent among events, eliminating hydraulic head variability as a confounding factor.

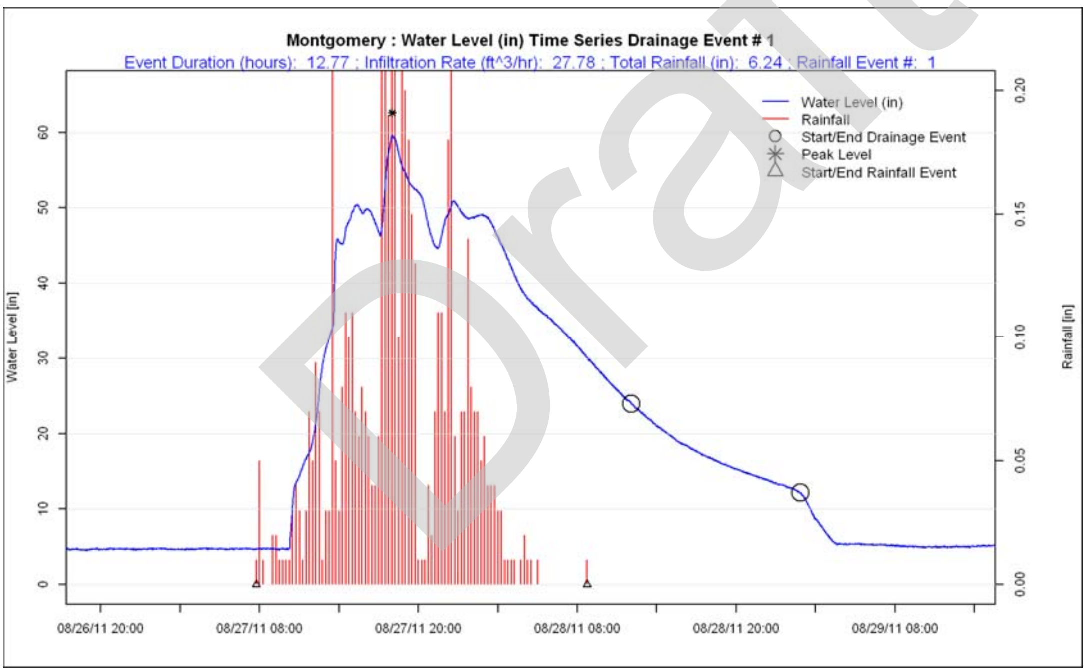


Figure C-9: Montgomery Ave. SMP Infiltration Calculations for Storm Event 08/27/2011

Applying these criteria resulted in seven storm event recession periods for which estimates of infiltration rate were made. Estimated infiltration rate decreased from 30 ft^3 / hour to approximately 7 ft^3 / hour (Figures C-10 and C-11). This pattern of decreasing infiltration result is expected from summer to fall as evapotranspiration decreases. A complete year of data could validate whether or not this decrease can be attributed purely to seasonal changes.

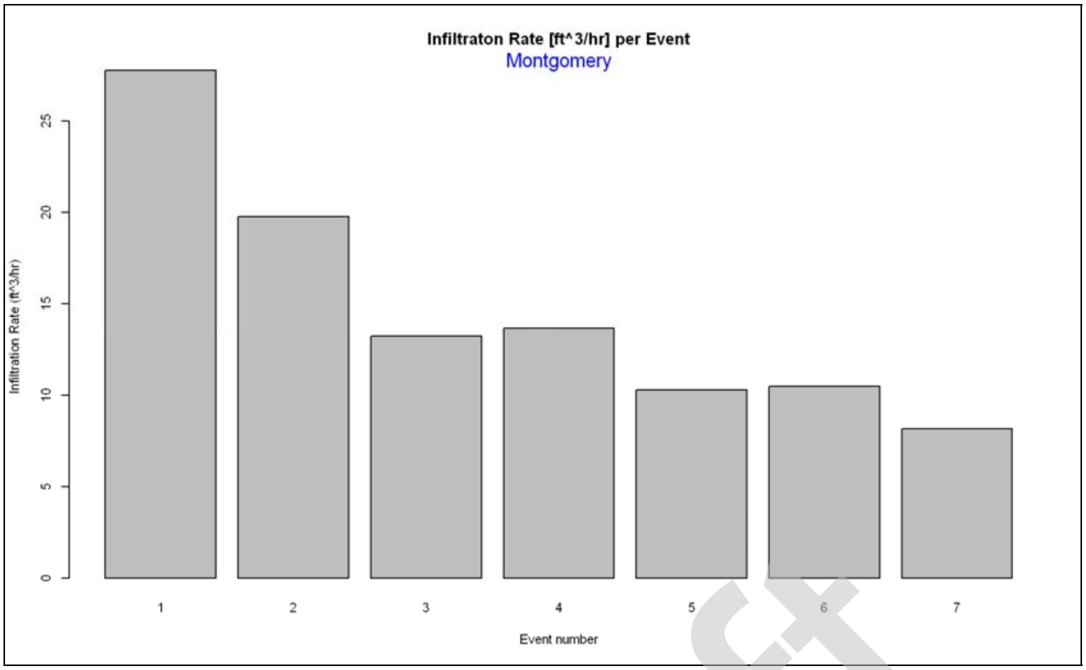


Figure C-10: Bar Plot of Calculated Infiltration Rates for Montgomery

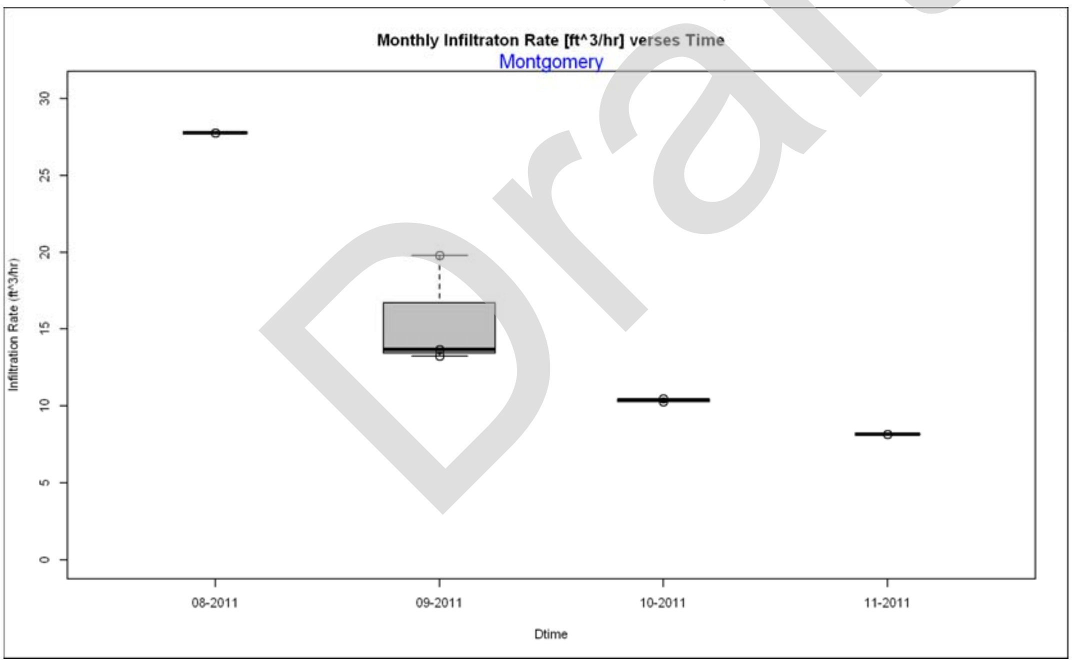


Figure C-11: Box Plots of Infiltration Rate by Month

Infiltration rate estimates can be very useful in operation and maintenance of GSI systems. At sites where infiltration was originally assumed to be minimal, a slow drain orifice is typically installed to connect the system to the sewer system. If infiltration is calculated to be significant, the site can be retrofitted to either reduce or remove the orifice to allow for additional combined sewer overflow (CSO) capture and groundwater recharge.

4.3.4 Cumulative Frequency Distribution of Water Surface Elevation

A cumulative frequency distribution (CFD) plot of water surface elevation gives an understanding of the proportion of time a GSI system is holding water. This information is useful in determining if the system is draining down between events. If a system is not draining down completely between events, the ability of GSI in reducing CSO is diminished. Additionally, a system that is not draining may require mosquito breeding considerations.

In some sites, the percentage of time the system remains wet may have implications for vegetation within the GSI. Some plants may have maximum or minimum requirements for percentage of time wet. This feedback may allow for a more informed selection of vegetation if the vegetation is located within the ponded area. Based on a 3 month deployment, the Montgomery Ave. SMP is dry roughly 66% of the time. The system is only completely full 1% of the time (Figure C-12).

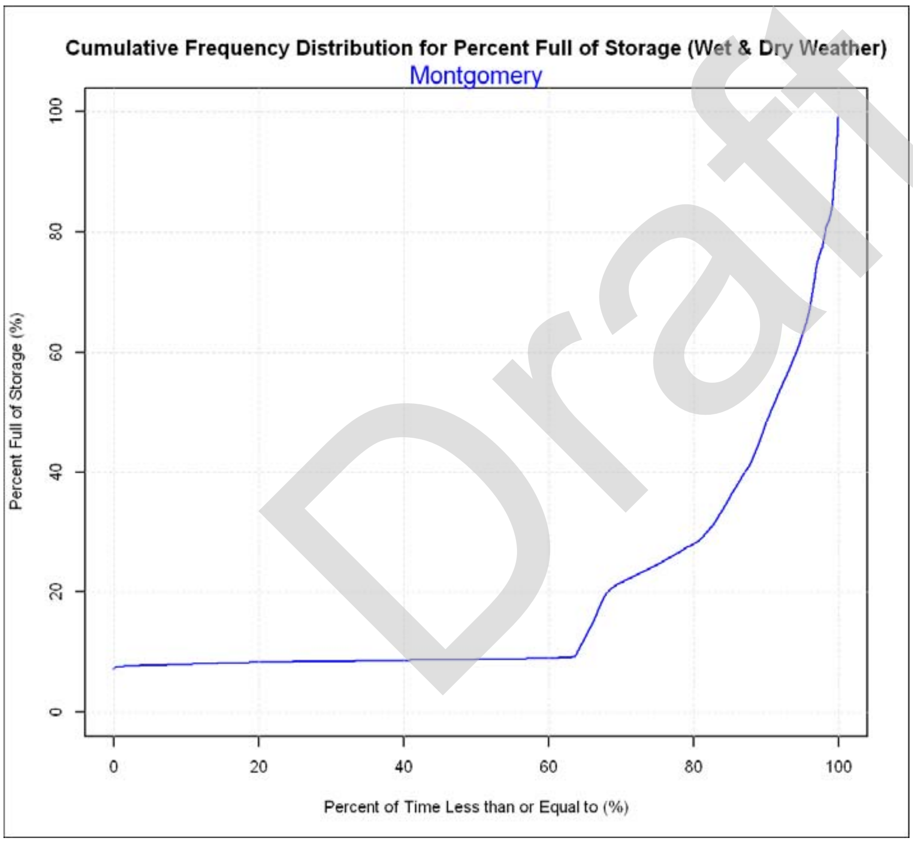


Figure C-12: Cumulative Frequency Distribution Plot of Water Surface Elevation

4.4 Additional Analyses and Case Studies

The primary focus of the initial phase of the GSI Monitoring program is to identify and develop cost effective and practical methods to assess the performance of GSI practices. As more projects are built and additional research objectives are identified, PWD will implement additional data analysis procedures. During the next five years of the *Green City, Clean Waters* program, PWD will continue to update this SOP document with additional examples and case studies as they become available.

5.0 Reporting

For each site at which a water level sensor was deployed for at least 3 months an annual report is prepared documenting the results of monitoring. Plots similar to the examples above will be presented along with preliminary narrative assessment of performance for each SMP. The annual report will be completed each year in September and included as an appendix in the PWD CSO Permit Annual Report.

6.0 Health and Safety Information

When working in the right of way adhere to PWD safety standards. Utilize road cones, signs, and safety tape to properly identify and isolate work areas and possible hazards. Use hard hats, safety gloves and protective eye wear where applicable.

7.0 Public Relations Guidelines

While working in the field you may be approached by residents or other members of the public. Remember that when working in the field you are representing PWD, and always conduct yourself appropriately. Residents may express concerns about basement flooding, safety, project aesthetics, or perhaps even PWD issues unrelated to the Green City Clean Waters program.

Do:

- Try to find a time and place where you can have a conversation with the person.
- Move away from traffic, generator, etc.
- Make eye contact
- Assume a friendly position and body language
- Listen to what the person has to say
- Explain what you are doing
- Have a fact sheet on site that explains the program
- Know the appropriate phone numbers for other PWD questions (215-685-6300)

Don't:

- Jeopardize data quality or safety
- Talk to people at length
- Allow yourself to be distracted
- Engage a person who is hostile
- Make promises about what PWD will or won't do

Appendix D

The Water Department's Standard Operating Procedures for Simulated Runoff Testing of Green Stormwater Infrastructure Practices

Appendix D Table of Contents

1.0 Introduction

This section describes the Philadelphia Water Department's (PWD) procedures for performing simulated runoff tests and water level measurements in observation wells and other monitoring devices located within Green Stormwater Infrastructure (GSI) Stormwater Management Practices (SMPs). The primary goal or objective of this document is to outline a process that provides meaningful and accurate hydrologic data to inform design, modeling, and performance estimates working in conjunction with other groups within PWD such as GSI Maintenance, GSI Implementation, and Hydrologic and Hydraulic Modeling. It is suggested that at least 3 people participate in the administration of this procedure due to the manual readings required, equipment used, and safety concerns when operating in the public right of way. This document will be updated frequently as monitoring and data analysis methods are refined during the first five years of implementation of the *Green City, Clean Waters* program. The most up-to-date version of this document is available on the PWD Office of Watersheds server at the following path:

\\pwdoows1\Watershed Sciences\GSI Monitoring\SOPs\SOP_SimulatedRunoffTesting_MM_DD_YYYY.doc

2.0 Simulated Runoff Testing Procedures

2.1 Office Tasks and Preparation

1.) Synchronize laptop and camera clocks with official U.S. time (http://www.time.gov/timezone.cgi?Eastern/d/-5)
2.) Check batteries in all equipment, verify SD storage card is in camera
3.) Use current Fire Hydrant operating form (\\Pwdoows1\Watershed Sciences\GSI Monitoring\Hydrant Use\Hydrant Operation Reports\Hydrant Op. Report-Template.xls)
4.) Use current Simulated Runoff Testing Field Report form (\\Pwdoows1\Watershed Sciences\GSI Monitoring\Field Forms\SRT_field_report_20121105.doc
5.) Prepare field forms by exporting information from GSI Monitoring Database for the SMP that is being tested.
    a. Database name: GSI_Monitoring.mdb
    b. Database location: \\pwdoows1\Watershed Sciences\GSI Monitoring\Monitoring Database\
    c. Determine Project Name and Project ID for each site to be visited.
    d. For each SMP, determine the monitoring device ID(s) and if sensors are already deployed.
    e. Determine the vertical reference elevation for each monitoring device (*e.g.*, well cap, top of PVC well pipe, etc.).
    f. Determine the source of barometric pressure correction
    g. PWD contact name and local contact name if present in the database
    h. Determine nearest rain gage.

i. Determine whether there has been significant (> 0.05 in) rainfall within the past 24hrs and document on Simulated Runoff Testing Field Report.

6.) Plan a route and print maps/directions if necessary.
7.) Verify that hydrology delineated in Engineering Record Viewer matches site conditions (Check that there's no directly connected impervious areas that could contribute drainage. If there are recalculate drainage area (But **DO NOT** change drainage area in database).
8.) Use verified drainage area to calculate 1" storm (or other design storm in question) using rational method and determine target flows and volume to be applied to the SMP in question. Excel worksheets can be found here (\\pwdoos1\Watershed Sciences\GSI Monitoring\SOPs\Simulated Runoff Testing\SRT_ModeledResults_20121119.xls) Do not exceed the 1" per hour storm or apply flow to the SMP for more than two hours.
9.) Verify that water meters to be used in procedure (From Section 2.2 Equipment Check List) will accommodate the target flows.
10.) Prepare water level logger (Typ. Hobo (U20-001-04)) by verifying functionality (deploy to bucket of water)
11.) Review Hydrant Operating Procedure (\\Pwdoows1\Watershed Sciences\GSI Monitoring\Hydrant Use) and contact appropriate PWD personnel if you have not received training to safely operate Fire Hydrants.
12.) Verify that hydrant can produce necessary flows to replicate design storm. Check the estimated pressure at the hydrant and corresponding flow rate.
13.) Verify that the tools for operating the closest hydrant to the site in question are correct and current.
14.) Post no parking signs the day before or day of, if required.
15.) Make sure each participant is familiar with the procedure and knows the specific tasks they will be responsible for. If three people are participating it is recommended that the following division of tasks be used while flow is applied.
    1. Taking manual readings at water meter, and keeping master time record.
    2. Taking manual readings at observation well and/or control structure.
    3. Photo Documenting site, Interacting with public, and ensuring safe operation of all equipment.
16.) If any of the following conditions are true the simulated runoff test cannot be administered.
    1. Rain is forecasted 24 hours preceding the planned test date.
    2. Rain is forecasted 48 hours following the planned test date.
    3. Temperature is at or below 0 degrees C/32 degrees F.
    4. Unsafe field conditions as determined by personnel administering the performance testing.
    5. Presence of excessive sediment in the area of flow application that cannot be removed.
    6. Any other arbitrary or unconsidered condition that may occur and be deemed unsafe or considered to significantly impact the results of the test.

2.2 Equipment Checklist

Equipment is organized in three separate lists. Sensitive electronic equipment and field forms should be stored separately from hand tools.

1.) “Clean Bag”

- Laptop with HOBOware software
- Optical USB shuttle and USB cable
- Clipboard and pencils
- Field forms and permits
- Digital camera
- Information resources for residents

- Water Level Loggers - Typically Hobo (U20-001-04) Continuous Water Level Logger
- Deployment Dependent on site but typically to include monitoring well locations and barometric pressure correction (minimum of 2 Water Level Loggers).

2.) “Tool Bag”

- Electric tape with extra battery
- Ruler or solid metal bar for horizontal reference measuring point
- Tape measure
- Flashlight
- Key(s) for control structure, padlocks etc. needed to access facilities
- Ratchet and socket for well caps
- Hammer
- Small pry bar or chisel
- 2 flathead screwdrivers
- Stainless steel cable (1/16" diameter) (x number of Water Level Loggers to be deployed)
- Wire cutter/Crimping tool
- Carabiners
- Ferrules
- Work gloves
- Safety goggles
- Safety Vest or High Visibility Shirt
- Traffic Cones
- Hose Ramps
- Green Street Hydrant Testing Sign
- Shop rags
- Bottle brush or pipe cleaners
- Hand sanitizer
- First Aid Kit

- Hydrant Wrench, CCL Key, and or a Hydra Shield - Depending on hydrant type to be used (All of these wrenches can be obtained at the Stores Warehouse at 29th and Cambria)
- Sand bags to control flow near green inlet

3.) "Hydrant Testing Apparatuses”

- Associated Pipe fittings (TBD) -
- "2 1/2" inch Dia x 100' Long Fire Hose - (Can vary from site to site based on nearest hydrant available, available from PWD).
- Portable Meter Test Equipment - Sensus W-1250 - (http://www.sensus.com/web/usca/water/product-line/portable-meter-test-equipment) or equivalent.
- Swivel Diffuser and associated pipe fittings to be attached to flow meter outflow.

2.3 Simulated Runoff Testing (SRT) Field Procedures

1.) Photo Document the site periodically during the testing procedure. Try to document from consistent locations. Make sure to document metered location, inlet, and any point of interest where the water budget can be observed.
2.) Where able video document the procedure.
3.) Sketch a site layout showing equipment locations, SMP inlet points, and measurement points. Note where cars could or do impede the administration of the test.
4.) Setup safety cones or safety tape near inlet, around metering device, and hydrant.
5.) Locate the site and monitoring device(s), inspect the site for any unusual conditions and establish appropriate safety measures such as cones or pedestrian barriers.
6.) Document site conditions via photos, making sure to take pictures of inlets, inside inlets where able, vegetation, monitoring well locations, and hydrant location noting conditions on the field reporting form.
7.) Remove cap from observation well or otherwise gain access to the monitoring location such as control structure, etc.
8.) Take a manual water level reading before beginning any flow testing, pre-wetting or removing any sensors (see Section 2.4 Water Level Measurements with Electric Tape). Record the water level, time, units, and measurement device (*e.g.*, electric tape) on field form where indicated.
9.) If site is currently being monitored follow procedure in Appendix C, Section 2.2 Water Level Monitoring Field Procedure to download data and redeploy sensor and go to section 2.3 item # (18) after completion of that procedure. If no monitoring is currently taking place continue to next item.
10.) Wipe the logger clean and inspect the pressure sensor port for any debris. Carefully clean the port with a bottle brush or pipe cleaner if necessary.
11.) Disconnect the logger body from its plastic cap and connect the optical USB shuttle, observing the correct alignment of flat threading on the logger.
12.) Start HOBOware Pro software.

13.) Connect optical USB shuttle to laptop USB port
14.) Verify device ID in lower left hand corner of interface.
15.) Use a flashlight to inspect, or sound the bottom of the well if possible to determine if there is debris accumulation.
16.) Re-launch the logger (Device>Launch) with 5 minute logging interval on the next interval, recording absolute pressure and temperature. Name the deployment [Sensor_ID]_[SMP_ID]_ [Monitoring Device ID] *e.g.*, 9951601_690_OW1. It is imperative that both sensors are recording at the same time interval. e.g. Both sensors recorded a data point for the time 12:00:00 AM, not one at 12:00:00 and the other at 12:01:30.
17.) Reinstall the sensor in the well by slowly lowering the sensor. Avoid any obstructions such as rebar that may be present within the well. The logger should be hanging freely (*i.e.*, not resting on the bottom of the well) and there should be no cable slack when the sensor is properly deployed. Record time on the field form.
18.) Take a manual water level reading just after installing the sensor per section 2.4 of Appendix C. Record the monitoring device ID, water level, time, units, and measurement device on field form.
19.) See Section 2.3 of Appendix C for installation of Barometric correction.
20.) Reinstall the well cap, ensuring well cap is vented to the atmosphere to allow for proper barometric pressure compensation.
21.) Use Hydrant Operating Procedure from ((\\Pwdoows1\Watershed Sciences\GSI Monitoring\Hydrant Use\Fire Hydrant Operation Procedure.doc) to begin operation of nearby Hydrant.
22.) Once Hydrant is ready, install simulated runoff testing apparatus and associated pipe and hose fittings.
23.) Place Sensus WL 1250 portable water meter with diffuser at either of the following two points depending on if the test seeks to eliminate inlet bypass from the mass balance and if field conditions allow.
    a) At an inflow point such that the discharge from the meter will reach the inlet at approximately steady state (slightly upstream of inlet to allow turbulence to dissipate a specific distance for different flows TBD.)
    b) Remove inlet grate and direct the diffuser such that water will discharge directly into the inlet.
24.) If sand bags are used to minimize bypass ensure that they are safely arranged at the inlet.
25.) Connect fire hoses to hydrant and portable water meter.
26.) Photo Document setup prior to and after applying flow to the system.
27.) Make sure enough time has elapsed from the installation of the water level logger to allow for thermal equilibrium (refer to specific sensor specification sheets for specific time interval, typically 10 minutes for Hobo (U20-001-04)).
28.) Apply flow to the system noting the start time in the field report.
29.) Using the portable flow meter apply the target flow.
30.) Initially observe flow around inlet and adjust sandbags as needed.

31.) Take visual reading of meter every minute of the test beginning when flow is started from the meter. Note the reading on the field report form.
32.) Take manual water level reading in observation well every 15 minutes during the application of flow and for the first hour following cessation of flow to the SMP to validate the observation well readings.
33.) If there is no outflow structure for the SMP being tested, perform the test until the inflow structure is over flowing and bypassing to the storm sewer inlet. Note the time that over flow occurs in the field report form.
34.) Note when or if the inlet or structure feeding flow to the SMP is overtopped.
35.) Take manual readings at monitoring locations as soon as possible if the inlet structure is overflowing. Note on field report time, location, and depth.
36.) During application of flow be sure to note observations of SMP performance. For example if the inlet is experiencing what appears to be 25% flow bypass (estimate visually) note on the field report when it is noticed and if it changes or stops.
37.) Once the hydrant has applied a volume of water equivalent to the target design storm stop the flow from the hydrant, **do not** exceed the total volume of the 1 in per hour storm.
38.) Take another reading in the monitoring well immediately after stopping flow (Independent of the readings taken every 15 minutes). Note on field report time, location, and depth.
39.) Once flow from the hydrant is cut off dismantle simulated runoff apparatus and clean up tools and equipment.
40.) Allow water level loggers to remain in place overnight, or until complete drain-down has occurred. Time interval can be adjusted as if application of these procedures indicates more time is needed according to the observations of the personnel involved.
41.) Using the procedure in Appendix C, Section 2.4, collect the data from the site when the water level loggers are ready to be removed.
42.) Use the following naming convention for data files when saving the continuous water level logger data. SRT_[SMP_ID]_[Sensor_ID]_ [Monitoring Device ID]_ [YYYYMMDD-YYYYMMDD]_[initial].[extension] (ex. SRT_1_9951597_OW1_20121123_20121125_SW.csv)

2.4 Water Level Measurements with Electric Tape

1.) Manual water level readings should be taken with the pressure transducer installed in the well. For new deployments, take a water level reading after deploying sensors initially. When visiting existing sites, record a level reading just before removing the sensor when reading out data from sensor deployments and immediately after redeploying the sensor for its next deployment.
2.) Refer to the monitoring device information to determine the vertical reference elevation for water level readings, (*e.g.*, well cap, top of PVC well pipe, etc.). The vertical reference elevation should be a level surface. Watch for uneven pavement or debris.
3.) Place a horizontal reference object (*e.g.*, ruler, solid metal bar) across the opening of the vertical reference. Bar should be placed perpendicular to curb line of nearest street if possible.
4.) Measure water level at the center of the opening (Figure D-1)

5.) Repeat the measurement, adjusting the sensitivity of the instrument as required, to determine the exact distance to the air/water interface in 1/100ths of a foot.
6.) Record the monitoring device ID, water level, time, units, and measurement device (*e.g.*, electric tape) on field form.

Figure D-1: Manual Water Level Measurement in Observation Well

3.0 Data Processing

3.1 Water Level Data Processing

1) Raw Data Import
   a) Uncorrected water level and barometric pressure data are exported from the HOBOware software and stored as comma separated value (CSV) files using the following naming convention:
   SRT_[SMP_ID]_[Sensor_ID]_[Monitoring Device ID]_ [YYYY-MM-DD].[extension]*e.g.*, 690_9951601_OW-1_2012-09-27.csv
   e.g., 690_9951601_OW-1_2012-09-27.hobo
   (see section 2.2 for more information)
   b) Save these files into the "Raw Data" folder for each SMP. Do not perform analysis within these files and then save! Keep these raw files as the original copies of the data. This will aid in troubleshooting with quality assurance and control (QA/QC) procedures.

2) Time Step Check Procedures
   a) Create a new time step check Excel workbook from the available template located in the following directory: "\\Pwdoows1\watershed sciences\GSI Monitoring\Monitoring Database\GSI_QAQC_Database_Templates. The time step check Excel workbook is used to compare and standardize the date and time for the barometric pressure sensor data and the water level sensor data.
   b) Previous studies and experiences have indicated that a 1 minute logging interval is sufficient to capture the hydrologic processes given the scope of the flow testing. However if, as a result of evaluating the data, or in the opinion of Hydrologic and Hydraulic analysts, the measurement interval should be changed, the standard time column can be adjusted for different time steps by changing the values in the Excel formula. For example, (1/60)/24 is for 1-minute time steps, (5/60)/24 is for 5-minute time steps. Note that errors or inconsistencies could be present within the data record(s) even if beginning and end times match. A simple scan of the data is probably sufficient to detect these errors.
   c) Save the time step check workbook according to the following naming convention: SRT _timestep_check__[SMP_ID]_[Sensor_ID]_ [Monitoring Device ID]_ [data date range(YYYYMMDD-YYYYMMDD)]_[editing date (YYYY-MM-DD)]_[initial].[extension]
   e.g., SRT_time_check_690_9951601_OW-1_20120718-20120719_2012-10-12_EL.xls
3) QA/QC Excel workbooks
   a) For a new site or new test, create a new SRT water level data workbook from the QA/QC template. The water level data QA/QC sheet templates are located here: \\Pwdoows1\watershed sciences\GSI Monitoring\Monitoring Database\GSI_QAQC_Database_Templates" .Save the workbook in the appropriate folder by SMP or Project Name, while using the following naming convention: [SMP_ID]_SRT_[Sensor_ID]_ [Monitoring Device ID]_[Q3-12]_QAQC_[YYYY-MM-DD]_[initial].[extension]
   e.g., 690_SRT_9951601_OW-1_Q3-12_QAQC_2012-10-12_EL.xls
   b) Barometric compensation data from the time step check excel worksheet can be pasted directly into the "Data" worksheet of the QA/QC workbook you just created. Only column D "Dtime Baro" and column E "Abs Pres Baro (psi)" need to be pasted into the QAQC sheet for barometric data (note that temperature data collected by the barometric pressure sensor are not used).
   c) Water level data from the time step check Excel worksheet can be pasted directly into the "Data" worksheet of the QA/QC workbook. Only column E "Date Time, GMT-04:00", column F "Abs Pres, psi" and column G "Temp, ºF" need to be pasted into the QAQC sheet for barometric data. The "Date Time, GMT-04:00" column should be rounded to the nearest "Standard Dtime" on the sheet (*e.g.*, if barometric data time starts at 14:47:23 and water level time starts at 14:46:10, paste all the data starting at 14:45:00). This will make future data manipulation easier. If the data loggers are launched correctly then the sensors Dtime and the standard Dtime should be equivalent.

d) The plot worksheets should update automatically and display all the data after the values are pasted into the data tab.
e) Review the water level plots for periods of erroneous data. Examples of erroneous data include travel data (*i.e.*, observations logged at times when the sensor was not properly installed in the well) data that was collected during the beginning of the monitoring period when the temperature sensor had not yet had time to come to thermal equilibrium with the water temperature in the well; negative water level data; Remove bad data records and record information about the period removed and why on the QA/QC "Removed Data" worksheet. When removing bad data, only delete the values in the "Corrected Water Depth (ft)" column in the "Data" tab.
f) Once all the data have been thoroughly checked, copy the data from the "Data" worksheet and then paste-special-values into the "Final_Import_Site" worksheet while keeping the headers. Then save the Excel QA/QC workbook and close.

3.2 Use of Alternative Sources of Barometric Pressure Correction Data

Due to unforeseen circumstances (*e.g.*, sensor failure, vandalism, loss or theft) it may be necessary to use alternative sources of barometric pressure correction to salvage water level observation data. When an alternative source of correction data is used, final data reports should contain information about the source of correction data, frequency of recording, distance from the GSI monitoring location, and an assessment of the degradation of water level accuracy that would be expected to result from using the alternative source rather than a local source of correction data. In practice, the PWD GSI monitoring program has already achieved a sufficient density of monitoring sites such that using correction data from the nearest neighboring deployment is usually the preferred alternate source of barometric pressure correction data.

If a source of barometric pressure data other than a local pressure transducer is used, barometric data may require interpolation in order to match the frequency of water level observations. For example, meteorological data from National Oceanographic and Atmospheric Agency Climatological Observation Stations Network record barometric pressure at 1 hr intervals. Linear interpolation is the recommended method of interpolation.

3.3 Green Stormwater Infrastructure Monitoring Database

See Appendix C, Section 3.2.3.

4.0 Data Analysis and Interpretation

4.1 Overview

Pressure transducers are used to monitor the water surface elevation within GSI practices. The data from the SRT can be analyzed and interpreted to allow insight into how the SMP is performing.

This information is provisional and meant to inform the department about the estimated performance of the SMP in question. The more simulated runoff tests that are performed on a given SMP the more accurate the results and conclusions about the SMP become. Multiple SRT(s) spread over different climate conditions gives a clearer picture of seasonal changes in soil properties as well as providing a larger sample population from which to draw significant conclusions. It is beyond the scope of this SOP document to describe all possible conditions that could be interpreted from these analyses. PWD will continue to update this document with additional case studies as additional data are collected.

4.2 Qualitative Analysis of Storm Hydrograph Plots

As described above in section 3, data processing, it is important to plot water level and simulated runoff data to verify that expected patterns are present. Generally, water level within the SMP should increase rapidly due to simulated runoff. The recession rate, or decrease in storage volume should be more rapid when there is greater hydraulic head driving infiltration and/or flow through the slow release orifice, if present. In general, unusual results may be observed for tests in which simulated runoff was not distributed evenly. Variability in the recession rate should be expected seasonally depending on temperature, and to some degree, between storms, due to antecedent soil moisture conditions and other factors.

Qualitative analysis can potentially identify construction defects, as well as transient or chronic conditions such as clogging. For example, if an inlet feeding the SMP overflows but fails to fill up it may be the case that inlets or distribution pipes are clogged. Or if the SMP fails to fill up despite an adequate volume of simulated runoff recorded in the data set, there could be leaks or infiltration to nearby sanitary sewer. Unusual inflections in the receding limb of the hydrograph could indicate leaks in the system and provide information about at what elevation within the system the leak is located. Conclusions should only be drawn based on a sufficient number of SRT(s). Unusual conditions observed in water level data analysis should be investigated in cooperation with the GSI Implementation and GSI Maintenance groups.

4.3 Quantitative Hydrologic and Hydraulic Analysis

Beyond the simple qualitative analysis described above, quantitative analysis can be performed using assumptions about SMP dimensions and contributing drainage area. Seldom will putative findings arise from this type of monitoring. However it may become clear that one of the underlying assumptions is wrong. Interpretation of these data requires sound application of engineering principles.

4.3.1 Basic Calculations and Assumptions

In order to analyze the data thoroughly using only continuous water surface elevation, additional information about the site is required. Simulated runoff quantity, site drainage area, and a level to volume relationship for the SMP storage are required. The following mass balance equation derived from the water balance equation can be applied to determine infiltration rate and ET.

$$Q_{in} = Q_{out} + \text{ or } - \text{Change in Storage}$$

Mass balance

$$\Delta h * A * n = \Delta S$$

Change in Storage Volume of SMP(Slow release Orifice) (See Section 4.3 of Appendix C)

$$V_{orifice} = C * A * \sqrt{gh\Delta t}$$

Orifice Discharge equation

Where

S=storage volume in SMP

h = Change in height of water in monitoring device

A=Area of storage footprint associated with monitoring location

n=porosity

Q(in) = Flow in

Q(out) = Flow out

V(orifice)= Flow out of slow release orifice

C=dimensionless coefficient (dependent on the units used)

g=gravitational constant

t = unit of time

A = cross sectional area of orifice

Under the simulated runoff testing conditions Q(in) = Simulated Runoff. Q(out) = Change in Storage in the SMP+ Groundwater Recharge + Evapotranspiration + Inlet Bypass + Orifice Discharge. Plugging these variables in gives the following.

$$R_{sim} = \Delta S + G + ET + B + V_{orifice}$$

Where:

ET = Evapotranspiration

G=Groundwater recharge

B=Bypass

Plugging in for Storage and Slow release orifice from above gives

$$R_{sim} = (\Delta h * A * n) + G + ET + B + \left(C * A * \sqrt{gh\Delta t}\right)$$

Collecting data during the simulated runoff test gives the volume of simulated runoff, and allows calculation of orifice discharge and change in storage. Rearranging for unknowns gives the following.

$$R_{sim} - \left(C * A * \sqrt{gh\Delta t}\right) - (\Delta \mathbf{h} * \mathbf{A} * \mathbf{n}) = G + ET + B$$

Depending on the type of test performed and on which type of SMP this test is performed certain unknowns can be eliminated or combined. For example using the basic tree trench design from PWD the variables in equation above can be defined as:

R(sim) = metered flow from data set

h=height of water in monitoring device from continuous data set

"t" is determined from data set

"A" and "n" are given by design specs or as-built drawings (verify if possible during test)

"C" and "g" are constants

ET was assumed to be negligible for the order of magnitude and set to zero.

Inlet bypass was assumed to be zero and the inlet is assumed to be operating at 100% capture efficiency. (Based on observations from the field can vary.)

With orifice plugged so V(orifice)=0

Using these assumptions the equation describing the water balance for testing a typical tree trench design from PWD becomes:

$$R_{sim} - (\Delta \mathbf{h} * \mathbf{A} * \mathbf{n}) = G$$

Graphing the plot of height in the monitoring location to the time step used in the procedure can indicate where possible system failure is occurring. For instance if the system is bound on all sides by impermeable barriers with percolation occurring only at the bottom of the SMP but the water level height drops sharply after flow is removed for first foot but then begins to drop at a much slower rate than would be expected simply from change in hydraulic head alone it is possible that the system is leaking out of the impermeable barrier(s) somewhere in the top one foot of storage.

Performing the simulated runoff test with the outflow end of the Portable Meter/Diffuser setup angled directly into the inlet can eliminate the inlet bypass from the equation for future case studies without making an assumption. If inlet bypass needs to be determined, performing the test on another day with similar climate conditions in close temporal proximity with the portable meter/diffuser setup discharging to a point upstream of the inlet and comparing the results to the SRT with the diffuser discharging directly into the inlet could allow for an estimate of inlet efficiency under the design storm in question.

4.3.2 Calculating Infiltration Rate

Infiltration rate calculations are scripted with the R Statistical programming language (R Core Team 2012). Refer to "Infiltration" calculation SOP found here:

\\pwdoows1\watershed sciences\GSI Monitoring\Infiltration Calculation Program\SOP_GSI_Infiltration_Performance_Program_121106_EL.doc

When analyzing infiltration rates be sure to note where the boundaries of storage are. For example, when the water level sensor is deployed take note of where the stone storage bed begins in relation to the monitoring equipment location.

5.0 Reporting

For each site at which a Simulated Runoff Testing was performed a report detailing the analysis of the data collected will be created. Plots similar to the examples above will be presented along with preliminary narrative assessment of performance for each SMP tested. The annual report will be completed each year in September and included as an appendix in the PWD Combined Sewer Overflow Permit Annual Report.

6.0 Health and Safety Information

When working in the right of way adhere to PWD safety standards. Utilize road cones, signs, and safety tape to properly identify and isolate work areas and possible hazards. Use hard hats, safety gloves and protective eye wear where applicable. During the administration of the testing designate personnel to monitor and respond to safety issues. Take into account during operation of hydrant the possibility of water hammer effects on the hydrant and review the hydrant operating procedure previously mentioned.

7.0 Public Relations Guidelines

While working in the field you may be approached by residents or other members of the public. Remember that when working in the field you are representing PWD, and always conduct yourself appropriately. Residents may express concerns about basement flooding, safety, project aesthetics, or perhaps even PWD issues unrelated to the *Green City, Clean Waters* program.

Do:

- Try to find a time and place where you can have a conversation with the person
- Move away from traffic, generator, etc.
- Make eye contact
- Assume a friendly position and body language
- Listen to what the person has to say
- Explain what you are doing
- Have a fact sheet on site that explains the program
- Know the appropriate phone numbers for other PWD questions (215-685-6300)

Don't:

Jeopardize data quality or safety
Talk to people at length
Allow yourself to be distracted
Engage a person who is hostile
Make promises about what PWD will or won't do

Appendix E

Summary of Temporary Sewer Flow Monitors

Table E.1 Metering Location IDs, Type, and Deployment Dates for PWD Portable Flow Monitoring Program

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
23	Level, Velocity, Flow	Sanitary	NE	368	08/09/99 - 04/27/00
5	Level, Velocity, Flow	Sanitary	NE	9,401	08/10/99 - 06/13/00
15	Level, Velocity, Flow	Sanitary	NE	187	08/10/99 - 04/10/00
31	Level, Velocity, Flow	Sanitary	NE	380	08/10/99 - 06/12/00
12	Level, Velocity, Flow	Sanitary	NE	613	08/12/99 - 04/28/00
14	Level, Velocity, Flow	Sanitary	NE	181	08/12/99 - 04/28/00
19	Level, Velocity, Flow	Sanitary	NE	369	08/12/99 - 11/03/99
27	Level, Velocity, Flow	Sanitary	NE	685	08/12/99 - 04/27/00
29	Level, Velocity, Flow	Sanitary	NE	251	08/12/99 - 11/03/99
30	Level, Velocity, Flow	Sanitary	NE	275	08/12/99 - 04/27/00
40	Level, Velocity, Flow	Sanitary	SW	4,852	08/12/99 - 09/30/01
18	Level, Velocity, Flow	Sanitary	NE	344	08/30/99 - 06/12/00
32	Level, Velocity, Flow	Sanitary	NE	265	09/20/99 - 06/22/00
41	Level, Velocity, Flow	Sanitary	SW	6,239	11/02/99 - 11/06/01
43	Level, Velocity, Flow	Sanitary	NE	2,430	11/03/99 - 02/14/00
44	Level, Velocity, Flow	Sanitary	NE	1,486	11/03/99 - 06/12/00
T14_Outfall	Level	Combined	NE	NA	01/11/00 - 07/02/01
CSE-0115	Level	Combined	SW	NA	03/05/00 - 09/25/00
R08-A	Level	Combined	SE	NA	04/06/00 - 05/16/00
49	Level, Velocity, Flow	Sanitary	SE	1,972	04/28/00 - 09/12/02
47	Level, Velocity, Flow	Sanitary	SW	227	05/03/00 - 08/27/04
48	Level, Velocity,	Sanitary	SE	868	05/03/00 - 10/10/00

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
	Flow				
51	Level, Velocity, Flow	Sanitary	SW	5,579	05/03/00 - 02/01/01
52	Level, Velocity, Flow	Sanitary	SE	431	05/03/00 - 09/14/00
46	Level, Velocity, Flow	Sanitary	SW	214	05/04/00 - 04/24/01
55	Level, Velocity, Flow	Sanitary	SW	252	06/12/00 - 10/10/00
56	Level, Velocity, Flow	Sanitary	SW	133	06/13/00 - 04/24/01
57	Level, Velocity, Flow	Sanitary	SW	141	06/13/00 - 09/10/01
58	Level, Velocity, Flow	Sanitary	SW	86	06/23/00 - 09/27/01
60	Level, Velocity, Flow	Sanitary	SE	NA	06/28/00 - 02/12/01
71	Level, Velocity, Flow	Sanitary	SE	691	10/13/00 - 04/23/01
70	Level, Velocity, Flow	Sanitary	NE	276	11/10/00 - 07/12/04
72	Level, Velocity, Flow	Sanitary	NE	301	11/13/00 - 06/28/05
11	Level	Sanitary	SW	NA	01/31/01 - 07/18/08
73	Level, Velocity, Flow	Sanitary	SW	68	02/13/01 - 09/10/01
74	Level, Velocity, Flow	Sanitary	SW	90	02/16/01 - 04/24/01
T14-026945	Level	Combined	NE	5	04/20/01 - 05/23/02
T14-026910	Level	Combined	NE	3	04/23/01 - 05/23/02
75	Level, Velocity, Flow	Sanitary	NE	176	05/16/01 - 09/09/04
76	Level, Velocity, Flow	Sanitary	NE	128	05/18/01 - 09/13/02
77	Level, Velocity, Flow	Sanitary	NE	133	07/11/01 - 09/10/02
80	Level, Velocity, Flow	Sanitary	SW	289	09/17/01 - 10/20/04
78	Level, Velocity, Flow	Combined	SW	419	09/20/01 - 09/11/02
79	Level, Velocity, Flow	Combined	SW	109	10/22/01 - 09/09/02
81	Level	Sanitary	SW	678	11/08/01 - 11/21/01

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
82	Level, Velocity, Flow	Combined	SW	202	02/16/02 - 09/10/02
83	Level, Velocity, Flow	Combined	SW	20	02/16/02 - 09/10/02
84	Level, Velocity, Flow	Combined	SW	25	10/18/02 - 05/02/06
85	Level, Velocity, Flow	Combined	SW	98	10/24/02 - 07/28/04
87	Level, Velocity, Flow	Combined	SW	286	04/15/03 - 06/24/03
88	Level, Velocity, Flow	Sanitary	NE	80	04/25/03 - 06/24/03
MSH1	Level, Velocity, Flow	Sanitary	NE	NA	02/02/04 - 05/25/05
95	Level, Velocity, Flow	Sanitary	NE	3,358	06/02/04 - 09/19/07
96	Level, Velocity, Flow	Sanitary	NE	12,433	06/03/04 - 09/18/07
91	Level, Velocity, Flow	Combined	SW	29	07/07/04 - 03/09/06
90	Level, Velocity, Flow	Sanitary	NE	358	08/31/04 - 06/03/08
92	Level, Velocity, Flow	Sanitary	NE	257	09/15/04 - 05/18/05
97	Level, Velocity, Flow	Sanitary	NE	273	09/30/04 - 05/04/05
Q120-05-S0007	Level, Velocity, Flow	Sanitary	NE	NA	11/11/04 - 01/03/05
CT-B0590	Level, Velocity, Flow	Sanitary	NE	NA	11/12/04 - 01/03/05
CT-B0670	Level, Velocity, Flow	Sanitary	NE	NA	11/12/04 - 01/03/05
S50-016995	Level, Velocity, Flow	Sanitary	SW	59	11/12/04 - 01/03/05
T089-03-S0010	Level, Velocity, Flow	Sanitary	NE	NA	11/12/04 - 01/03/05
W086-01-S0165	Level, Velocity, Flow	Sanitary	SW	NA	11/12/04 - 01/03/05
W086-07-S0065	Level, Velocity, Flow	Sanitary	SW	NA	11/12/04 - 01/03/05
P108-08-S0065	Level, Velocity, Flow	Sanitary	NE	NA	11/15/04 - 01/03/05
P108-11-	Level, Velocity,	Sanitary	NE	NA	11/15/04 - 11/17/05

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
S0063	Flow				
T080-01-S0008	Level, Velocity, Flow	Sanitary	NE	NA	11/15/04 - 01/04/05
T080-02-S0010	Level, Velocity, Flow	Sanitary	NE	NA	11/15/04 - 01/03/05
T089-01-S0050	Level, Velocity, Flow	Sanitary	NE	NA	11/15/04 - 01/03/05
WLL-B0790	Level, Velocity, Flow	Sanitary	SW	42	11/15/04 - 01/03/05
PP-B1075	Level, Velocity, Flow	Sanitary	NE	NA	11/16/04 - 01/03/05
T089-02-S0010	Level, Velocity, Flow	Sanitary	NE	NA	11/16/04 - 01/04/05
W086-07-S0040	Level, Velocity, Flow	Sanitary	SW	NA	11/16/04 - 01/03/05
P112-01-S0045	Level, Velocity, Flow	Sanitary	NE	NA	11/30/04 - 01/03/05
98	Level, Velocity, Flow	Sanitary	NE	12,422	04/06/05 - 09/18/07
99	Level, Velocity, Flow	Combined	SW	24	09/09/05 - 09/04/07
D54-000070	Level	Combined	SE	91	09/19/05 - 12/21/05
D45-001660	Level, Velocity, Flow	Combined	SE	7	09/19/05 - 12/22/05
D54-003317	Level, Velocity, Flow	Combined	SE	20	09/19/05 - 12/27/2005
D54-003890	Level, Velocity, Flow	Combined	SE	7	09/19/05 - 12/21/05
D45-000080	Level	Combined	SE	638	09/20/05 - 12/22/05
D54-000080	Level	Combined	SE	83	09/20/05 - 12/22/05
D68-000430	Level	Combined	SE	151	09/20/05 - 12/27/05
D45-000445	Level	Combined	SE	21	09/21/05 - 12/22/05
D45-003620	Level	Combined	SE	237	09/22/05 - 12/21/05
D68-000085	Level, Velocity, Flow	Combined	SE	142	09/22/05 - 07/28/06
100	Level	Combined	SW	42	09/23/05 - 07/24/06
102	Level	Combined	SW	214	10/05/05 - 07/14/06
103	Level	Combined	SW	148	10/06/05 - 07/24/06
D54-000095	Level, Velocity, Flow	Combined	SE	28	10/10/05 - 01/11/06
D66-001625	Level, Velocity, Flow	Combined	SE	27	10/10/05 - 01/11/06

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
D66-000130	Level, Velocity, Flow	Combined	SE	128	10/18/05 - 12/27/05
D45-000165	Level	Combined	SE	177	11/01/05 - 01/11/06
D68-000135	Level, Velocity, Flow	Combined	SE	88	11/02/05 - 07/27/06
D68-001505	Level, Velocity, Flow	Combined	SE	7	11/07/05 - 01/11/06
101	Level	Combined	SW	80	11/30/05 - 03/13/07
104	Level, Velocity, Flow	Combined	SW	80	12/09/05 - 03/08/07
D44-000075	Level	Combined	SE	135	04/20/06 - 07/26/06
D45-001425	Level	Combined	SE	104	04/20/06 - 07/28/06
D45-000070	Level, Velocity, Flow	Combined	SE	NA	04/20/06 - 09/20/06
D45-000490	Level, Velocity, Flow	Combined	SE	NA	04/20/06 - 07/28/06
D45-000510	Level, Velocity, Flow	Combined	SE	NA	04/20/06 - 07/28/06
D39-000110	Level, Velocity, Flow	Combined	SE	NA	04/21/06 - 09/20/06
D45-000610	Level, Velocity, Flow	Combined	SE	NA	04/21/06 - 07/20/06
D45-003705	Level, Velocity, Flow	Combined	SE	NA	04/21/06 - 09/20/06
D54-003653	Level, Velocity, Flow	Combined	SE	NA	04/24/06 - 07/28/06
D66-000140	Level, Velocity, Flow	Combined	SE	NA	04/25/06 - 07/28/06
D66-001585	Level, Velocity, Flow	Combined	SE	59	04/25/06 - 07/28/06
S42-000130	Level, Velocity, Flow	Combined	SW	73	04/25/06 - 09/21/06
D45-000045	Level, Velocity, Flow	Combined	SE	NA	05/05/06 - 08/14/06
D54-000015	Level, Velocity, Flow	Combined	SE	171	05/18/06 - 09/20/06
D45-000450	Level, Velocity, Flow	Combined	SE	NA	05/19/06 - 07/28/06
D44-000025	Level, Velocity, Flow	Combined	SE	NA	06/12/06 - 09/21/06
C24-000010	Level, Velocity, Flow	Combined	SW	32	10/10/06 - 05/11/07
D03-000010	Level, Velocity,	Combined	NE	108	11/09/06 - 05/11/07

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
	Flow				
D18-000010	Level, Velocity, Flow	Combined	NE	178	11/09/06 - 05/11/07
F23-000010	Level, Velocity, Flow	Combined	NE	51	11/09/06 - 05/11/07
F07-000010	Level, Velocity, Flow	Combined	NE	82	11/21/06 - 05/11/07
T10-000010	Level, Velocity, Flow	Combined	NE	55	11/21/06 - 02/09/07
106	Level, Velocity, Flow	Combined	SW	25	01/24/07 - 07/08/08
107	Level, Velocity, Flow	Combined	SW	203	01/30/07 - 06/19/08
108	Level, Velocity, Flow	Combined	SE	97	04/02/07 - 07/17/08
112	Level	Sanitary	NE	NA	04/03/07 - 07/17/08
111	Level	Combined	SW	10	04/05/07 - 07/10/08
109	Level	Combined	SW	29	05/14/07 - 06/20/08
110	Level	Combined	SW	4	05/14/07 - 07/09/08
115	Level	Combined	SW	204	05/14/07 - 07/17/08
114	Level, Velocity, Flow	Sanitary	NE	47	05/14/07 - 11/27/07
113	Level, Velocity, Flow	Combined	SW	62	05/16/07 - 07/17/08
CT-B0590	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07
CT-B0670	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07
P112-01-S0045	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07
Q120-05-S0007	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07
S50-016995	Level, Velocity, Flow	Sanitary	SW	59	08/16/07 - 11/17/07
T080-01-S0008	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07
T080-02-S0010	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07
T089-01-S0050	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07
T089-03-S0010	Level, Velocity, Flow	Sanitary	NE	NA	08/16/07 - 11/17/07

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
WLL-B0790	Level, Velocity, Flow	Sanitary	SW	42	08/16/07 - 11/17/07
P112-01-S0090	Level, Velocity, Flow	Sanitary	NE	NA	08/27/07 - 11/17/07
P108-08-S0065	Level, Velocity, Flow	Sanitary	NE	NA	08/28/07 - 11/17/07
P108-11-S0063	Level, Velocity, Flow	Sanitary	NE	NA	08/28/07 - 11/17/07
P108-11-S0070	Level, Velocity, Flow	Sanitary	NE	NA	08/28/07 - 11/17/07
PP-B1075	Level, Velocity, Flow	Sanitary	NE	NA	08/28/07 - 11/17/07
W086-01-S0165	Level, Velocity, Flow	Sanitary	SW	NA	08/28/07 - 11/17/07
W086-07-S0040	Level, Velocity, Flow	Sanitary	SW	NA	08/28/07 - 11/17/07
W086-07-S0065	Level, Velocity, Flow	Sanitary	SW	NA	08/28/07 - 11/17/07
PC-0975	Level, Velocity, Flow	Sanitary	NE	NA	08/31/07 - 11/17/07
Q120-05-S0010	Level, Velocity, Flow	Sanitary	NE	23	08/31/07 - 11/17/07
T089-02-S0010	Level, Velocity, Flow	Sanitary	NE	NA	08/31/07 - 11/17/07
P112-04-S0175	Level, Velocity, Flow	Sanitary	NE	NA	09/07/07 - 11/17/07
PC-1065	Level, Velocity, Flow	Sanitary	NE	NA	09/07/07 - 11/17/07
W084-02-S0235	Level, Velocity, Flow	Sanitary	SW	NA	10/26/07 - 11/17/07
Q121-01-S0010	Level, Velocity, Flow	Sanitary	NE	43	11/09/07 - 07/01/09
PC-0290	Level, Velocity, Flow	Sanitary	NE	NA	11/16/07 - 11/20/08
PC-0320	Level, Velocity, Flow	Sanitary	NE	NA	11/16/07 - 11/20/08
PC-0345	Level, Velocity, Flow	Sanitary	NE	NA	11/16/07 - 11/20/08
PC-0385	Level, Velocity, Flow	Sanitary	NE	NA	11/16/07 - 02/07/08
PC-0420	Level, Velocity, Flow	Sanitary	NE	NA	11/16/07 - 02/07/08
PC-0440	Level, Velocity,	Sanitary	NE	NA	11/16/07 - 02/25/08

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
	Flow				
S50-000300	Level, Velocity, Flow	Sanitary	SW	518	11/16/07 - 01/29/09
D39-000110	Level, Velocity, Flow	Combined	SE	NA	11/21/07 - 02/05/09
D39-000125	Level, Velocity, Flow	Combined	SE	4,618	11/21/07 - 02/05/09
S42-000130	Level, Velocity, Flow	Combined	SW	73	11/21/07 - 12/02/08
47	Level, Velocity, Flow	Sanitary	SW	227	11/28/07 - 12/02/08
S50-000075	Level, Velocity, Flow	Combined	SW	7,342	12/05/07 - 12/09/08
Q120-10-S0010	Level, Velocity, Flow	Sanitary	NE	67	12/06/07 - 02/25/08
Q120-11-S0010	Level, Velocity, Flow	Sanitary	NE	83	12/06/07 - 12/10/08
Q121-02-S0015	Level, Velocity, Flow	Sanitary	NE	73	12/06/07 - 12/10/08
Q121-05-S0010	Level, Velocity, Flow	Sanitary	NE	49	12/06/07 - 12/09/08
R13-SW0010	Level, Velocity, Flow	Combined	NE	NA	12/06/07 - 06/25/08
R14-SW0010	Level, Velocity, Flow	Combined	NE	NA	12/06/07 - 06/25/08
S20-000015	Level, Velocity, Flow	Combined	SW	266	12/06/07 - 12/02/08
Q120-02-S0010	Level, Velocity, Flow	Sanitary	NE	85	12/07/07 - 12/10/08
LSW-0077	Level, Velocity, Flow	Combined	SW	NA	12/17/07 - 12/16/08
S50-016788	Level, Velocity, Flow	Sanitary	SW	NA	01/22/08 - 02/10/09
Q107-05-S0010	Level, Velocity, Flow	Sanitary	NE	26	03/12/08 - 03/18/09
Q107-06-S0010	Level, Velocity, Flow	Sanitary	NE	44	03/12/08 - 03/18/09
Q120-03-S0010	Level, Velocity, Flow	Sanitary	NE	44	03/12/08 - 03/18/09
Q120-08-S0010	Level, Velocity, Flow	Sanitary	NE	108	03/13/08 - 03/19/09
BC-0010	Level, Velocity, Flow	Sanitary	NE	3,358	07/05/08 - 02/01/10

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
PC-0010	Level, Velocity, Flow	Sanitary	NE	12,433	07/28/08 - 02/01/10
PC-0045	Level, Velocity, Flow	Sanitary	NE	12,422	07/28/08 - 07/09/09
47_Aspen	Level, Velocity, Flow	Special	SW	NA	08/06/08 - 03/26/09
47_Fairmount	Level, Velocity, Flow	Special	SW	NA	08/06/08 - 03/26/09
FCHL-0175	Level, Velocity, Flow	Combined	NE	19,068	12/17/08 - 01/05/10
PC-B1530	Level, Velocity, Flow	Sanitary	NE	222	12/17/08 - 01/04/10
T01-000010	Level, Velocity, Flow	Combined	NE	164	12/17/08 - 01/04/10
T10-000010	Level, Velocity, Flow	Combined	NE	55	12/17/08 - 05/25/10
Q119-01-S0015	Level, Velocity, Flow	Sanitary	NE	NA	12/23/08 - 01/04/10
BC-B0675	Level, Velocity, Flow	Sanitary	NE	230	12/31/08 - 01/04/10
PC-B1330	Level, Velocity, Flow	Sanitary	NE	355	02/13/09 - 02/01/10
D15-000020	Level, Velocity, Flow	Combined	NE	99	05/25/09 - 09/24/09
C15-000020	Level, Velocity, Flow	Combined	SW	6	05/28/09 - 02/01/10
C27-000010	Level, Velocity, Flow	Combined	SW	26	05/28/09 - 02/01/10
C37-DW010	Level, Velocity, Flow	Combined	SW	NA	05/28/09 - 12/30/09
T13-000015	Level, Velocity, Flow	Combined	NE	115	05/28/09 - 02/01/10
D41-000010	Level, Velocity, Flow	Combined	SE	57	06/25/09 - 02/03/10
S38-000015	Level, Velocity, Flow	Combined	SW	288	07/14/09 - 02/01/10
C12-000020	Level, Velocity, Flow	Combined	SW	56	08/29/09 - 02/01/10
D02-000020	Level, Velocity, Flow	Combined	NE	313	10/06/09 - 02/01/10
D03-000010	Level, Velocity, Flow	Combined	NE	108	10/06/09 - 02/01/10
Q114-12-	Level, Velocity,	Sanitary	NE	68	10/06/09 - 02/01/10

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
S0010	Flow				
D40-000010	Level, Velocity, Flow	Combined	SE	46	10/07/09 - 02/01/10
W067-06-S0015	Level, Velocity, Flow	Sanitary	SW	NA	10/09/09 - 12/15/09
W068-05-0015	Level, Velocity, Flow	Sanitary	SW	NA	10/29/09 - 02/02/10
W067-06-S0040	Level, Velocity, Flow	Sanitary	SW	31	12/15/09 - 03/17/10
C37-000010	Level, Velocity, Flow	Combined	SW	13	12/30/09 - 01/01/11
IALL-B0810	Level, Velocity, Flow	Sanitary	SW	231	01/06/10 - 01/06/11
W077-02-S0060	Level, Velocity, Flow	Sanitary	SW	217	01/08/10 - 01/08/11
CT-B0590	Level, Velocity, Flow	Sanitary	NE	NA	02/03/10 - 05/04/10
CT-B0670	Level, Velocity, Flow	Sanitary	NE	NA	02/03/10 - 05/04/10
T080-01-S0008	Level, Velocity, Flow	Sanitary	NE	NA	02/03/10 - 05/19/10
T089-01-S0050	Level, Velocity, Flow	Sanitary	NE	NA	02/03/10 - 05/17/10
T089-03-S0010	Level, Velocity, Flow	Sanitary	NE	NA	02/03/10 - 05/04/10
P112-04-S0175	Level, Velocity, Flow	Sanitary	NE	NA	02/04/10 - 05/05/10
PC-1065	Level, Velocity, Flow	Sanitary	NE	NA	02/04/10 - 05/05/10
P108-08-S0065	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/07/10
P108-11-S0063	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/07/10
P108-11-S0070	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/05/10
P112-01-S0045	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/05/10
P112-01-S0090	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/05/10
PC-0975	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/05/10
PP-B1075	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/07/10

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
Q120-05-S0007	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/05/10
Q120-05-S0010	Level, Velocity, Flow	Sanitary	NE	23	02/05/10 - 05/05/10
S50-016995	Level, Velocity, Flow	Sanitary	SW	59	02/05/10 - 06/01/10
T080-02-S0010	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/05/10
T089-02-S0010	Level, Velocity, Flow	Sanitary	NE	NA	02/05/10 - 05/17/10
W084-02-S0235	Level, Velocity, Flow	Sanitary	SW	NA	02/05/10 - 05/07/10
W086-01-S0165	Level, Velocity, Flow	Sanitary	SW	NA	02/05/10 - 05/07/10
W086-07-S0040	Level, Velocity, Flow	Sanitary	SW	NA	02/05/10 - 05/26/10
W086-07-S0065	Level, Velocity, Flow	Sanitary	SW	NA	02/05/10 - 05/07/10
WLL-B0790	Level, Velocity, Flow	Sanitary	SW	42	02/05/10 - 05/07/10
W067-06-S0035	Level, Velocity, Flow	Sanitary	SW	31	03/18/10 - 06/02/10
T14-026945	Level, Velocity, Flow	Combined	NE	5	04/30/10 - 11/02/10
USE-0365	Level, Velocity, Flow	Sanitary	SW	814	04/30/10 - 08/30/10
F11-000130	Level, Velocity, Flow	Combined	NE	169	05/14/10 - 05/19/11
S25-000015	Level, Velocity, Flow	Combined	SW	52	05/14/10 - 09/07/10
T06-000075	Level, Velocity, Flow	Combined	NE	55	05/14/10 - 05/19/11
P105-06-S0035	Level, Velocity, Flow	Sanitary	NE	192	06/11/10 - 06/14/11
D05-001187	Level, Velocity, Flow	Combined	NE	245	07/07/10 - 07/08/11
D25-000150	Level, Velocity, Flow	Combined	NE	333	07/07/10 - 07/08/11
S05-004405	Level, Velocity, Flow	Combined	SW	9	07/08/10 - 03/09/11
S50-000105	Level, Velocity, Flow	Combined	SW	6,723	07/08/10 - 07/15/10
P108-17-	Level, Velocity,	Sanitary	NE	76	07/09/10 - 09/29/11

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
S0010	Flow				
P109-05-S0015	Level, Velocity, Flow	Sanitary	NE	38	07/09/10 - 07/14/11
W060-11-S0015	Level, Velocity, Flow	Sanitary	SW	30	07/09/10 - 07/14/11
W076-13-S0100	Level, Velocity, Flow	Sanitary	SW	110	07/09/10 - 07/14/11
S50-011535	Level, Velocity, Flow	Combined	SW	687	07/12/10 - 08/06/10
USE-0500	Level, Velocity, Flow	Sanitary	SW	438	08/11/10 - 08/23/10
WLL-0028	Level, Velocity, Flow	Sanitary	SW	8,237	08/11/10 - 08/12/11
C05-000010	Level, Velocity, Flow	Combined	SW	25	08/26/10 - 05/26/11
S30-000010	Level, Velocity, Flow	Combined	SW	21	08/26/10 - 02/10/11
S44-000510	Level, Velocity, Flow	Combined	SW	40	08/26/10 - 09/07/10
S20-000070	Level, Velocity, Flow	Combined	SW	89	09/08/10 - 09/09/11
T14-000345	Level, Velocity, Flow	Combined	NE	982	09/29/10 - 02/01/11
T03-000010	Level, Velocity, Flow	Combined	NE	92	10/13/10 - 10/19/11
THL-B0375	Level, Velocity, Flow	Combined/Sanitary	NE	186	11/08/10 - 06/04/12
W086-03-S0015	Level, Velocity, Flow	Sanitary	SW	32	11/08/10 - 11/17/11
S36A-000045	Level, Velocity, Flow	Combined	SW	124	12/06/10 - 12/08/11
S44-000015	Level, Velocity, Flow	Combined	SW	264	12/06/10 - 12/08/11
PP-B0770	Level, Velocity, Flow	Sanitary	NE	47	12/09/10 - 12/12/11
P104-09-S0025	Level, Velocity, Flow	Sanitary	NE	46	12/10/10 - 07/02/12
Q102-05-S0063	Level, Velocity, Flow	Sanitary	NE	NA	12/31/10 - 08/24/11
D65-SW010	Level	Combined	SE	NA	01/01/11 - 08/05/11
D67-SW010	Level	Combined	SE	NA	01/06/11 - 08/05/11
D65-000010	Level, Velocity, Flow	Combined	SE	261	01/06/11 - present

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
D67-000010	Level, Velocity, Flow	Combined	SE	126	01/06/11 - 08/05/11
T14-000490	Level, Velocity, Flow	Combined	NE	238	02/01/11 - present
T14-014030	Level, Velocity, Flow	Combined	NE	328	02/11/11 - present
T14-013940	Level, Velocity, Flow	Combined	NE	650	02/18/11 - 08/16/11
F04-000180	Level, Velocity, Flow	Combined	NE	55	03/01/11 - 03/07/12
S05-000012	Level, Velocity, Flow	Combined	SW	711	03/18/11 - present
C31-000035	Level, Velocity, Flow	Combined	SW	32	05/20/11 - 09/09/11
T14-023480	Level, Velocity, Flow	Combined	NE	124	05/26/11 - present
D66-001595	Level, Velocity, Flow	Combined	SE	56	06/10/11 - 07/05/12
D22-000120	Level, Velocity, Flow	Combined	NE	78	06/13/11 - 09/09/11
S38-000247	Level, Velocity, Flow	Combined	SW	85	06/13/11 - 09/09/11
T14-029300	Level, Velocity, Flow	Combined	NE	92	06/15/11 - present
T08-000420	Level, Velocity, Flow	Combined	NE	631	06/22/11 - present
S50-001600	Level, Velocity, Flow	Combined	SW	71	06/24/11 - 07/05/12
T08-000270	Level, Velocity, Flow	Combined	NE	1,775	06/24/11 - present
T14-013985	Level, Velocity, Flow	Combined	NE	503	09/14/11 - present
D05-000150	Level, Velocity, Flow	Combined	NE	337	10/11/11 - present
D05-001112	Level, Velocity, Flow	Combined	NE	455	10/11/11 - present
P083-03-S0050	Level, Velocity, Flow	Sanitary	NE	270	10/11/11 - present
C17-000810	Level, Velocity, Flow	Combined	SW	158	10/13/11 - present
F21-009745	Level, Velocity, Flow	Combined	NE	380	10/13/11 - present
S45-001110	Level, Velocity,	Combined	SW	62	10/13/11 - present

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
	Flow				
D39-009050	Level, Velocity, Flow	Combined	SE	116	10/14/11 - 08/05/12
D63-000035	Level, Velocity, Flow	Combined	SE	357	10/14/11 - present
S42A-000795	Level, Velocity, Flow	Combined	SW	76	10/14/11 - present
T14-000140	Level, Velocity, Flow	Combined	NE	4,817	10/14/11 - present
S42-000530	Level, Velocity, Flow	Combined	SW	113	10/17/11 - 08/02/12
T14-001300	Level, Velocity, Flow	Combined	NE	245	10/17/11 - present
C11-000110	Level, Velocity, Flow	Combined	SW	147	10/20/11 - 07/05/12
PR-0150	Level, Velocity, Flow	Sanitary	NE	1,158	10/20/11 - present
C11-000030	Level, Velocity, Flow	Combined	SW	278	10/21/11 - 12/07/11
Q101-03-S0020	Level, Velocity, Flow	Sanitary	NE	112	10/21/11 - present
Q117-04-S0105	Level, Velocity, Flow	Sanitary	NE	34	10/21/11 - present
S05-001085	Level, Velocity, Flow	Combined	SW	336	10/21/11 - present
S50-009140	Level, Velocity, Flow	Combined	SW	4,314	10/21/11 - 11/11/11
T088-01-S0050	Level, Velocity, Flow	Sanitary	NE	294	10/21/11 - present
D65-SW010	Level	Combined	SE	NA	10/28/11 - present
D67-SW010	Level	Combined	SE	NA	10/28/11 - present
D67-000010	Level, Velocity, Flow	Combined	SE	126	10/28/11 - present
D67-DW015	Level, Velocity, Flow	Combined	SE	NA	10/28/11 - present
D65-DW0020	Level, Velocity, Flow	Combined	SE	NA	10/31/11 - present
D61-000015	Level, Velocity, Flow	Combined	SE	25	11/18/11 - present
D62-000020	Level, Velocity, Flow	Combined	SE	9	11/18/11 - present
D63-000080	Level, Velocity, Flow	Combined	SE	177	11/18/11 - present

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
P090-02-S0715	Level, Velocity, Flow	Sanitary	NE	384	11/29/11 - present
P113-04-S0463	Level, Velocity, Flow	Sanitary	NE	80	11/29/11 - 06/07/12
PR-0060	Level, Velocity, Flow	Sanitary	NE	1,508	11/30/11 - present
S45-000470	Level, Velocity, Flow	Combined	SW	249	11/30/11 - present
S50-002920	Level, Velocity, Flow	Combined	SW	105	11/30/11 - present
W068-05-S0047	Level, Velocity, Flow	Sanitary	SW	520	11/30/11 - present
BC-0055	Level, Velocity, Flow	Sanitary	NE	2,826	12/01/11 - present
T089-04-S0055	Level, Velocity, Flow	Sanitary	NE	98	12/01/11 - 04/05/12
IALL-B0355	Level, Velocity, Flow	Sanitary	SW	214	12/12/11 - present
C17-003360	Level, Velocity, Flow	Combined	SW	193	12/13/11 - present
D39-000080	Level, Velocity, Flow	Combined	SE	NA	12/14/11 - 04/17/12
PP-B1080	Level, Velocity, Flow	Sanitary	NE	1,814	01/27/12 - 03/19/12
Q114-12-S0010	Level, Velocity, Flow	Sanitary	NE	68	01/27/12 - present
T14-013795	Level, Velocity, Flow	Combined	NE	1,342	01/27/12 - present
T14-S031640	Level, Velocity, Flow	Combined	NE	139	01/27/12 - 05/08/12
D25-004055	Level, Velocity, Flow	Combined	NE	NA	01/30/12 - 02/17/12
D39-000145	Level, Velocity, Flow	Combined	SE	4,597	01/30/12 - 04/05/12
D54-000150	Level, Velocity, Flow	Combined	SE	159	01/30/12 - present
PC-0010	Level, Velocity, Flow	Sanitary	NE	12,433	01/30/12 - present
T14-000330	Level, Velocity, Flow	Combined	NE	1,601	01/30/12 - present
W086-01-S0060	Level, Velocity, Flow	Sanitary	SW	228	01/30/12 - 02/28/12
W076-13-	Level	Sanitary	SW	110	02/27/12 - present

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
0035					
C06-000010	Level, Velocity, Flow	Combined	SW	98	02/27/12 - present
C24-000010	Level, Velocity, Flow	Combined	SW	32	02/27/12 - present
D38-000690	Level, Velocity, Flow	Combined	SE	191	02/28/12 - present
D48-000030	Level, Velocity, Flow	Combined	SE	299	02/28/12 - 04/06/12
D54-000045	Level, Velocity, Flow	Combined	SE	106	02/28/12 - 04/05/12
D54-001970	Level, Velocity, Flow	Combined	SE	19	02/28/12 - present
T14-013875	Level, Velocity, Flow	Combined	NE	961	02/28/12 - present
W076-01-0015	Level	Sanitary	SW	89	03/29/12 - present
D54-004077	Level, Velocity, Flow	Combined	SE	NA	03/29/12 - present
USE-0365	Level, Velocity, Flow	Sanitary	SW	814	03/30/12 - present
USE-0500	Level, Velocity, Flow	Sanitary	SW	438	03/30/12 - 07/05/12
T14-010220	Level, Velocity, Flow	Combined	NE	302	04/27/12 - present
USE-0660	Level, Velocity, Flow	Sanitary	SW	289	07/05/12 - present
S052-05-0015	Level, Velocity, Flow	Sanitary	SW	NA	08/24/12 - present
M005-06-0050	Level	Sanitary	SW	NA	09/27/12 - present
M005-06-0075	Level	Sanitary	SW	NA	09/27/12 - present
M005-07-0050	Level	Sanitary	SW	NA	09/27/12 - present
M005-07-0070	Level	Sanitary	SW	NA	09/27/12 - present
M005-08-0015	Level	Sanitary	SW	NA	09/27/12 - present
M005-08-0048	Level	Sanitary	SW	NA	09/27/12 - present
M005-08-0065	Level	Sanitary	SW	NA	09/27/12 - present

Meter ID	Measurement Type	Sewer Type	Drainage District	Basin Area (acres)	Data Range
M005-09-0060	Level	Sanitary	SW	NA	09/27/12 - present
M005-09-0140	Level	Sanitary	SW	NA	09/27/12 - present
M005-09-0170	Level	Sanitary	SW	NA	09/27/12 - present
C07-000010	Level, Velocity, Flow	Combined	SW	NA	10/19/12 - present

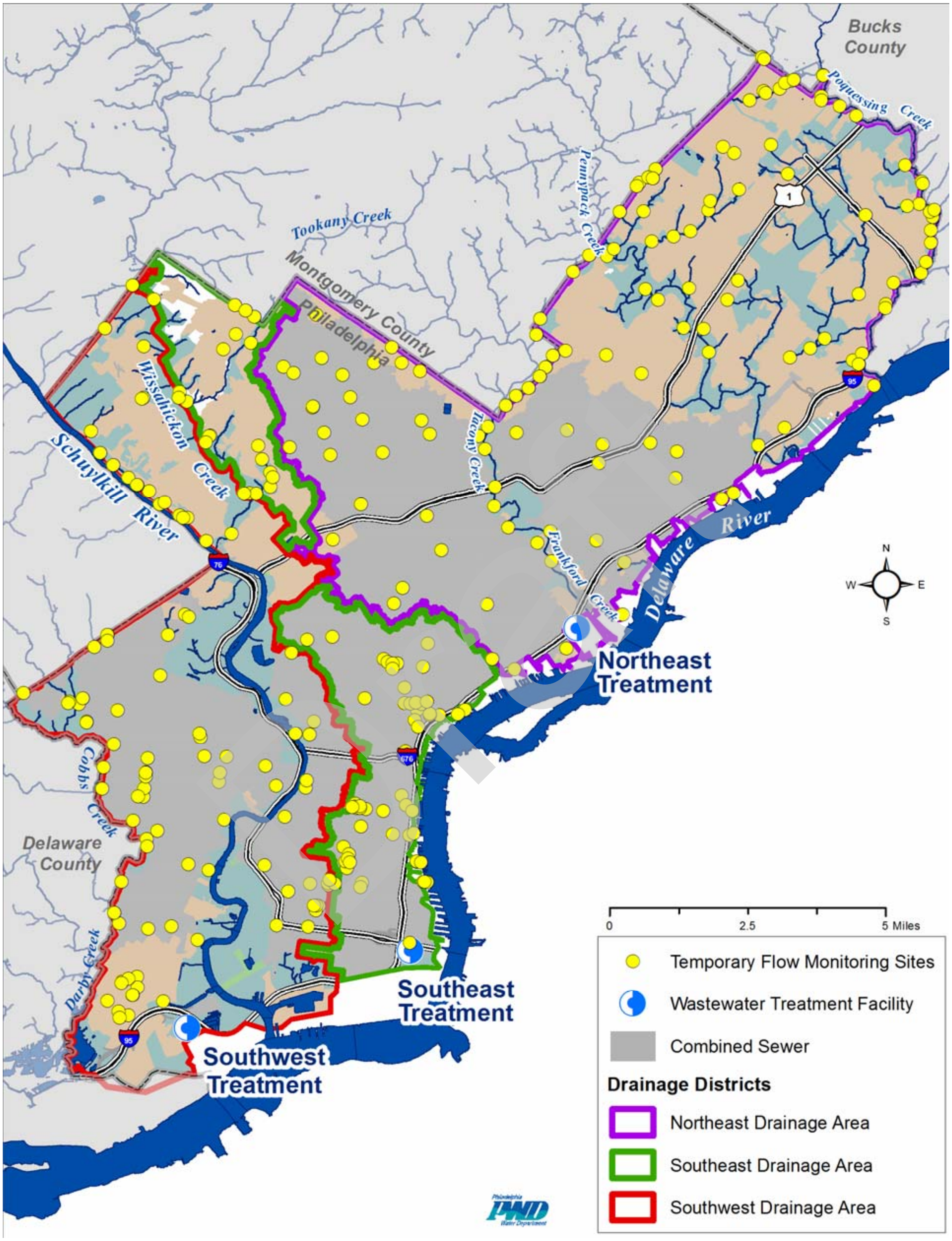


Figure E-1 Temporary Flow Monitoring Sites

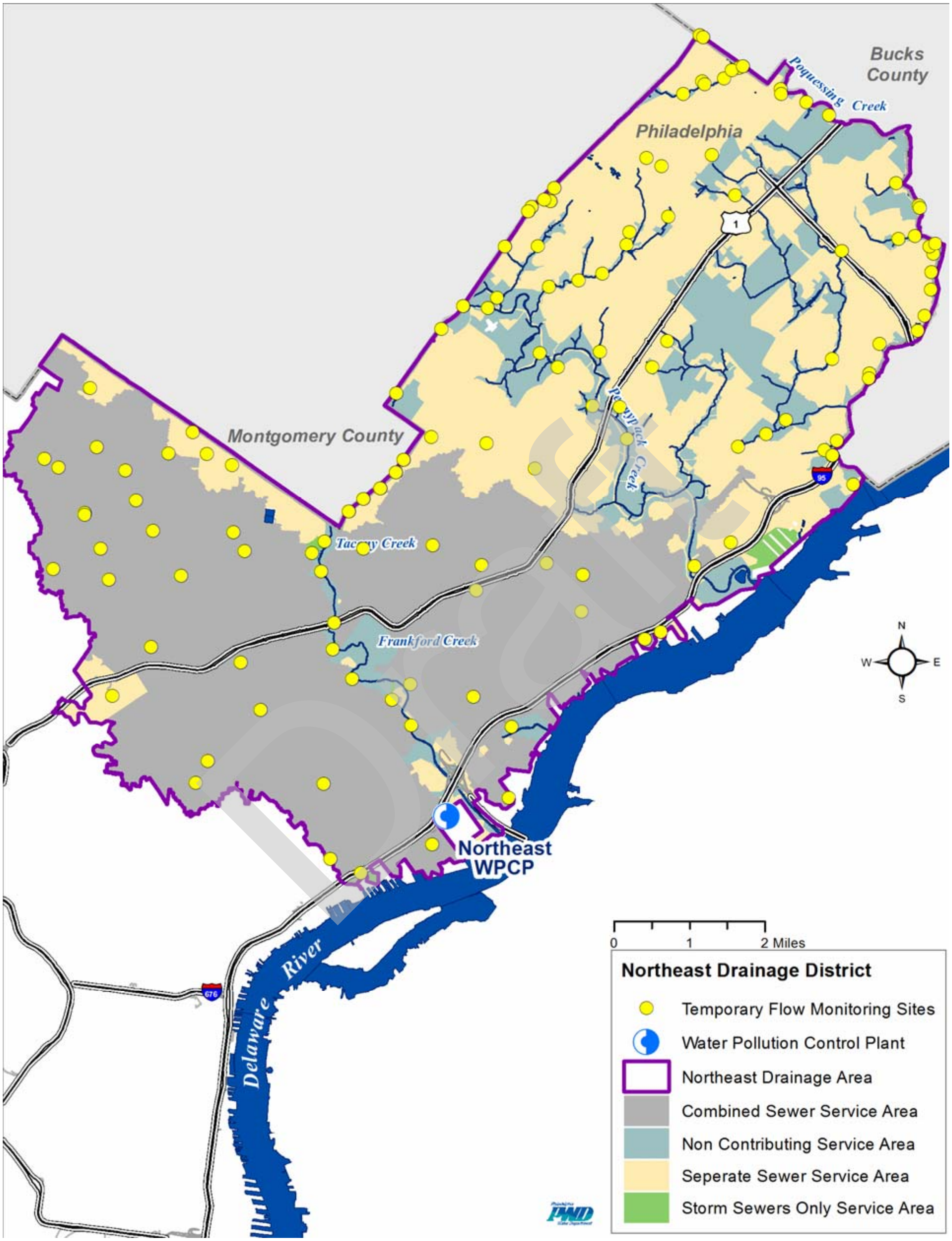


Figure E-2 Temporary Flow Monitoring Sites for Northeast Drainage District

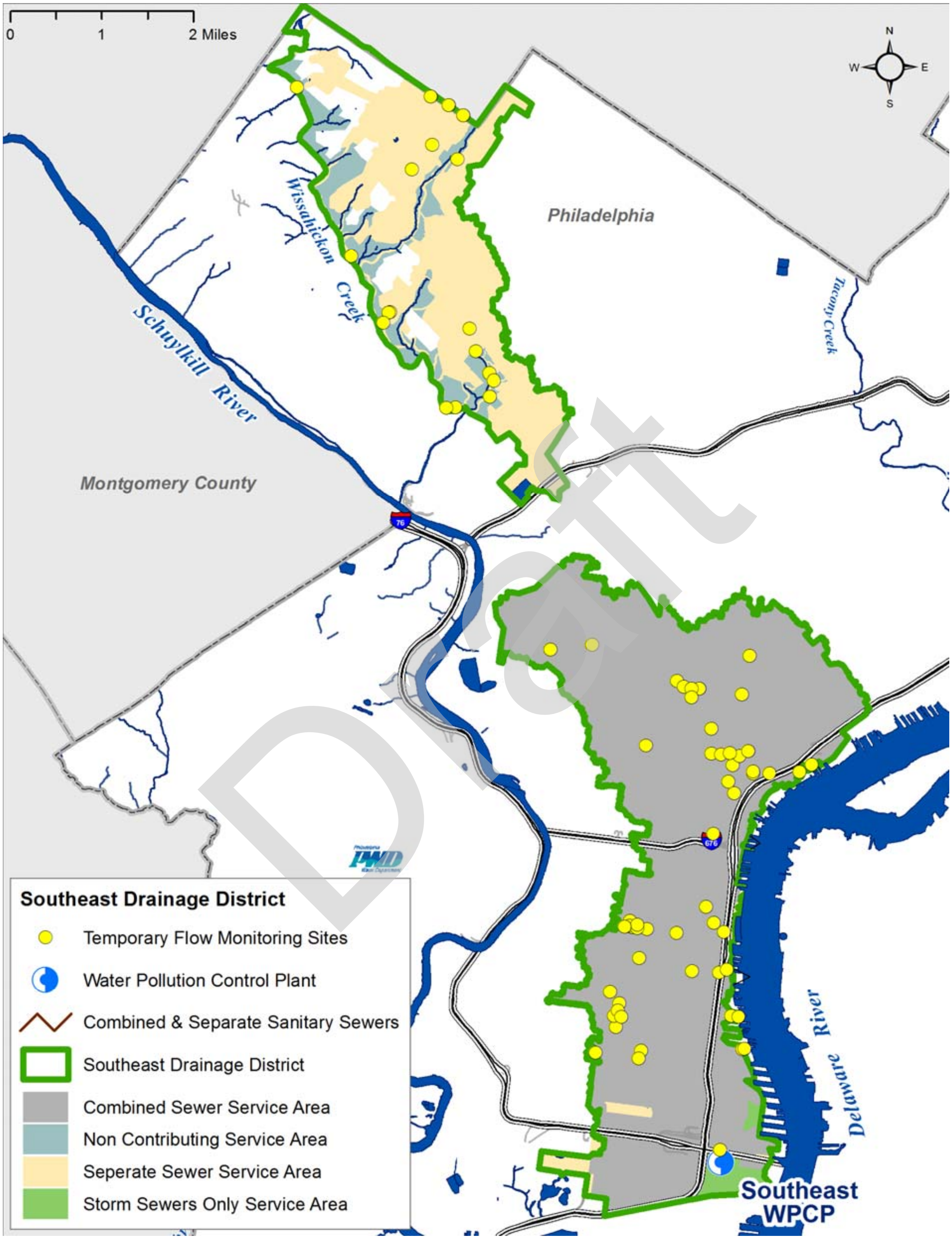


Figure E-3 Temporary Flow Monitoring Sites for Southeast Drainage District

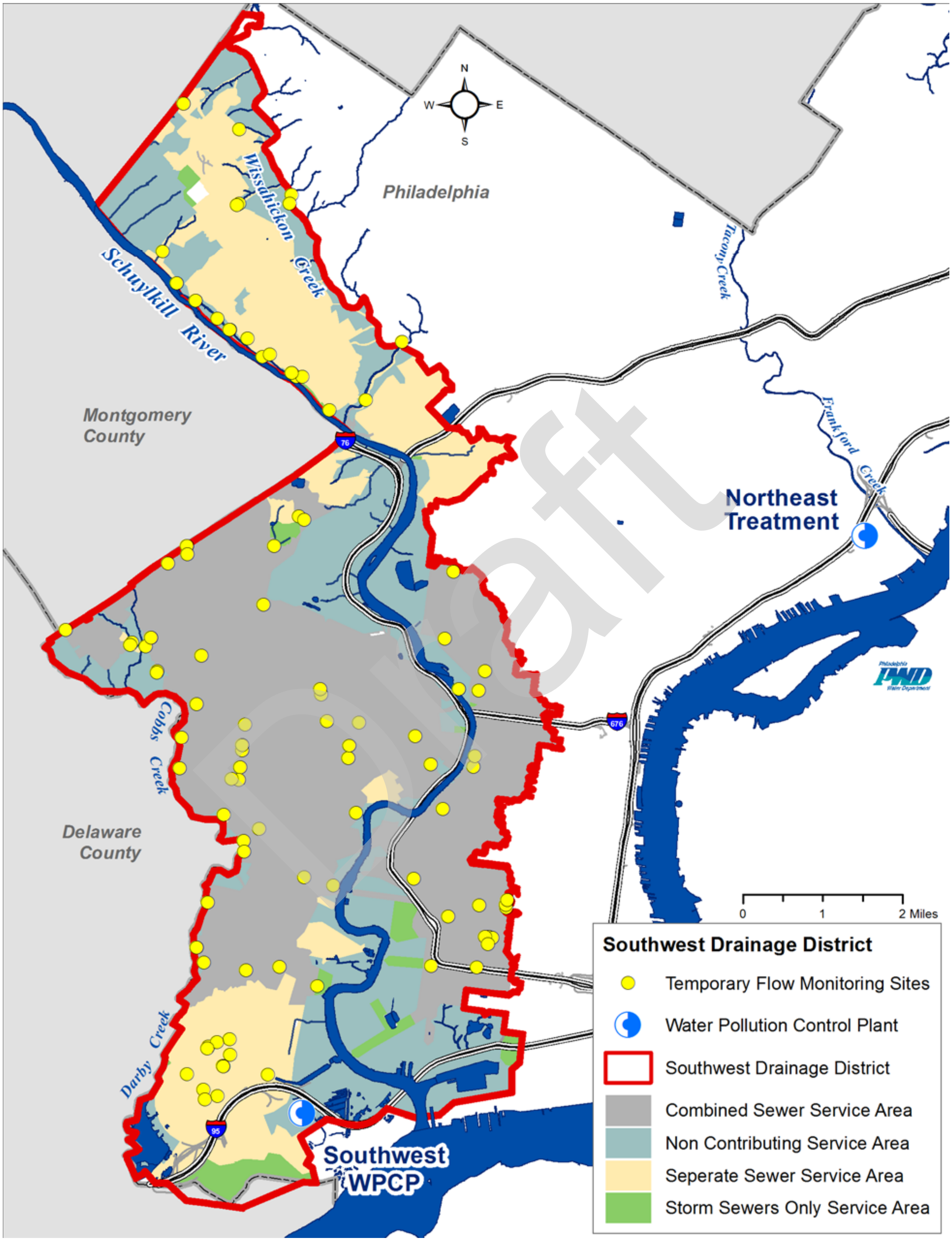


Figure E-4 Temporary Flow Monitoring Sites for Southwest Drainage District

Appendix F

Example Temporary Flow Monitor Site Investigation Report

Site Name/Manhole # D54-001970 Primary: X Alternate: Grade: 5

Investigation Date: 1/24/12 Time: 12:42 Crew Members: LR/SC

Installation Date: Time: Crew Members:

Address/Location: 215 Spruce Street

Latitude: N 39°56.673’ Longitude: W 75°08.727’

Weather Conditions: Wet Dry

Philadelphia PWD Water Department

Hydraulic Conditions

Influent Flow:

Velocity _3_ ft/sec (visual)

Depth _1_ in

Turbulence Amplitude:

Less than 0.25”
0.25” to 0.75”
0.75” to 1.5”
1.5” to 3”
Greater than 3”

Sewer Line Characteristics:

	Influent 1	Influent 2	Effluent
Height	42” Approx.		42” Approx.
Width	42” Approx.		42” Approx.
Material	Brick		Brick
Shape	Round		Round

Sediment Present:

Yes Hard packed: ____________ in. deep
No Soft: ____________ in. deep

Surcharge / Backwater Influence:

No evidence visible
Remains in pipe
_____ft from rim
Reaches Rim (potential meter damage)
Evidence unclear: _____________ft from rim

Gas Investigation:

Good ___(condition)

Site Conditions

Site Access:

Good (no problems accessing site)
Fair (minor traffic control, truck accessible off-road site, can safely carry equipment to site)
Poor (remote areas, steel embankments, No safe place to park, elevated MH >3 ft)
Traffic Control only (Requires extra traffic control
Unusable (Document in Comments section)

Manhole Information:

Elevated Manhole: Yes No

Height above ground ____ ft
Manhole depth 12’10”
Structural Integrity of Manhole:
Good Fair Poor

Pipe Bends: *None within camera view*
Influent Effluent Manhole
Approx Distance to bend: ____ ft

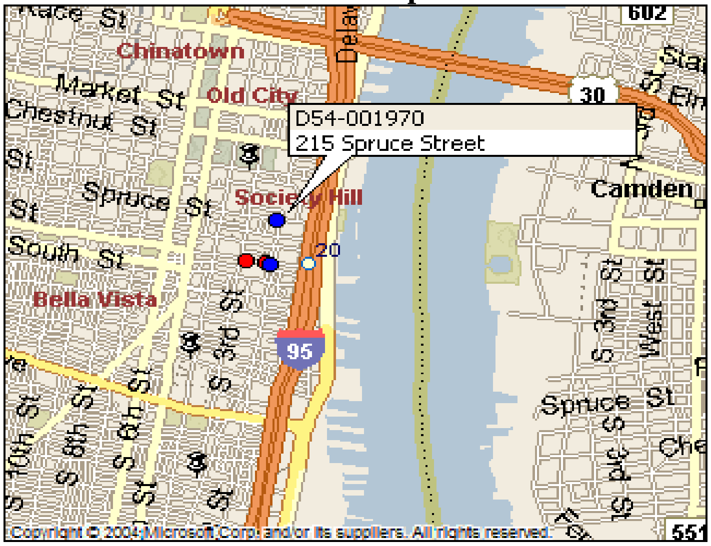
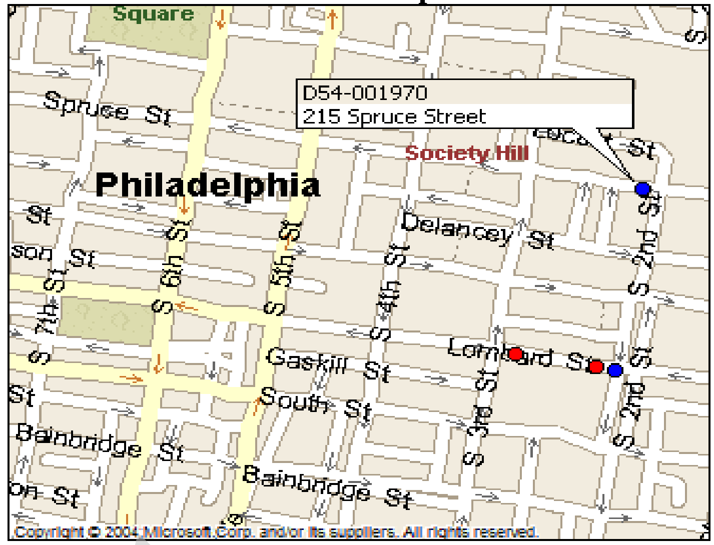
Pipe Size/Geometry/Material Change:
Influent Effluent Manhole
Approx Distance to change:_________ft
(detail is comments)

Crew Member: Can you maintain this site?
Yes No Maybe

Sensor Configuration:
(Please include Serial Numbers when possible)

Level	Primary:	
	Redundant:	
Velocity	Primary:	
	Redundant:	
Meter Logger		

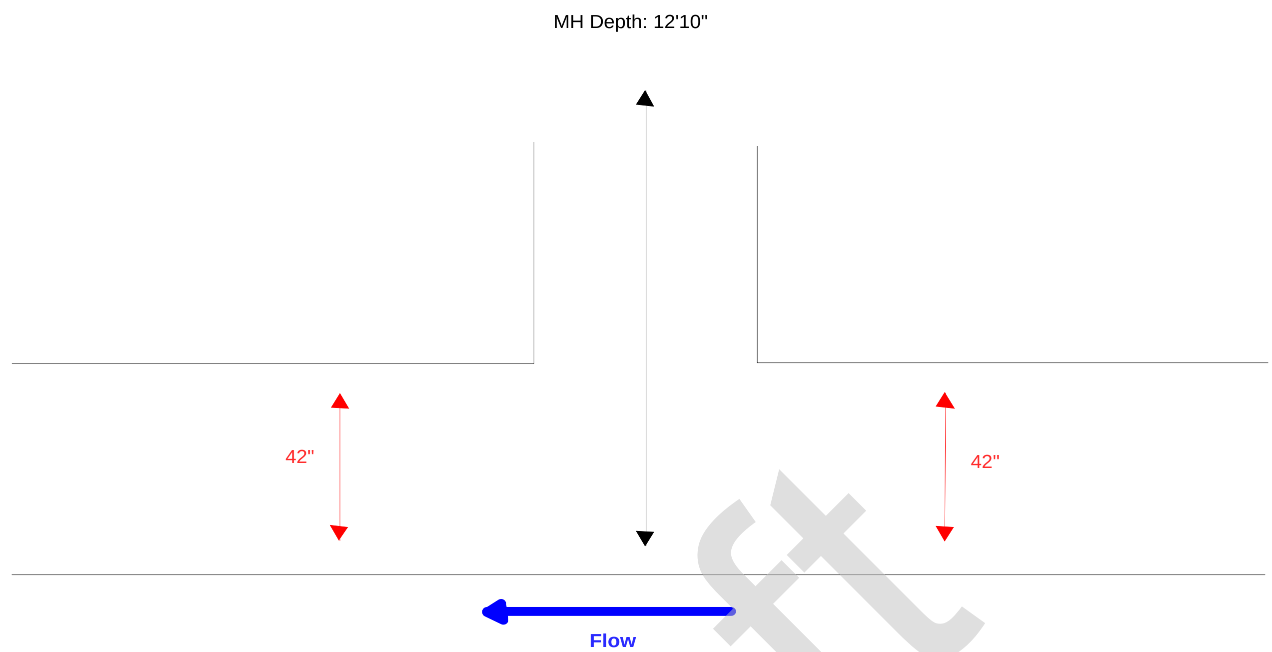
Comments: Concrete pipe changes to brick manhole. On Bus Route 42, tight traffic issue.

Area Map	Detail Map
	

View from top of MH	Site Overview
	

View of flow through influent line	View of flow through effluent line
	

Dimensional Structure Profile View (profile sketch showing location of sensors)



Dimension Structure Detail (pipe profile)

Site Location Plan View

Sketch or plat showing upstream and downstream manholes, connections, and bends.