SAINT PAUL

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2016 Water Quality & Quantity Monitoring Program

Monitoring Report

June 2017

Prepared for

City of Saint Paul
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Saint Paul, MN 55102

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WSB

THE CITY OF ST. PAUL

2016 STORMWATER QUALITY AND QUANTITY MONITORING PROGRAM

June 2017

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LIST OF ABBREVIATIONS

BMP	Best Management Practices
CCB	Capital City Bikeway
CRWD	Capitol Region Watershed District
Cu-ft	Cubic feet
DP	Dissolved phosphorus
EMC	Event mean concentration
ft	Feet
FWA	Flow-weighted average
HDPE	High-density polyethylene
IESF	Iron-enhanced sand filtration ponds
In/hr	Inches per hour
IR	In-rock
lbs	Pounds
mg/L	Milligrams per liter
MS4	Municipal Separate Storm Sewer System
MSWM	Minnesota Stormwater Manual
MPN	Most probable number
MnDOT	Minnesota Department of Transportation
NPDES	National Pollutant Discharge Elimination System
OCS	Outlet control structure
SP	Poorly graded sand
SPCD	Saint Paul City Datum
SRP	Soluble reactive phosphorus
TBNS	Trout Brook Nature Sanctuary
TP	Total phosphorus
TSS	Total suspended solids

1. INTRODUCTION

The purpose of this report is to present the findings of the City of Saint Paul's (City) 2016 Stormwater Monitoring Program. The monitoring was conducted to fulfill requirements of the City's National Pollutant Discharge Elimination System (NPDES) MS4 Phase I Permit. Data collected and analyzed is used to quantify stormwater volumes and loads from the Municipal Separate Storm Sewer System (MS4) and assist in the assessment of effectiveness of the City's Stormwater Management Program.

Since 2006, the City has been required by local watershed agencies to construct stormwater volume reduction Best Management Practices (BMPs) concurrent with City projects that generate or reconstruct impervious surfaces. The watershed requirements stipulate that these BMPs must provide volume reduction for the runoff from a one-inch rainfall event over the impervious surfaces of the project. In 2015, the watershed updated their standard to require that the BMP provide volume reduction for the runoff from a 1.1-inch rainfall event over the impervious surface of the project. The City has typically achieved this by constructing infiltration BMPs.

The focus of the City's stormwater monitoring program has been to monitor the effectiveness and maintenance needs of stormwater BMPs. Outfall monitoring data, collected by Capitol Region Watershed District (CRWD), is used to evaluate pollutant loading from major sub-watersheds, and to estimate City-wide pollutant loading from the MS4.

Fifteen BMPs were monitored in 2016 to quantify progress toward meeting the City's stormwater management goals and to refine current design and maintenance practices. Rainfall was also measured at five locations in the City. The 2016 monitoring sites are shown on **Figure 1-1** and listed in **Table 1-1**. This effort focused on evaluating four major parameters during the monitoring period:

- Water level / infiltration rate
- Volume reduction
- Pollutant removal
- BMP maintenance

To evaluate these parameters, electronic monitoring equipment was used to continuously measure system water levels, inflow/outflow volumes, pollutant concentrations, groundwater elevation, and rainfall amounts. In addition, visual inspections and measurements of sediment accumulation were conducted periodically for each system to assess maintenance needs.

Three of the monitored BMPs are pervious pavement sites, evaluated for infiltration performance. Long-term monitoring at these sites is completed to research the benefits, feasibility, and sustainability of pervious surface parking lanes, alleyways, and bike trails in the City.

This report describes the procedures and methods used to collect water quality and quantity data, provides background information for each site monitored, and presents the results of the monitoring that was completed.

Table 1-1: 2016 City of Saint Paul Monitoring Site Summary

BMP Site Name	BMP Type	Monitored Parameters[1]
Beacon Bluff	Underground Infiltration Gallery & Rain Garden	WL, Q, WQ, GW
Hillcrest Knoll Park	Underground Infiltration Gallery	WL, Q, GW
St. Alban's Street	Underground Infiltration Gallery	WL, Q
Hampden Park	Underground Infiltration Gallery	WL, Q, WQ, GW
Arundel Street	Underground Infiltration Gallery	WL
Wordsworth	Infiltration Trench	WL
Montreal	Infiltration Trench	WL
Flandrau – Hoyt Pond	Stormwater Pond	WL
Sackett Park Pond	Stormwater Pond	WL
Trout Brook Nature Sanctuary – Maryland Pond	Iron-Enhance Sand Filtration Pond	WL, Q, WQ
Trout Brook Nature Sanctuary – Magnolia Pond	Iron-Enhance Sand Filtration Pond	WL, Q, WQ
Trout Brook Nature Sanctuary – Jenks Pond	Iron-Enhance Sand Filtration Pond	WL, Q, WQ
Victoria Street Pervious Pavers	Pervious Pavers	Infiltration
Hamline-Midway Library Pervious Pavement	Pervious Asphalt	Infiltration
Jackson Street Pervious Bike Path	Pervious Asphalt	Infiltration
Wilder Recreation Center	Rainfall Monitoring Location	R
Fire Station 18	Rainfall Monitoring Location	R
Hampden Park Co-op	Rainfall Monitoring Location	R
Frost Elementary School	Rainfall Monitoring Location	R
Edgecumbe Recreation Center	Rainfall Monitoring Location	R

1 - Water Level, Q – Flow Rate, WQ – Water Quality, GW – Groundwater, R – Rainfall

2. PROCEDURES AND METHODOLOGY

This section outlines the procedures and methods followed to perform monitoring and data analysis. For more detailed information related to equipment use monitoring protocols that were followed for this monitoring program, see the 2016 Stormwater Monitoring Protocols document located in **Appendix E**.

2.1. Infiltration Rate

The infiltration rate was measured at applicable locations by collecting water level data on a continual basis. The data was then analyzed to estimate the average infiltration rates observed during the monitoring period. The following provides a detailed description of how this was completed. Infiltration rates were not calculated for the Trout Brook Nature Sanctuary (TBNS) iron-enhanced sand filtration ponds (IESF), Flandrau-Hoyt Pond, and Sackett Park Pond as part of this assessment. The water level data collected at those sites was reviewed to determine level fluctuation over the monitoring period and to compare against normal and high water elevations.

Data Collection

Water levels were monitored using electronic level loggers. The loggers were configured at each site to log data at a minimum of one reading per hour for groundwater and once every 15 minutes for BMPs.

Enclosures for the infiltration gallery level loggers were installed at Beacon Bluff, Hillcrest Knoll Park, St. Albans Street, and Arundel Street Sites. These consisted of three-inch-diameter PVC pipes with four rows of half-inch-diameter holes drilled along the pipe achieving approximately twenty holes per foot. The enclosures were then wrapped with a highly permeable geotextile fabric and secured with zip ties to protect the instrument from fine sediment accumulation. Enclosures were secured to the system floor and to the access riser wall (**Photo 2-1**). Groundwater, in-rock (IR), and rain garden locations were monitored from permanent monitoring wells (**Photo 2-2**). Sites with IR monitoring locations include Beacon Bluff, Hillcrest Knoll Park, and Hampden Park. These monitoring wells are completed to the depth of the rock base of the BMP.

Photo 2-1: Infiltration gallery level monitoring enclosure

Photo 2-2: Beacon Bluff Rain Garden and in-rock permanent monitoring wells

Data Analysis

The data collected at each site reflected hydrograph-type curves resulting from the rise and fall of water within the systems during and after significant rainfall events. The data was analyzed in Microsoft Excel to develop stage/infiltration rate relationships for each system. Since the infiltration rates increase exponentially at higher depths in the systems, this relationship was developed by calculating the infiltration rate at each half foot height increment. These calculations also accounted for the volume of runoff entering the system while drawdown was occurring. Infiltration of water in the horizontal direction through the vertical surfaces of the trenches was not included in this analysis as the policies of the watershed districts only recognize infiltration through the bottom horizontal surface. The infiltration rates calculated at each increment were averaged and plotted on a graph.

The following equation was used to perform these calculations at each half foot increment:

$$\boldsymbol{Infiltration\ Rate}\left(\frac{\boldsymbol{in}}{\boldsymbol{hr}}\right) = \frac{\mathbf{0.5}\ \boldsymbol{ft} + \frac{\mathbf{V_{in}}}{\mathbf{WHSA}}}{\boldsymbol{\Delta t}}$$

where:

V_{in} = Inflow Volume (cu-ft)
WHSA = Wetted Horizontal Surface Area (sq-ft)
Δt = Time it takes for water level to drop by 0.5 ft

The same analysis method was used to evaluate infiltration rates in the Arundel Street, Montreal and Wordsworth BMPs, however, since no monitored inflow data was available, inflow volume was not accounted for.

2.2. Volume Reduction

Stormwater runoff volume was measured at Beacon Bluff, Hillcrest Knoll, St. Albans Street, and Hampden Park using continuous flow monitoring equipment to determine the total volume of water draining to and captured by each system. The volume of treated water passing through the IESF ponds at the TBNS sites was also monitored to calculate load reductions. Collected data was analyzed using Flowlink software and Microsoft Excel to quantify the volumes measured during each discrete rainfall event recorded during the monitoring periods. The following section provides brief descriptions of the methods and procedures used to quantify volume reduction at each system.

Data Collection

Teledyne ISCO 2150 area velocity flow modules and sensors were used to monitor runoff volumes. These devices measure water level and flow velocity. Combining this information with a known conduit shape, the flow rate and flow volume through the conduit were calculated. Each of the monitored systems received stormwater runoff from a diversion structure located along the storm sewer system. The 2150 flow sensors were positioned at the upstream and downstream pipes in these structures to measure the total volume draining to each BMP and the total volume that bypassed each BMP. **Photos 2-2** and **2-3** show the flow meters installed in the Beacon Bluff diversion structure

The flow modules were configured at each site to log data at one minute intervals once the water level in the upstream pipe was greater than one-inch above the pipe invert to increase the resolution of the flow data.

Photo 2-2: Flow monitoring module

Photo 2-3: Flow sensor in upstream pipe in Beacon Bluff diversion structure

Flow sensors at the TBNS IESF Pond sites were installed within the outlet control structure pipe of the ponds (**Photo 2-4**). Water treated by the IESF is conveyed to the outlet control structure by eight-inch drain tile beneath the sand benches (**Phot 2-5**) Additional details regarding the TBNS IESF pond monitoring configurations are described in **Section 2.3** and **Section 10.**

Photo 2-4: Jenks Pond outlet contro structure

Photo 2-3: Jenks Pond 8" drain tile and outlet pipe within the outlet control structure

<u>**Data Analysis**</u>

Flow data was regularly imported into Flowlink 5.1 for storage and analysis. Data was analyzed and validated using built-in velocity error checking parameters. The flow level and velocity data was converted to total flow volumes and exported to a Microsoft Excel spreadsheet for further analysis. Each rainfall event and associated inflow and outflow volumes were tabulated. Turbulent and high velocity flow at the Beacon Bluff site contributed to occasional erroneous level data at the upstream sensor location. Each flow event was evaluated individually and if the data was determined to be of poor quality (i.e. level drop out, significantly higher volumes recorded at the downstream location) the total event volume was modeled using the rainfall to runoff ratio developed for the site using historical monitoring data.

For the Beacon Bluff and Hampden Park BMPs, runoff volume was estimated for un-monitored system inlets by taking the monitored flow data and multiplying by the ratio the respective drainage areas.

2.3. Water Quality

Water quality was monitored at the Beacon Bluff, Hampden Park, and TBNS IESF Pond sites. The following section provides a summary of the methods and procedures used to collect and test water quality samples and analyze the data.

Data Collection

ISCO 6712 automatic samplers were installed in the diversion structures at Beacon Bluff and Hampden Park (**Photos 2-6** and **2-7**).

Photo 2-6: ISCO 6712 Sampler at Beacon Bluff

Photo 2-7: ISCO Bottle Configuration

The automatic samplers were configured to collect 200 mL samples at constant volume intervals. The flow pacing intervals were initially estimated for each site to provide a minimum of six samples during a quarter-inch storm but less than 120 samples for the three-inch storm. Flow pacing was refined during the monitoring period to achieve this objective.

The sampling configuration at each of the three TBNS IESF Ponds consisted of a job box containing two ISCO 6712 automated samplers, triggered by a 2150 flow meter within the outlet control structure pipe (**Photos 2-8** and **2-9**). Tubing was routed from the first sampler through a buried conduit to a float within the pond basin. This location was established as the pre-treatment sample. Tubing was routed for the second sampler along with the 2150 flow meter to a position in the outlet pipe of the outlet control structure. This location was established as the post-treatment sample. The samplers were programmed to collect simultaneous flow weighted samples based on flow pacing monitored in the outlet control structure. The flow pacing at each pond was refined during the monitoring period to best capture the entire flow profile of a treatment event, while still meeting the 48-hour hold time for the ortho-phosphate laboratory method.

Photo 2-8: Maryland Pond sampler configuration

Photo 2-9: Magnolia Pond pretreatment sample float

Samples from sufficiently sized rainfall events were submitted to a certified laboratory for analysis. The samples were composited using a batch mixing technique to create one sample for the event. Beacon Bluff and Hampden Park composite samples were analyzed for the parameters listed in the **Table 2-1** below, as volumes allowed, in accordance with the City's NPDES Permit. Grab samples were also collected during select storm events and analyzed for E. Coli. The most probable number (MPN) procedure was used to determine the concentration of E. Coli in the stormwater runoff. The TBNS IESF Pond samples were submitted for analysis of total phosphorus (TP), dissolved phosphorus (DP), and ortho-phosphate [soluble reactive phosphorus (SRP)].

Table 2-1: Water Quality Parameters

Monitoring Parameters			
Parameters	**Method**	**Sample Type**	**Frequency**
BOD, Carbonaceous 5-Day (20 Deg C)	SM 5210B	Composite or Grab	Quarterly
Chloride, Total	SM4500	Composite or Grab	For loading calculations
Copper, Total (as Cu)	EPA 200.7	Composite or Grab	Monthly
E. coli		Grab	Quarterly
Flow	NA	Measurement	NA
Hardness, Carbonate (as CaCo3)	SM 2340B	Composite or Grab	Monthly
Lead, Total (as Pb)	EPA 200.7	Composite or Grab	Monthly
Nitrite Plus Nitrate, Total (asN)	SM4500/NO3F	Composite	For loading calculations
Nitrogen, Ammonia, Un-ionized (as N)	EPA 350.1	Composite	Quarterly
Nitrogen, Kjeldahl, Total	EPA 351.2	Composite	For loading calculations
pH	EPA 9045D	Composite or Grab	Quarterly
Phosphate, total Dissolved or Ortho	EPA 365.1	Composite	Quarterly
Phosphorus, Total as P	EPA 365.1	Composite	For loading calculations
Precipitation	NA	Measurement	1 x Day
Solids, Total Dissolved (TDS)	SM2540 C-97	Composite	Quarterly
Solids, Total Suspended (TSS)	ASTM D3977-97	Composite	For loading calculations
Sulfate	EPA 9056A	Composite or Grab	2 x Year
Volatile Suspended Soilds (VSS)	EPA 160.4	Composite	For loading calculations
Zinc, Total (as Zn)	EPA 200.7	Composite or Grab	Monthly

Data Analysis

The event mean concentrations (EMCs) derived from sampling events were multiplied by the corresponding volume measurements taken at each site for every rainfall event sampled. For storm events with no sampling data, a flow weighted EMC concentration from that site's entire monitoring period was used. This information was tabulated and summed to determine the total amount of pollutants generated in the contributing drainage areas and the amount of pollutants captured by the BMP.

2.4. Maintenance Inspections

BMP Inspections were conducted at Beacon Bluff, Hillcrest Knoll Park, St. Albans Street, Hampden Park, and Arundel Street Sites periodically during the monitoring period. Pre-treatment structures were inspected for accumulated sediment depth and floatable debris. Underground chambers were observed from the access riser for accumulation of sediment, debris, and standing water that would require maintenance. The TBNS IESF

Ponds were inspected for muck accumulation and iron clumping within the sand filtration benches. Inspection photos are included as **Appendix D**.

2.5. Pervious Surface Infiltration Rate

The infiltration rate of the permeable surfaces was measured at the Victoria Street, Hamline-Midway Library, and Jackson Street pervious pavement sites following the protocols outlined in ASTM method C1701 (**Appendix F**). The following section provides a summary of those methods.

<u>Data Collection</u>

Infiltration tests were conducted according to the modified ASTM C1701 methods for measuring infiltration rates. Five to 11 tests were conducted at each of the permeable surface sites at random locations to develop an average infiltration rate measurement. Tests were taken at locations that remained consistent year to year and included a combination of high and low traffic areas. At each test location, a pre-wet test was conducted, followed by two infiltration tests. The two infiltrations tests were averaged to generate the infiltration rate for each location. If after fifteen minutes of monitoring during a pre-wet test no infiltration was observed, the test was concluded and no subsequent tests were completed.

Photo 2-10: Permeable Pavement Infiltration Test

3. BEACON BLUFF

This system, shown in **Figure 3-1**, is owned and operated by the City. The Saint Paul Port Authority contributed financially to the project and oversaw its construction. Volume reduction credits were split between the City and the Saint Paul Port Authority based on the respective financial contribution. Performance monitoring of the system has been conducted since 2012 and rainfall monitoring for the Site is conducted at the Wilder Recreation Center, located 0.8 miles to the west. The BMP system details are provided in **Table 3-1**.

The system is comprised of three connected stormwater treatment structures, which include a stormwater pond west of the Duchess cul-de-sac (west pond), an infiltration basin east of the cul-de-sac (rain garden), and an underground infiltration chamber constructed directly beneath the rain garden. The underground chamber consists of three, parallel, 215-foot-long, ten-foot-diameter perforated metal pipes for infiltration.

The Beacon Bluff system has a total drainage area of 143.6 acres, which consists of three subwatersheds. Stormwater from a 136.8-acre drainage area is routed to a diversion structure in the storm sewer along Duchess Street (MH7). The diverted stormwater passes through a manhole equipped with a SAFL Baffle pre-treatment system for particle settling, and then discharges to the rain garden (**Photo 3-2**). Two inlets on the eastern side of the rain garden discharge stormwater from a 4.7-acre drainage area immediately surrounding the BMP. Stormwater from a 2.1-acre drainage area discharges to the west pond, which outlets directly to the underground chamber (**Photo 3-1**).

Overflow grates within the rain garden allow stormwater to spill from the rain garden, directly into the underground chamber. When the underground chamber reaches capacity, stormwater discharges from the underground system, through an outlet control structure, back to the main stormsewer line.

Table 3-1: Beacon Bluff BMP Details

Total Drainage Area to BMP	143.6 acres
Sub-watershed to Diversion Structure (discharge to rain garden)	*136.8 acres*
Sub-watershed to Eastern Inlet Pipes (discharge to rain garden)	*4.7 acres*
Sub-watershed to West Pond (discharge from west pond to underground chamber)	*2.1 acres*
Year Constructed	2011
Total Construction Cost	$980,000
Storage Volume[1]	159,350 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	116,435 cu-ft
Volume Reduction Credit Received by Saint Paul Port Authority	42,925 cu-ft

Photo 3-1: Underground infiltration chamber (Facing west)

Photo 3-2: Rain garden located above storage chambers (Facing east)

3.1. Water Level and Infiltration Rate Monitoring

Water level in the rain garden (IR-33) and the underground system (IR-32) were measured using continuous water level loggers placed in piezometers. An additional logger was installed within the outlet control structure of the system to confirm when flow was being conveyed back to the stormsewer from the underground chamber. Groundwater elevation was also measured in two locations at the site. Water level elevations within the system and groundwater, and daily rainfall totals are presented on **Chart A.1** and **A.2** of **Appendix A**.

Photo 3-3: Rain garden and IR-32 (underground system) monitoring piezometers (yellow caps), and open grate overflow structure to underground chamber

Water level in the rain garden ranged from 0 feet (ft) to 3.8 ft of depth in 2016. Overflow from the rain garden to the underground system, through open grate structures (**Photo 3-3**), occurred during most treatment events. The 2016 infiltration rate and infiltration rate trends are provided on **Charts A.3** and **A.5** of **Appendix A**, respectively. The 2016 average infiltration rate for the rain garden was 0.43 in/hr, which is less than the Minnesota Stormwater Manual (MSWM) recommended infiltration rate for SP (poorly graded sand) soils of 0.8 in/hr.

From 2012 to 2016, the infiltration rate in the rain garden decreased from 2.9 in/hr to 0.43 in/hr, with the largest decline following the first year of monitoring in 2012 (see **Table 3-2**). The decrease in infiltration in the rain garden is primarily due to sediment accumulation, which was observed ranging from 0.5 ft to 1.5 ft of depth, across the basin. The 141.5-acre drainage area discharging directly to the pond, conveys a significant amount of sediment and debris, which has accumulated primarily around the diversion inlet pipe. The rain garden was free of standing water for 33 out of 230 days monitored in 2016, primarily in early May and October.

Table 3-2: Beacon Bluff Infiltration Rates

Location	Average Infiltration Rate (in/hr)				
	2012	2013	2014	2015	2016
Beacon Bluff Rain Garden (IR-33)	2.9	0.85	0.70	0.29	0.43
Beacon Bluff Underground System (IR-32)	2.6	0.57	0.64	0.30	0.15

Water level in the underground system ranged from 5.6 ft to 18.2 ft of depth. The data indicates that the system did not drain to empty throughout the 2016 monitoring period, including over winter months. The underground system discharged back to the storm sewer (system outflow) during nine storm events in 2016. This is an increase from discharge events occurring in 2012-2014 (0) and 2015 (5). The increased frequency of system discharge events is a result of the standing water in the underground system and the capacity it utilizes. Groundwater elevations at the site were a minimum of twelve ft below the bottom of the underground chamber, which suggests that groundwater mounding is not the cause of standing water in the system.

The 2016 infiltration rate and infiltration rate trends are provided on **Charts A.4** and **A.6** of **Appendix A**, respectively. The 2016 average infiltration rate for the underground system was 0.15 in/hr, which is less than MSWM recommended infiltration rate for SP soils of 0.8 in/hr. From 2012 to 2016, the infiltration rate has decreased from 2.6 in/hr to 0.15 in/hr, with the largest decline following the first year of monitoring in 2012 (see **Table 3-2**). As mentioned above, standing water in the underground system has resulted in a decrease in infiltration rates each year.

3.2. Volume Reduction Monitoring

Stormwater flowing into the BMP was measured in the Duchess Street diversion structure and at the outlet of the west pond, which discharges directly to the underground chamber. Volume that bypassed the system was measured with a flow meter downstream of the Duchess Street diversion structure. Inflow volume from the inlets discharging into the eastern side of the rain garden was modeled using the Duchess upstream flow data and the ratio of drainage areas. Level logger data from within outlet structure was used to estimate flow leaving the system. Flow rates and daily rainfall are depicted on **Chart B.1** of **Appendix B**. An event-based volume reduction summary is provided with the pollutant loading data in **Table C.2** of **Appendix C**. A summary of the 2016 Beacon Bluff Volume Reduction is included in **Table 3-3** below.

In 2016, total runoff to the Beacon Bluff system was 3,062,696 cubic feet (cu-ft). Of that volume, 1,402,050 cu-ft was captured by the system, resulting in a volume reduction of 46 percent. The total flow conveyed back to the storm sewer from the underground system was 426,158 cu-ft, which is 23 percent of the volume that was diverted to the BMP. For the 136.8-acre drainage area to the diversion structure, the total water yield was 20,246 cu-ft/acre which is equivalent to 5.6 inches of runoff. The greatest volume captured by the BMP was 118,502 cu-ft. This volume represents 74% of the total storage capacity of the system. The system exceeded 100% capacity on several occasions, but only a portion of the total capacity was available for infiltration due to standing water in the BMP.

Table 3-3: Beacon Bluff Volume Reduction

Monitoring Period	4/18/2016 - 10/29/2016		
Total Rainfall		30.04	in.
Diversion Structure Water Balance			
Runoff Volume:		2,769,682	cu-ft
Bypassed Volume:		1,182,351	cu-ft
Volume Diverted into BMP:		1,535,923	cu-ft
Beacon Bluff Rain Garden and Infiltration Gallery Inputs			
Inflow Volume from Diversion Structure:	SubWSHD A	1,535,569	cu-ft
Inflow Volume from West Pond:	SubWSHD B	162,814	cu-ft
Inflow Volume from Eastern Inlets	SubWSHD C	129,825	cu-ft
System Discharge (conveyed back to storm sewer from OCS)		426,158	cu-ft
Beacon Bluff System Performance			
Total Runoff Volume:		3,062,696	cu-ft
Total Runoff Volume Captured:		1,402,050	cu-ft
Percent of Total Runoff Volume Captured:		46	%
Maximum Percentage of Storage Volume Utilized [1]		74	%

1- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume. The system exceeded 100% capacity on several occasions, but only a portion of the total capacity was available for infiltration due to standing water in the BMP.

3.3. Pollutant Removal Monitoring

A water quality sampler was placed in the Duchess Street diversion structure to collect samples during runoff events. The sampler was paced to collect samples at equal volume intervals to provide a representative sampling of each storm event. Samples for each event were tested as a composite to provide EMC during each event for each parameter analyzed. Grab samples were collected in the diversions structure near the automated sampler quarterly, and tested for E Coli. See **Charts C.1** and **C.2** of **Appendix C** for the complete water quality summary and pollutant loading calculations.

Table 3-4 below provides a load reduction summary for the loading parameters defined in NPDES Permit issued to the city in addition to ortho-phosphate. During the monitoring period, 7,046 pound of TSS and 33 pounds of TP were captured by the system. Over the past five years of monitoring, 56,603 pounds of TSS and 239 pounds of TP have been captured at the Beacon Bluff Site.

Table 3-4: Beacon Bluff Load/Capture Summary

Monitoring Period		4/18/2016 – 10/29/2016		
Total Rain		30.04 in.		
Water Quality Parameter	**Flow Weighted Average (mg/L)**	**Total Pollutant Load (lbs)**	**Load Captured (lbs)**	**Percent Reduction %**
Total Suspended Solids	76	14,036	7,046	50.2
Volatile Suspended Solids	33	6,150	3,073	50
Total Phosphorus	0.36	66.7	33	49.5
Ortho-phosphate	0.17	30.7	14.9	48.3
Chloride	4.1	758	374	49.4
Total Kjeldahl nitrogen	1.86	352	171.4	48.7
Nitrate + Nitrite as N	0.34	64.7	31.4	48.6

3.4. Maintenance Inspection

Visual inspections of the pretreatment structure, rain garden, and underground system were completed during site visits to determine performance and maintenance needs. As shown in **Table 3-5**, sediment depths in the pretreatment device were approximately 0.1 ft to 0.2 ft throughout the 2016 season. Floatables were observed in the pretreatment structure on most visits and within the rain garden. Sediment accumulation ranging from 0.5 ft to 1.5 ft in depth was observed across the entire rain garden in 2016. It is recommended that the rain garden undergo dredge maintenance.

Standing water was observed in the underground system on all visits, as discussed in **Section 3.1**. The last chamber inspection was completed in November 2014 when the system was mostly empty. At that time, roughly 0.25 ft of sediment was observed within the grooves of the corrugated pipe, along the bottom. It's recommended that the underground chamber be pumped down and inspected. See **Appendix D** for the **Photolog,** for photos of the BMP inspections.

Table 3-5: Beacon Bluff Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)[1]	Standing Water in Infiltration Gallery?	Observations
5/20/2016	0.1	NM	Y	Floatables present in Pre-treatment and rain garden. Standing water in BMP
6/28/2016	0.1	NM	Y	Floatables present in Pre-treatment and rain garden. Standing water in BMP
8/1/2016	0.2	NM	Y	Floatables present in Pre-treatment and rain garden. Standing water in BMP
9/20/2016	0.1	NM	Y	Floatables present in Pre-treatment. Significant sediment accumulation in rain garden. Standing water in BMP
11/15/2016	0.1	NM	Y	Sheen on water in pre-treatment. Pungent odor in BMP. Trash present in pretreatment. Standing water in BMP

1-Not Measured – A visual observation of sediment levels in the infiltration galley could not be completed due to the presence of standing water.

4. HILLCREST KNOLL

This system, shown in **Figure 4-1**, is owned and operated by the City. It was constructed in 2012 to help address local flooding issues near Hillcrest Knoll Park (**Photo 4-1**) and to contribute additional volume reduction credits to the City's general credit bank. Performance monitoring of the system has been conducted since 2013.

The system consists of an underground pipe gallery infiltration system containing nine parallel 275-foot-long, 60-inch-diameter perforated high-density polyethylene (HDPE) pipes (**Photo 4-2**). Stormwater runoff within the 37.1 acre subwatershed is directed to the system via a diversion structure in the trunk storm sewer system along Flandrau Street. When the system has reached its storage capacity, a float forces down a gate valve that restricts flow to the BMP, and the runoff continues to flow downstream through the storm sewer. Pre-treatment for this design includes a Vortechs hydrodynamic separator and an isolator row within the storage gallery. Rainfall monitoring for this site is conducted at the Frost Lake Elementary School which is located approximately 0.4 miles west of the system. The BMP details are provided in **Table 4-1**.

Table 4-1: Hillcrest Knoll BMP Details

Total Drainage Area to BMP	37.1 acres
Year Constructed	2012
Total Construction Cost	$1,175,00
Total Storage Volume	86,606 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	86,606 cu-ft

Photo 4-1: Hillcrest Knoll Park Entrance

Photo 4-2: 60" Perforated HDPE pipes during system construction

4.1. Water Level and Infiltration Rate Monitoring

Water elevation was monitored in the system at two locations and groundwater at one using continuous water level loggers placed in piezometers and PVC within the BMP pipe gallery. Water levels, within the BMP pipe and groundwater, and daily rainfall totals are presented on **Charts A.7** and **A.8** of **Appendix A**. Water Levels in the infiltration gallery ranged from 219.5 ft SPCD to 225.5 ft SPCD (bottom and top infiltration pipe elevations are 218.3 ft SPCD and 223.55 ft SPCD, respectively). The 2016 minimum BMP water level of 219.5 ft SPCD (1.2 ft of water) was observed in April 2016, indicating that the system did not drain to empty over the 2015-2016 winter. Water level monitoring during the 2013-2014 and 2014-2015 winter seasons showed that the system was draining to empty. Groundwater levels were documented at elevations within the infiltration gallery from January 2016 through December 2016, indicating that standing water within the BMP is primarily due to perched groundwater at the site. Groundwater interference has been observed during every season monitored to-date.

2016 infiltration rates and infiltration rate trends are presented on **Charts A.9** and **A.10** of **Appendix A,** respectively**.** In 2016, the average infiltration rate within the BMP pipe was 0.58 in/hr (**Table 4-2**). This is below the MSWM recommended infiltration rate of 0.8 in/hr for SP soils and the design infiltration rate of 2.0 in/hr. The 2016 infiltration rate is similar to rates calculated in 2013 and 2014. Overall, the limiting factor for infiltration within the system is groundwater intrusion.

Table 4-2: Hillcrest Knoll Infiltration Rate

	Average Infiltration Rate (in/hr)			
Location	**2013[1]**	**2014[1]**	**2015**	**2016**
Hillcrest Knoll BMP Pipe	0.40	0.36	0.92	0.58

1- In the 2015 Water Quality and Quantity Monitoring Report, the 2013 and 2014 infiltration rates were inadvertently reported to be 0.67 and 0.52 in/hr, respectively.

4.2. Volume Reduction Monitoring

Flow meters were installed upstream and downstream of the diversion structure located on Flandrau Street. The difference in the upstream and downstream volume recorded for a runoff event is volume that has been conveyed to, and infiltrated by, the BMP. Flow rates and daily rainfall are depicted on **Chart B.2** of **Appendix B**.

In 2016, the total runoff for the Hillcrest Knoll System was 1,318,123 cu-ft. Of that volume, 473,615 cu-ft was conveyed to, and infiltrated by, the underground infiltration gallery resulting in an overall volume reduction of 36 percent (**Table 4-3**). This is an increase from the 23 percent captured in 2015. The total water yield for the BMP drainage area is 35,528 cu-ft/acre which is equivalent to 9.8 inches of runoff over the 37.1-acre drainage area. The greatest volume received by the BMP was 33,680 cu-ft from a 0.93-inch rain event on October 6, 2016, which is 39 percent of the total storage capacity of the system. Storm-specific rainfall and volume reduction data is provided on **Chart B.3** of **Appendix B.**

Table 4-3: Hillcrest Knoll Volume Reduction

Monitoring Period	4/20/2016 - 11/18/2016
Total Rainfall	30.8 in.
Diversion Structure Water Balance	
Runoff Volume:	1,318,123 cu-ft
Bypassed Volume:	844,508 cu-ft
Volume Diverted into BMP:	473,615 cu-ft
Hillcrest Knoll Park System Performance	
Percent of Runoff Volume Captured:	36 %
Maximum Percentage of Storage Volume Utilized[1]:	39 %

1- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume

4.3. Maintenance Inspection

The pretreatment device and the underground infiltration system were inspected during site visits to evaluate maintenance needs. The results of those visits are shown in **Table 4-5**. Garbage was observed occasionally in the pretreatment structure, although none was observed in the infiltration gallery. Standing water was observed in the infiltration gallery during all maintenance visits in 2016, primarily a result of perched groundwater at the site. Due to the standing water, sediment accumulation within the infiltration gallery could not be evaluated. During the last visual inspection of the BMP pipe gallery, major sediment accumulation was not observed.

The float mechanism for the system gate valve was inspected regularly in 2016. The float was exercised during multiple maintenance visits in 2016 to ensure that it was not stuck in the closed position, which would result in excess flow bypassing the infiltration system. Maintenance of the float is recommended for 2017. Photos from the inspection visits are included in the photo log (**Appendix D**).

Photo 4-3: System gate valve and float

Table 4-5: Hillcrest Knoll System Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)[1]	Standing Water in Infiltration Gallery?	Observations
4/01/2016	NM	NM	NM	Float stuck, exercised. Water was released but drained within 5 minutes. Odor and bottles in pre-treatment.
5/20/2016	0.1	NM	Y	Float stuck, exercised. No backed-up water observed.
6/28/2016	0.1	NM	Y	Small amount of standing water observed in the gallery. Float stuck, exercised.
7/15/2016	NM	NM	NM	Float stuck, exercised.
7/29/2016	0.2	NM	Y (5.3 ft)	No trash or debris observed in the pre-treatment or BMP
9/20/2016	0.85	NM	Y (5.5 ft)	Gate valve closed due to system at capacity. Sheen on surface of water in the pre-treatment chamber, significant accumulation of sediment/muck in pretreatment
1/15/2016	0.1	NM	Y (3.75 ft)	Strong odor and sheen in pre-treatment chamber. Some grass clippings present in BMP.

NM – not measured during visit
1 – Due to standing water within the infiltration gallery, the presence of sediment could not be determined.

5. ST. ALBANS STREET

This system, shown in **Figure 5-1**, was constructed in 2010 to provide volume reduction along the Central Corridor light rail transit way. Volume and flow have been monitored at the site since 2012, with water quality being monitored in 2014 and 2015.

A manhole structure positioned along the main storm sewer under Aurora Avenue diverts stormwater into the underground infiltration system (**Photo 5-1**) via a 30-inch elliptical pipe (**Photo 5-2**). The system is also connected to the University Avenue storm sewer system. Any runoff that does not get treated by the infiltration trenches and tree planters along University Avenue is directed to this system. When the system reaches its storage capacity, water flows west through the existing storm sewer system. The system includes a pretreatment structure comprised of a grit chamber and baffled weir to provide settling for sediment and skimming. Rainfall monitoring for the site is conducted on the roof of Fire Station 18, located across the street from the BMP. The BMP system details are provided in **Table 5-1.**

Table 5-1: St. Albans Street BMP Details

Total Drainage Area to BMP	22.2 acres
Year Constructed	2010
Total Construction Cost	$381,903
Storage Volume	31,189 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	31,189 cu-ft

Photo 5-1: St. Albans 48" perforated HDPE installation

Photo 5-2: St. Albans flow meter installation at the Aurora diversion structure

5.1. Water Level and Infiltration Rate Monitoring

BMP water level was monitored in the access manhole at the northwest corner of the system. 2016 water elevations and daily rainfall is provided on **Chart A.11** of **Appendix A.** Water level monitoring indicated that the infiltration gallery reached 100 percent capacity during two occasions in 2016. Every treatment event monitored in 2016 resulted in the infiltration gallery drawing down to empty in less than a 24-hour period.

Infiltration rates are presented on **Chart A.12** of **Appendix A**. In 2016, the average infiltration rate of the BMP pipe was 36.2 in/hr (**Table 5-2)**, which is above the MSWM recommended infiltration rate for SP soils of 0.8 in/hr and the design infiltration rate of 26.0 in/hr. Infiltration rate trends for the St. Albans Street BMP pipe are depicted on **Chart A.13**. Infiltration rates have exceeded the design rate every year since monitoring was initiated at the Site in 2012.

Table 5-2: St. Albans Infiltration Rate

Location	Average Infiltration Rate (in/hr)				
	2012	2013	2014	2015	2016
St. Albans Street BMP Pipe	38.5	35.7	64.8	55.3	36.2

5.2. Volume Reduction Monitoring

Two flow meters were installed in the storm sewer diversion manhole located in the intersection of St. Albans Street and Aurora Avenue. One meter was installed in the elliptical pipe to capture flows into the system from the south and the other was installed in the downstream pipe to measure flows bypassing the system to the west. The difference in volume recorded by the two meters is assumed to be diverted into, and infiltrated by, the BMP. An additional flow meter was installed in the 30-inch storm sewer near the corner of St. Albans Street and University Avenue to capture flows into the system from the north. Flow rates and daily rainfall are depicted on **Chart B.4** of **Appendix B**.

In 2016, total runoff for the St. Albans Street system was 764,648 cu-ft. Of that volume, 739,151 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 97% (**Table 5-3**). Of the volume diverted to the BMP, 55% was conveyed from the Aurora diversion and 45% from the University Avenue inlet pipe. The total water yield for the BMP drainage area is 35,528 cu-ft/acre which is equivalent to 9.8 inches of runoff over the 22.2-acre drainage area. The greatest volume received by the BMP was 83,877cu-ft resulting from a 3.34-inch rain event on 08/10/2016. This volume represents 267% of the total storage capacity of the system. Storm-specific rainfall and volume reduction data is provided on **Chart B.5** of **Appendix B.**

Table 5-3: St. Albans Street Volume Reduction

Monitoring Period	05/09/16 – 11/23/16	
Total Rainfall	29.4	in
System Water Balance		
Aurora Runoff Volume:	429,556	cu-ft
Aurora Bypassed Volume:	19,673	cu-ft
St. Albans and University Volume	309,595	cu-ft
St. Albans System Performance		
Total Runoff Volume	758,754	cu-ft
Total Runoff Volume Captured	753,516	cu-ft
Percent of Runoff Volume Captured:	97	%
Maximum Volume Discharge to BMP	83,877	cu-ft
Maximum Percentage of Storage Volume Utilized[1]	267	%

1- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume

5.3. Maintenance Inspection

The pretreatment device and the underground infiltration system were inspected during site visits to evaluate maintenance needs of the BMP. As shown in **Table 5-4**, minimal sediment was observed in both the pretreatment device and the infiltration gallery. Garbage was observed in the pretreatment structure during several visits. Water level monitoring in the in the infiltration gallery confirms that the system is regularly drawing down to empty, which is consistent with no standing water observed during most BMP inspection visits. See **Appendix D** for the **Photolog.**

Table 5-4: St. Albans Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)	Standing Water in Infiltration Gallery?	Observations
5/20/2016	0.1	0.1	N	(Level logger installation) No standing water in infiltration gallery.
6/20/2016	0.1	0.1	N	Trace amounts of sediment in pre-treatment and infiltration gallery.
8/1/2016	0.5	0.1	N	Trash observed in pre-treatment and infiltration gallery.
9/2/2016	0.2	0.0	N	Some trash and minimal sediment in infiltration gallery and pre-treatment structure.
11/16/2016	0.1	0.1	N	Some trash and minimal sediment in infiltration gallery and pre-treatment structure.

6. HAMPDEN PARK

The Hampden Park infiltration gallery, shown in **Figure 6-1,** was constructed in 2014. The system consists of eight parallel perforated pipes that are five ft in diameter, and range in length from 40 to 100 ft. Runoff is routed to the system via a 24-inch RCP from the storm sewer line near Hampden and Raymond Avenues. Prior to entering the infiltration gallery, stormwater passes through a Vortech's pre-treatment chamber for particle settling. The infiltration gallery receives flow from a second inlet location along Hampden Avenue, farther to the north. When the system reaches full capacity, stormwater is routed back to the storm sewer via a 24-inch pipe from the southeast side of the system. Rainfall monitoring is conducted on top of the Hampden Park Co-Op across the street from the park. Monitoring has been conducted at the site since 2014. The BMP system details are provided in **Table 6-1** below.

Photo 6-1: Hampden Park BMP Construction

Table 6-1 Hampden Park BMP Details

Total Drainage Area to BMP	7.8 acres
Year Constructed	2014
Total Construction Cost	$687,132
Total Storage Volume	31,808 cu-ft
Volume Reduction Credit Received by the City of Saint Paul – Public Works	24,908 cu-ft
Volume Reduction Credit Received by the City of Saint Paul – Parks and Recreation	6,900 cu-ft

6.1. Water Level and Infiltration Rate Monitoring

Water levels were monitored within the underground infiltration system at two locations, and groundwater at three locations, using electronic water level loggers. In October 2016, monitoring was reduced to one location within the system (BMP Pipe) and one groundwater location (P-2) and the remaining piezometers were abandoned to allow for more recreation space in the park. Water levels and daily rainfall for 2016 are provided on **Chart A.14** and **A.15** of **Appendix A.** Water level within the BMP ranged from 0 to 3.4 ft (188.2 ft SPCD to 191.6 ft SPCD). Water levels must exceed 6.5 ft (194.7 ft SPCD) for the system to reach capacity and for water to be conveyed back to the sewer system. Based on the 2016 level data, no flow discharged back to the sewer system.

Groundwater at the site was a of minimum of 8.7 ft below the bottom of the infiltration gallery, indicating that groundwater intrusion into the system is not an issue at the site. Groundwater levels at P-1 and P-3 fluctuated four ft and three ft, respectively, throughout the season, though no mounding occurred. Groundwater elevations at PZ-1 showed no level change because of the infiltration.

The 2016 infiltration rates are presented on **Chart A.16** of **Appendix A**. The average infiltration rate for the BMP was 14.36 in/hr which is greater than the MSWM recommended infiltration rate for SP soils of 0.8 in/hr and the design infiltration rate of 1.8 in/hr. Infiltration rates at the base of site during construction were calculated to be, on average, 60 in/hr using Double Ring Infiltrometers (DRI). Water level data shows that all volume in the system is infiltrated within 48 hours of a treatment event, apart from one event, in which the last 0.5 ft of water did not fully drain until four days later.

Table 6-2: Hampden Park Infiltration Rate

Location	Average Infiltration Rate (in/hr) 2016
Hampden Park BMP	14.38

6.2. Volume Reduction

Two flow meters were installed at Hampden Park. One meter was located in the 24-inch RCP diverting flow from the main storm to the BMP pipe from the intersection of Hampden and Raymond Avenues. The metered drainage area consists of 6.7 acres of the total 7.8-area drainage area to the BMP. The second meter was installed in the system outlet pipe to monitor flow diverted back to the main sewer line. The 2016 flow rates and daily rainfall are depicted on **Chart B.6** of **Appendix B**. No discharge was observed at the system outlet therefore that data is not plotted.

In 2016, the total runoff monitored at the Hampden and Raymond Avenues system inlet was 393,560 cu-ft. The inflow from the second system inlet along Hampden Avenue was estimated to be 64,937 cu-ft based on the ratio of the drainage areas. Since no discharge was observed, 100 percnet of the runoff was infiltrated by the system which totaled 458,498 cu-ft (**Table 6-3**). The total water yield for the BMP drainage area is 58,781 cu-ft/acre which is equivalent to 16.2 inches of runoff over the 7.8-acre drainage area. The greatest volume received by the BMP was 51,788 cu-ft as a result of a 2.76-inch rain event on August 10, 2016. This volume represents 163 percent of the total storage capacity of the system. Storm-specific rainfall and volume reduction data is provided on **Chart B.6** of **Appendix B.**

Table 6-3: Hampden Park Volume Reduction

Monitoring Period	4/18/2016 – 11/18/2016	
Total Rainfall	28.34	in
Hampden Park Water Balance		
Raymond/Hampden Runoff Volume:	393,560	cu-ft
Hampden (2nd inlet) Runoff Volume[1]	64,937	cu-ft
System Bypass Volume	0	cu-ft
Hampden Park System Performance		
Total Runoff Volume	458,498	cu-ft
Total Runoff Volume Captured	458,498	cu-ft
Percent of Runoff Volume Captured:	100	%
Maximum Volume Discharge to BMP	51,788	cu-ft
Maximum Percentage of Storage Volume Utilized[2]	163	%

1 – The second system inlet along Hampden Avenue is not monitored, and the volume discharged to the system from that location is estimated based on monitored data at Hampden/Raymond and the ratio of the drainage areas

2- This is the maximum volume infiltrated by the BMP for a treatment event as a percentage of the total storage volume

6.3. Pollutant Removal Monitoring

A water quality sampler was placed in Hampden and Raymond Avenue system inlet to collect samples during runoff events. The sampler was paced to collect samples at equal volume intervals to provide a representative sampling of each storm event. Samples for each event were tested as a composite to provide EMC during each event for each parameter analyzed. Grab samples were collected for select runoff events and tested for E Coli. See **Charts C.3** and **C.4** of **Appendix C** for the complete water quality summary and pollutant loading calculations.

Table 6-4 below provides a load reduction summary for the loading parameters defined in NPDES Permit issued to the city in addition to ortho-phosphate. During the monitoring period, 612 pounds of TSS and 3.3 pounds of TP were captured by the system.

Table 6-4: Hampden Park Load/Capture Summary

Monitoring Period		4/18/2016 – 11/19/2016		
Total Rain		28.34 in.		
Water Quality Parameter	**Flow Weighted Average (mg/L)**	**Total Pollutant Load (lbs)**	**Load Captured (lbs)**	**Percent Reduction %**
Total Suspended Solids	21.4	612	612	100
Volatile Suspended Solids	8.2	234	234	100
Total Phosphorus	0.114	3.3	3.3	100
Ortho-phosphate	0.045	1.3	1.3	100
Chloride	2.1	65.2	65.2	100
Total Kjeldahl nitrogen	0.78	22.4	22.4	100
Nitrate + Nitrite as N	0.27	7.7	7.7	100

6.4. Maintenance Inspection

Sediment depths in the pretreatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 6-5** minimal sediment was observed in both the pretreatment device and infiltration gallery.

Table 6-5: Hampden Park BMP Maintenance Inspection

Date	**Sediment Depth in Pre-treatment (ft)**	**Sediment Depth in Infiltration Gallery (ft)**[1]	**Standing water in Infiltration Gallery?**	**Observations**
5/20/2016	0.0	0.0	N	Garbage and organic debris in pretreatment. Minimal sediment observed in pretreatment, none in the infiltration gallery.
6/28/2016	0.1	0.0	N	Standing water in sump, but not in BMP pipe. Trash in pre-treatment.
8/1/2016	0.16	0.0	N	No trash noted in pre-treatment
9/20/2016	0.2	0.0	N	Water in sump, but none in infiltration gallery. Pre-treatment felt mucky, some trash present as well.
11/15/2016	0.1	0.0	N	Slight odor and sheen on water pre-treatment, some trash present as well.

7. ARUNDEL STREET

This system, shown in **Figure 7-1**, was constructed in 2011 to provide volume reduction along the Central Corridor light rail transit way. A sump in the main storm sewer in Arundel Street diverts flow into the infiltration system via an 18-inch pipe. When the system reaches full capacity, water begins bypassing the diversion sump and continues downstream to the north. The system includes a pre-treatment structure which consists of a box culvert section and baffled weir to provide skimming and settling of runoff prior to entering the infiltration chamber. Infiltration rates at the site have been monitored since 2012.

Table 7-1: Arundel Street BMP Details

Total Drainage Area to BMP	4.9 acres
Year Constructed	2011
Total Construction Cost	$76,300
Storage Volume	4,521 cu-ft
Volume Reduction Credit Received by the City of Saint Paul	4,521 cu-ft

Photo 7-1: Arundel infiltration system access manhole and BMP level monitoring location

7.1. Water Level and Infiltration Rate Monitoring

BMP pipe water level was monitored at the access manhole at the south end of the system. Water levels and daily rainfall are presented on **Chart A.17 of Appendix A.** Water Levels in the infiltration gallery ranged from 166.7 ft SPCD to 171.9 ft SPCD (bottom and top infiltration pipe elevations are 166.7 ft SPCD and 170.7 ft SPCD, respectively). Level data shows that the system drained to empty two times in 2016. Following a rain event on June 14, 2016, the system drained from 100 percent capacity to empty after 13 days, with no rain. The system exceeded 100 percent capacity during 31 runoff events in 2016.

The BMP pipe infiltration rates are presented on **Chart A.18 of Appendix A**. In 2016, the average infiltration rate of the BMP pipe was 0.16 in/hr (**Table 7-2)**, which is less than the MSWM recommended infiltration rate for SP soils of 0.8 in/hr, and the design infiltration rate of 17.6 in/hr. Infiltration rate trends are depicted on **Chart A.19.** The average infiltration rate has decreased every year since 2012, which is likely a result of sediment accumulation observed within the BMP. The BMP pipe has undergone jetting and vacuum maintenance in 2015 and 2016. Those maintenance activities removed sediment and debris accumulated within the BMP, however infiltration rates did not increase as a result.

Table 7-2: Arundel Infiltration Rate

Location	Average Infiltration Rate (in/hr)				
	2012	2013	2014	2015	2016
Arundel BMP Pipe	8.0	2.43	1.64	0.42	0.16

7.2. Maintenance Inspection

Sediment depths in the pre-treatment structure and in the underground infiltration system were measured during site visits to determine performance and maintenance needs. As shown in **Table 7-3**, sediment depths in the infiltration gallery ranged from 0.1 to 0.2 ft. In contrast, prior to 2015 maintenance, sediment depth in the BMP pipe was observed to be 2.0 ft. Standing water was routinely observed in the BMP pipe, as mentioned in the previous section. See **Appendix D** for the **Photolog.**

Table 7-3: Arundel Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)	Standing water in Infiltration Gallery?	Observations
6/28/2016	NM	0.1	N	No trash or standing water observed
8/05/2016	0.75	0.1	Y (2.7 ft)	Trash in both pre-treatment and BMP – Standing water present
9/20/2016	NM	0.2	Y (2.3 ft)	Trash in both pre-treatment and BMP – Standing water present
11/01/2016	NM	0.1	Y (0.7 ft)	Trash in BMP

8. FLANDRAU-HOYT POND

The Flandrau-Hoyt Pond was constructed to provide stormwater runoff storage for the neighborhood surrounding Prosperity Heights Park. The pond is located near the intersection of Ivy Avenue E and Germain Street in St. Paul. Water elevations were monitored at Flandrau-Hoyt Pond to evaluate water level fluctuation in the basin, and to provide hydrology data for future improvements. The pond location is provided as **Figure 8-1.**

Photo 8-1: Flandrau-Hoyt Pond outlet control structure

Photo 8-2: Flandrau-Hoyt Pond inlet

8.1. Water Level Monitoring

A level logger was installed near the pond outlet and configured to record elevations once per hour. Water elevation and rainfall are presented on **Chart A.20 of Appendix A.** A summary of select runoff events from 2016 is presented in **Table 8-1** below. The elevation of the top of the outlet control structure (concrete section) and the top of the emergency spillway are 205 ft SPCD and 218 ft SPCD, respectively.

Table 8-1: Flandrau-Hoyt Pond Water Level Summary

Date	Rainfall (in)	Rainfall Intensity (in/hr)	Level Increase (ft)	Peak Water Elevation (ft SPCD)	Time to Return to NWL (hrs)
7/5/2016	1.68	1.68	9.2	211.2	8
8/4/2016	1.75	0.88	14.8	214.9	8
8/10-8/11/2016	3.09	0.28	14.8	214.9	13
10/6/2016	0.91	0.15	3.8	206.4	9

During the 2016 monitoring season, water levels in the pond ranged from 201.7 ft SPCD on August 28, 2016 to 214.9 ft SPCD on August 4 and August 10, 2016. The largest level fluctuation occurred during the August 4th and August 10th rain events when the pond level increased by 14.8 ft. During all events monitored in 2016, water level in the pond decreased back to pre-event levels in less than 15 hours, and levels never exceeded the emergency spillway elevation.

9. SACKETT PARK POND

The Sackett Park Pond is situated in a wooded area between the Boys and Girls Club and the Chicago Northwestern Railroad on St. Paul's East Side. The basin receives runoff from the east via a storm sewer inlet pipe. The runoff flows northwest through a shallow channel, until it reaches an outlet control structure that conveys water away from the site though a 42-inch RCP pipe (**Photo 9-1**). When runoff exceeds the banks of the channel, it spills into the surrounding flood plain (**Photo 9-2**). Water elevations were monitored within the Sackett Park Pond to evaluate water level fluctuation in the basin, and to provide hydrology data for future improvements at that location. The pond location is provided as **Figure 9-1.**

Photo 9-1: Level logger configuration and outlet control structure

9.1. Water Level Monitoring

A level logger was installed near the pond outlet control structure and configured to record water elevations once every 15 minutes. Water elevations and rainfall are presented on **Chart A.21 of Appendix A.** A summary of select runoff events from 2016 is presented in **Table 9-1** below. The elevation of the top of the outlet control structure is 194 ft SPCD. Groundwater monitoring was conducted during the 2015 monitoring season and those results indicated that a continuous artesian condition was present at the site. Groundwater was not monitored in 2016.

Table 9-1: Sackett Park Pond Water Level Summary (Select Flow Events)

Date	Rainfall (in)	Rainfall Intensity (in/hr)	Level Increase (ft)	Peak Water Elevation (ft SPCD)	Depth above OCS (ft)
5/26/2016	0.18	0.09	1.26	194.1	0.1
6/9/2016	0.74	0.15	2.8	195.4	1.4
6/12/2016	0.53	0.27	1.1	194.4	0.4
7/5/2016	1.68	1.68	0.4	192.4	-1.6
8/4/2016	1.75	0.88	3.6	195.6	1.6
10/6/2016	0.91	0.15	2.2	194.2	0.2

In 2016, water levels in the pond ranged from 191.6 ft SPCD on July 8, 2016 to 195.6 ft SPCD on August 4, 2016. The maximum level occurred as a result of 1.82 inches of rain on August 4, which increased the level by 3.6 ft to a depth of 1.6 ft above the outlet control structure. Nine rain events ranging from 0.18 inches to 3.09 inches resulted in water level elevations that exceeded the top of the outlet control structure. Water levels exceeded the top of the outlet control structure on eight occasions in 2016. Following those events, the level decreased to below the top of the outlet control structure within 6 hours.

Photo 9-2: Sackett Park Pond outlet control structure – runoff exceeds channel bank and enters flood plain.

10. TROUTBROOK NATURE SANCTUARY – IRON-ENHANCED SAND FILTRATION PONDS

The Trout Brook Nature Sanctuary (TBNS) (**Figure 10-1**) is a 42-acre site located between Norpac Road and Maryland Avenue, west of I-35E. The objective of the construction effort, which was finalized in 2015, was to create a nature preserve in the heart of a heavily urbanized area. The focal points of the plan included expanding the Trout Brook Regional Trail and daylighting the Trout Brook Creek, which had previously been filled in and routed through underground sewer. Three iron-enhanced sand filtration (IESF) ponds were constructed in the TBNS to provide additional phosphorus treatment. Volume reduction credits for the stormwater features were split between the City Public Works and Parks and Recreation departments based on the respective financial contribution. Monitoring at TBNS has been conducted since 2015. The BMP system details are provided in **Table 10-1**.

Photo 10-1: Magnolia Pond Iron-Enhanced Sand Bench Sand Bench

Photo 10-2: Jenks Pond Iron-Enhanced

Table 10-1: Trout Brook Nature Sanctuary Site Details.

Total Drainage Area to BMP	144.4 acres
Year Constructed	2015
Total Construction Cost	$4 million ($1.53 million contributed by City of Saint Paul Public Works)
Storage Volume	155,571 cu-ft
Volume Reduction Credit Received by the City of Saint Paul Public Works	103,455 cu-ft
Volume Reduction Credit Received by the City of Saint Paul Parks and Recreation	5,445 cu-ft

At each of the three IESF pond locations, stormwater is conveyed to the basin from individual diversion structures along the 42-inch main storm sewer line that runs along the western side of the site. After flow is diverted from the sewer line, it passes through a Vortechs pre-treatment structure for particle settling, then discharges to the pond. As the level in the pond rises, the water gravity flows through a sand filtration bench that was mixed to have iron fillings at five percent by weight. The iron-enhanced sand provides a mechanism to remove SRP, a dissolved bio-available form of phosphorus, which is not effectively removed by settling pre-treatment devices. Beneath the sand bench is six-inch perforated drain tile that conveys the treated water to the outlet control structure of the pond. From the pond, the stormwater flows through a wetland, then connects with the constructed creek.

The monitoring conducted at TBNS is a collaborative effort between the City and Capitol Region Watershed District (CRWD). The monitoring completed by the City includes performance monitoring of three IESF ponds at the site: Maryland Pond (**Photo 10-3**), Magnolia Pond (**Photo 10-1** and **10-4**), and Jenks Pond (**Photo 10-2**). Monitoring completed by CRWD includes water quality and flow monitoring at the pond diversions diversion structures, and within the creek. The effectiveness of the IESF ponds was determined by collecting samples from the within the pond and the pond outlet control structure during treatment events. The samplers were programmed to collect simultaneous flow weighted samples based on flow pacing monitored in the outlet control structure. Additional information regarding equipment and monitoring procedures for the TBNS monitoring effort is described in **Section 2.3**.

Photo 10-3: Maryland Pond treatment

Photo 10-4 Magnolia Pond treatment

10.1. Water Level Monitoring

Water level was monitored at Maryland, Magnolia and Jenks Ponds from within the outlet control structure of each pond. Water levels with daily rainfall are provided on **Charts A.22**, **A.23** and **A.24** of **Appendix A**. A summary of water elevations is presented in **Table 10-2** below.

Table 10-2: TBNS Water Level Summary

Pond Location	Minimum Water Elevation (ft SPCD)	Normal Water Elevation (ft SPCD)	Maximum Water Elevation (ft SPCD)	Weir Overflow Elevation (ft SPCD)
Maryland	116.7	116.4	118.75	119.0
Magnolia	123.3	123.8	126.2	126.0
Jenks	93.5	95.5	95.5	98.0

The results of the level monitoring data are summarized below:

- Maryland Pond
  - Flow through the IESF benches was observed when water levels exceeded 116.8 ft SPCD
  - The minimum water level was 0.3 ft greater than the normal water level (recorded on July 5, 2016). The period from July 1, 2016 to July 5, 2016 was the only time that flow through the IESF system was not occurring.

  - Water levels did not exceed the weir overflow elevation in 2016.
- Magnolia Pond
  - Flow through the IESF benches was observed when water levels exceed 124.2 ft
  - The minimum water level was 0.5 ft less than the normal water level (Recorded on July 5, 2016)
  - Water levels exceeded the weir overflow elevation two times in 2016, with the maximum water elevation recorded on August 10, 2016
- Jenks Pond
  - Flow through the IESF benches was observed when water levels exceed 94.4 ft
  - The minimum water level was 2.0 ft less than the normal water level (recorded on May 24, 2016)
  - The maximum water level was equal to the normal water level (recorded on August 11, 2016)
  - Low water levels in Jenks Pond are a result of limited flow being conveyed from the storm sewer line to the pond.
  - Water level monitoring was concluded mid-September due to equipment malfunction.

10.2. Treatment Volume Monitoring

The treatment volume was monitored at each of the sites using a 2150 flow meter installed within the outlet control structure of each pond. Flow Rates and daily rainfall for the three sites are provided on **Charts B.7** through **B.9** of **Appendix B**. A summary of that data is provided in **Table 10-3** below.

Table 10-3 TBNS IESF Pond Flow Summary

Pond Location	2016 Flow Summary (cu-ft)		
	Total Flow	Event-Based Flow	Average Event-Based Flow
Maryland	1,607,714	969,962	23,094
Magnolia	229,794	229,794	10,827
Jenks	5,695	5,695	569

Maryland Pond treated the greatest volume of water of the three ponds, recording 1,607,714 cu-ft in the outlet control structure. Continuous flow was observed through the drain tile during the entire 2016 monitoring period, except for a five-day period in early July. The event-based flow was calculated to be 969,962, or 60 percent of the total flow. The baseflow present at Maryland Pond in 2016 was significantly greater than flow measured in 2015. When comparing the June through September monitoring periods in 2015 and 2016, the rainfall recorded in 2016 was 28 percent greater than 2015, yet the total monitored flow was 146 percent greater. Groundwater interaction at the Maryland IESF Pond will be evaluated further in the 2017 Monitoring Program.

Magnolia and Jenks pond treated 229,794 cu-ft and 6,075 cu-ft of stormwater, respectively. All treatment events monitored at Magnolia and Jenks Pond were completed within 48 hours following the rain event. As mentioned in **Section 10.1**, the diversion structure at Jenks Pond is not adequately conveying stormwater to the treatment pond. Treatment through the IESF occurred at Jenks Pond 10 times in 2016, compared to 21 and 42 treatment events at Magnolia and Maryland Ponds, respectively. The Jenks Pond treatment events were a result of rainfall ranging from 0.9 inches to 3.09 inches. In 2017, the diversion structure at Jenks Pond was modified to increase flow diverted to the basin.

10.3. Pollutant Reduction Monitoring

Water Quality was monitored at the three ponds by collecting flow-paced samples from within the pond (pre-treatment) and the outlet control structure (post-treatment). Samples were collected simultaneously using automated samplers programmed to collect samples based on the outlet flow pacing. The sample collected form the stormwater pond was collected approximately, one foot below the water surface. Grab samples were collected during sampling equipment malfunctions and for comparison to flow weighted sample concentrations. Samples were analyzed for total phosphorus, dissolved phosphorus and soluble reactive phosphorus (SRP). The water quality data is provided in **Tables C.5** through **C.10** of **Appendix C.** That data is summarized in **Table 10-4** below.

Photo 10-5 – Magnolia Pond sample float

Photo 10-6: 8/11/16 treatment event

Table 10-4: TBNS IESF Ponds Water Quality Summary

Pond Location	Pre-treatment		Post-treatment		Calculated Load Reduction (lbs)	% Reduction
	Pond AVG (mg/L)	Pond FWA (mg/L)	OCS AVG (mg/L)	OCS FWA (mg/L)		
Total Phosphorus						
Maryland	0.091	0.090	0.117	0.134	-2.6	-48
Magnolia	0.280	0.250	0.130	0.130	1.73	49
Jenks	0.102	0.062	0.102	0.062	0	0
Soluble Reactive Phosphorus						
Maryland	0.011	0.015	0.015	0.017	-0.17	-20
Magnolia	0.063	0.061	0.039	0.039	0.31	35
Jenks	0.019	0.013	0.022	0.016	-0.001	-23

AVG – Average concentration, FWA – Flow weighted average, OCS – Outlet Control Structure

Water quality samples collected at Maryland Pond showed an average load reduction of -48 percent for TP and -20 percent for SRP. This contrasts with data collected in 2015, that showed an average load reduction of 54 percent and 69 percent for TP and SRP, respectively. The pond Flow Weighted Average (FWA) for TP and SRP decreased by 53 percent and 75 percent from 2015 to 2016 respectively, while the OSC FWA for TP increased by 76 percent and was constant for SR. Events that demonstrated a positive load reduction were the first four consecutive sampling events of the season taking place in May and June. As discussed in **Section 10.2**, Maryland Pond experiences continuous flow, which may be a result of groundwater intrusion at the site. Continuous flow through the media can prevent proper aeration of the filter bed between treatment events, which is a design recommendation in the MSWM. Adjustments to the sampling protocols for Maryland Pond in 2017 will include the addition of baseflow samples for source characterization and additional QA/QC samples.

At Magnolia Pond, 1.73 pounds of TP and 0.31 pounds of SRP were removed by the iron-enhanced media (49 percent and 35 percent removal efficiency, respectively). This is an increase in the removal efficiency calculated for 2015 (37 percent of TP and 23 percent of SRP). Total load reductions were similar for both years, despite the increase in removal efficiency, due a decrease in TP and SRP concentrations in the pond.

Jenks pond had equal FWA concentrations for TP in the pond and OSC, which resulted in no reduction. SRP concentrations were slightly greater in the OCS than the pond, although this was based off four sampled events with two events demonstrating a reduction and two demonstrating a negative reduction. Due to limited treatment occurring at Jenks Pond, additional samples are needed to adequately evaluate the performance of the pond.

11. MONTREAL INFILTRATION TRENCH

This system, shown in **Figure 11-1** and **Photo 11-1**, consists of an infiltration trench situated beneath Montreal Avenue that was constructed to treat runoff from 1.38 acres of local right-of-way. Stormwater runoff is conveyed to the system from the east by a 15-inch RCP near Snelling Avenue into two 12-inch perforated pipes that total 225 ft in length. Stormwater drains through the pipe perforations into a six-foot-deep trench filled with aggregate for increased infiltration capability. Water levels were monitored within the trench beginning in 2016 to evaluate infiltration rates at the Site. The BMP system details are provided in **Table 11-1** below.

Table 11-1 Montreal BMP Details

Total Drainage Area to BMP	1.38 acres
Year Constructed	2014
Trench Storage Volume	8,069 cu-ft

Photo 11-1: Infiltration Trench Monitoring Location (Montreal & Snelling Avenues)

11.1. Water Level and Infiltration Rate Monitoring

The trench water level was monitored at the access manhole at the mid-point of the system. Water levels and daily rainfall are presented on **Chart A.25** of **Appendix A.** Water Levels in the trench ranged from 278.6 ft SPCD to 280.4 ft SPCD (bottom and top trench elevations are 278 ft SPCD and 284 ft SPCD, respectively). Level data shows that the trench drained to empty within 48 hours for every event in 2016. The trench infiltration rates are presented on **Chart A.26** of **Appendix A**. In 2016, the average infiltration rate was 7.51in/hr **(Table 11-2)**, which is greater than the design infiltration rate of 0.6 in/hr.

Table 11-2: Montreal Infiltration Rate

Location	Average Infiltration Rate (in/hr) 2016
Montreal Trench	7.51

12. WORDSWORTH INFILTRATION TRENCH

This system, shown in **Figure 12-1**, consists of an infiltration trench situated beneath a bioretention system, along Wordsworth Avenue. Stormwater is conveyed from Sue Street from the west and Edgecumbe Road from the east into two 12-inch perforated pipes (**Photo 12-1**) that total 559 ft in length. Stormwater drains through the pipe perforations into a six-foot-deep trench filled with aggregate for increased infiltration capability. Water levels were monitored within the trench (**Photo 12-2**) beginning in 2016 to evaluate infiltration rates at the Site. The BMP system details are provided in **Table 12-1** below.

Table 12-1: Wordsworth BMP Details

Total Drainage Area to BMP	4.5 acres
Year Constructed	2013
Trench Storage Volume	6,278 cu-ft
Total Storage Volume (Trench, Soil Area, & Bioretention)	8,805 cu-ft

Photo 12-1: Discharge location from Sue Avenue to the 2- 12" infiltration trench pipes

Photo 12-2: Infiltration Trench Monitoring Location (Wordsworth Avenue)

12.1. Water Level and Infiltration Rate Monitoring

The trench water level was monitored at the access manhole at the midpoint of the system. Water levels and daily rainfall are presented on **Chart A.27** of **Appendix A.** Water Levels in the trench ranged from 121.6 ft SPCD to 127.2 ft SPCD (bottom and top trench elevations are 122.5. ft SPCD and 128.5 ft SPCD, respectively). Level data shows that the trench drained to empty within 48 hours for every event from April through July. From August through November, infiltration occurred within 48 hours of a treatment event, with the exception of the bottom 0.4-1.4 ft of level. This was the case for all infiltration events during that time. Following a 0.73 in rain event on October 27, 2016, the bottom 1.0 ft gradually infiltrated over a period of 23 days. The trench infiltration rates are presented on **Chart A.28** of **Appendix A**. In 2016, the average infiltration rate was 4.35 in/hr **(Table 12-2)**, which is greater than the design infiltration rate of 0.6 in/hr.

Table 12-2: Wordsworth Infiltration Rate

Location	Average Infiltration Rate (in/hr)
	2016
Wordsworth Trench	4.35

13. PERVIOUS SURFACE INFILTRATION ASSESSMENT

The City has been monitoring the performance of pervious pavement BMPs constructed in the City since 2012. Pervious pavement is designed to allow infiltration of stormwater through the surface into the soil below where the water is naturally filtered. The purpose of the infiltration testing is to determine if and how the infiltration capability of the pervious surface changes over time. Pavement maintenance is also monitored to study the effect of routine and rehabilitative maintenance on these BMPs.

Infiltration testing was completed at the Victoria Street and Hamline Midway Library pervious pavement BMPs in July 2016 and the Jackson Street Pervious Bike Path BMP in November 2016 (new site in 2016). This section presents the results of the 2016 infiltration testing and maintenance activities.

13.1. Victoria Street

The Victoria Street pervious surface consists of a parking area completed with permeable concrete pavers designed to receive stormwater runoff from Victoria Street and the properties adjacent to it. The pavers themselves are non-permeable and they are separated with aggregate fill (**Photo 13-1** and **13-2**). The spaces between the pavers allow stormwater runoff to infiltrate into the parking surface instead of running off and being collected by the storm sewer system. The pavers were installed in 2011 and infiltration rates have been monitored annually since 2012. The site and the infiltration test locations are provided on **Figure 13-1.**

Photo 13-1: Victoria Street pavers

Photo 13-2: Victoria Street infiltration testing

Pavement Maintenance

The Victoria Street Site is swept twice annually during the spring and fall city-wide sweeping. The site was vacuumed one time in 2013, in which the trap rock was removed and subsequently replaced. No additional non-routine pavement maintenance has been completed at the site.

Infiltration Test Results and Observations

Five locations were tested for infiltration at the Victoria Street site. In 2015, the exact test locations from 2014 could not be located, so new locations were established in the immediate area and identified as A-E (these locations were used in 2016). Those locations are depicted on **Figure 13-1** and the results of the testing are presented in **Table 13-1**.

Table 13-1: Victoria Street Permeable Pavement Infiltration Rate

Infiltration Ring Location	2012 Infiltration Rate (in/hr)	2013 Infiltration Rate (in/hr)	2014 Infiltration Rate (in/hr)	2015 Infiltration Rate (in/hr)		2016 Infiltration Rate (in/hr)	
IR-1	168.6	18.1	0	A	0	A	4.8
IR-2	266.6	75.7	13.0	B	0.9	B	5.7
IR-3	271.1	92.2	18.6	C	0	C	1.6
IR-4	69.1	24.0	9.7	D	0	D	0
IR-5	149.8	49.2	30.8	E	3.7	E	4.44
Average	**185.04**	**51.84**	**14.42**	**0.92**		**3.33**	

A summary of the 2016 infiltration test results is provided below:

- No infiltration was observed at Location D, similar to 2015.
- Infiltration rates at Locations A, B, C, and E increased from 2015 to 2016.
- IR-6 infiltrated at 15.0 in/hr, which is less than the 2015 rate of 125.6 in/hr
- The overall site infiltration rate increased from 0.92 in/hr in 2015 to 3.33 in/hr in 2016

13.2. Hamline Midway Library

The Hamline Midway Library pervious surface consists of 920 square yards of porous asphalt within the two alleyways adjacent to the Hamline Midway Library and the center alleyway connecting the sections (**Photos 13-3** and **13-4).** The asphalt content of the mix is 6.3 percent and the specific voids ratio is 18 percent. The asphalt was installed in 2012 and infiltration rate monitoring has been completed annually since 2013. The site and the infiltration test locations are provided on **Figure 13-2**.

Photo 13-3: Hamline Midway Library porous asphalt (post-construction)

Photo-13-4: Hamline Midway Library porous asphalt

A chronology of site activities is provided below:

- November 2012: Construction Complete
- June 2013: Standard Broom Sweeping (Eglin Pelican Sweeper)
- July 2013: Infiltration Testing
- August 2013: Vacuum Sweeping (Eglin Crosswind)

- October 2013: Vacuum Sweeping (Eglin Crosswind)
- August 2014: Infiltration Testing
- September 2015: Vacuum Sweeping (Eglin Crosswind) and Pressure Wash (see details in section below)
- November 2015: Infiltration Testing
- July 2016: Regenerative Air Sweep and Pressure Wash (see details in section below)
- July 2016: Infiltration Testing

Pavement Maintenance

The following section describes recent maintenance efforts at the Hamline Midway Library Site, specifically activities completed in 2015 and 2016 aimed at optimizing procedures and equipment selection.

In 2015, three different maintenance procedures were tested in separate areas of the site prior to infiltration testing. The goal was to identify the most effective maintenance method to improve infiltration at the site. The following work was completed:

- Dry sweeping was completed in the area of IR-1, IR-2, IR-3, IR-4 and IR-8
- Wet vacuum sweeping was completed in the area of IR-7 and IR-9.
- Vacuum sweeping with subsequent pressure washing was completed in the area of IR-5 and IR-6.

Of the maintenance procedures, the vacuum sweeping with subsequent pressure wash was successful in improving the infiltration rate at one of the two test locations (**Table 13-2**). All other test locations showed no increase in infiltration after maintenance. Given the results of the 2015 maintenance and testing, vacuuming sweeping with pressure washing was recommended for the entire site in 2016.

Prior to infiltration testing in 2016, Reliakor was contracted to complete vacuum sweeping and pressure washing maintenance. The vacuum sweeping was completed using a Regenerative Air Sweeper which consists of two rotating brooms that agitate and move material to the suction head. Pressurized air forces the material from one end of the suction head to vacuum (**Photo 13-5**). Sweeping at the site consisted of three passes with the Regenerative Air Sweeper over each alleyway and additional passes over areas with more debris. Locations IR-1, IR-2, IR-3, IR-4, and IR-8 (western alley) were observed to have heavy sediment accumulation. Locations IR-5, IR-6, IR-7, and IR-9 had some sediment and organic debris present, but to a lesser extent than the previously mentioned locations.

Following the sweeping, the entire alley was pressure washed (**Photo 13-6**). Additional spraying was completed in areas that were observed to have heavier sediment accumulation prior to maintenance. Additional maintenance photos are provided in the **Appendix D**.

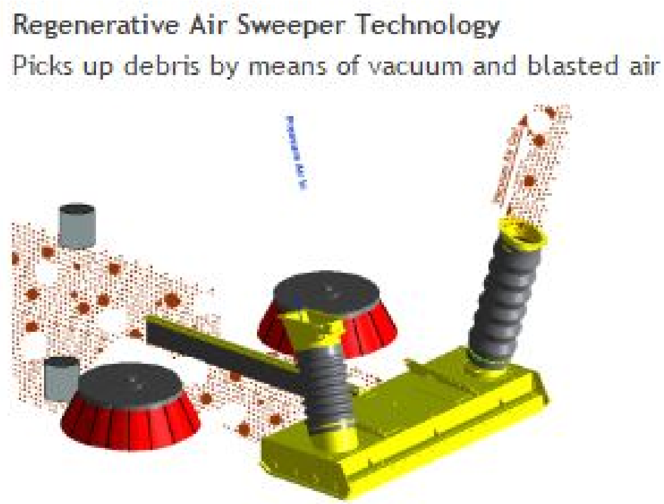


Photo 13-5: Regenerative Air Sweeper Technology (Source: Eglin Sweeper Company Website)

Photo 13-6: Pressure washing maintenance

<u>Infiltration Test Results and Observations</u>

Nine locations were tested for infiltration at the Hamline Midway Library Site. Those locations are depicted on **Figure 13-2** and the results are presented in **Table 13-2** which includes all infiltration test results to date. Prior to construction in 2012, the sub-surface soil infiltration rate was determined to be 29.0 inches per hour (in/hr) and 59.1 in/hr using a double ring infiltrometer.

Table 13-2: Hamline Midway Library Infiltration Rate Summary

Infiltration Test Location	July 2013 Infiltration Rate (in/hr)	August 2014 Infiltration Rate (in/hr)	November 2015 Infiltration Rate (in/hr)	July 2016 Infiltration Rate (in/hr)
IR-1	102.4	0.0	0	0
IR-2	14.9	0.0	0	0
IR-3	11.4	0.0	0	0
IR-4	172.7	0.0	0	0
IR-5	0.0	0.0	151.5	16.0
IR-6	1125.3	206.7	125.6	15.0
IR-7	290.2	73.0	0	0
IR-8	28.4	0.0	0	0
IR-9	115.6	0.0	0	0
Site Average	**206.8**	**31.1**	**30.78**	**3.44**

A summary of the 2016 infiltration test results is provided below:

- No infiltration was observed at IR-1, IR-2, IR-3, IR-4, IR-7, IR-8, and IR-9, which is consistent with testing completed in 2015.
- IR-5 infiltrated at 16.0 in/hr which is less than the 2015 rate of 151.5 in/hr
- IR-6 infiltrated at 15.0 in/hr, which is less than the 2015 rate of 125.6 in/hr
- None of the test locations demonstrated an increase in infiltration as a result of the maintenance completed in 2016.
- The overall site infiltration rate decreased from 30.78 in/hr in 2015 to 3.44 in/hr in 2016

The 2016 pavement rehabilitation effort at the Hamline Midway Library pervious asphalt site was not successful in improving the infiltration rate. The largest decrease in infiltration occurred during the first year when the 2014 infiltration was observed to be 85 percent less than the 2013 rate. In 2016, the infiltration has diminished to 98 percent less than the 2013 rate.

Significant sediment accumulation has been observed in the alleyway, specifically along the western pavement section. The condition and lack of surface lot maintenance of the adjacent properties in that area is believed to be a major factor in sediment loading to the pavement. In contrast, the eastern alley does not see significant contributions from adjacent properties. This is evident when comparing infiltration rates between the two sections. In 2014, the infiltration rate of the western section was 0.0 in/hr compared to 70 in/hr for the eastern section. It should also be noted that the City does not facilitate snow and ice control for the alley. This is typically contracted by adjacent properties owners, therefore the extent of salt and/or sand application to the alley is unknown.

The maintenance that has been completed at the Hamline Midway Library site has been completed in accordance recommended practices as summarized in the 2015 Minnesota Department of Transportation (MnDOT) Study, “Permeable Pavements in Cold Climates: State of the Art and Cold Climate Case Studies”. These activities include annual vacuum sweeping and/or power washing. The study identifies additional maintenance measures which include:

- Sediment control
- Vacuuming with a vac head
- Wetting the surface prior to vacuuming
- Increasing vacuuming frequency to two - four times per year

The logistics and cost/benefit of the implementing the above activities long-term should be reviewed

13.3. Jackson Street

The Jackson Street Pervious Bike Path (**Photo 13-7** and **13-8**) is a section of the Capital City Bikeway (CCB), a system of off-street bicycle trails in downtown St. Paul. The CCB Jackson Street section is eight blocks long and consists of approximately 2,750 square yards of pervious asphalt. The asphalt material selected for construction meets the MnDOT Specification 2360 S-158 for porous asphalt. In November 2016, infiltration testing was performed on the recently completed pavement section stretching from Kellogg Avenue to 7th Street. Construction of the final section between 7th Street and 11th Street was not finished at the time of infiltration testing. The site and infiltration test locations are depicted on **Figure 13-3**.

Photo 13-7: Capital City Bikeway (CCB) – Jackson Street/Kellogg Avenue

Photo 13-8: Location JS-8 Infiltration Testing

<u>Pavement Maintenance</u>

Since the Jackson Street Bike Path was a new site in 2016, no maintenance was completed

<u>Infiltration Test Results and Observations</u>

Eleven infiltration monitoring locations were established within the Jackson Street Pervious Bike Path between the blocks of Kellogg Avenue and 7th Street. The test areas were marked with a nail and curb paint so that locations remain consistent from year to year. The test locations were carefully selected to help determine the impacts of the following:

- Sediment loading and compaction within parking ramp entrances
- Sediment loading and compaction within pedestrian traffic areas (crosswalks)
- Sediment loading to pavement immediately adjacent to large areas of impervious surface
- Infiltration capability of high visibility paint used on the surface

The infiltration test results from the 11 locations are summarized in **Table 13-3.** The infiltration test locations are depicted on **Figure 13-3**.

Table 13-3: Jackson Street Infiltration Rate Summary

Infiltration Test Location	Test Location Description	November 2016 Infiltration Rate (in/hr)
JS-1	Northern half of Securian ramp entrance. Non-painted surface east of path center line.	143.2
JS-2	Midline of Securian ramp entrance. Non-painted surface east of path center line.	187.6
JS-3	Jackson Street pedestrian cross south of 6th Street. Near midline of bike path.	320.5
JS-4	Midblock between 6th & 5th Street. North of skyway. Near midline of bike path.	530.6
JS-5	345 parking ramp entrance. Non-painted surface just north of the midline of the entrance. Midline of bike path.	96.5
JS-6[1]	345 parking ramp entrance. Green painted stripe farthest south. West side of bike path.	29.7
JS-7	Jackson Street pedestrian cross north of 4th Street. Near midline of bike path.	133.4
JS-8	Midblock between 4th & Kellogg. Western edge of bike path (adjacent to concrete).	44.4
JS-9	Midblock between 4th & Kellogg. Eastern side of bike path.	69.5
JS-10	In line with the southern wall of the US Courthouse (facing Kellogg). Western edge of bike path adjacent to concrete.	139.5
JS-11	In line with the southern wall of the US Courthouse (facing Kellogg). Eastern side of the bike path.	117.9
	Site Average	**178.3**

Photo 13-9: Test Locations JS-1 and JS-2

Photo 13-10: Ring is Located on JS-10, Pink Dot on Path is Location of JS-11

During testing, there was significant variability in infiltration rates for a given pavement section. In some instances, visual observations of the surface gave a clear indication as to how well the chosen site would infiltrate. Some testing observations and recommendations are summarized below:

- The site with the highest infiltration rate, JS-4, was noted to have minimal sediment and debris present and was not adjacent to large areas of impervious surface. Based on visual observations prior to testing, this location was assumed to have the greatest infiltration rate.
- Locations JS-1 and JS-2 (Photo 13-9) were located in parking ramp entrances which were observed to have some sediment and debris accumulation from vehicular traffic. Those locations had greater infiltration rates than locations JS-8, JS-9, JS-10, and JS-11, which were not located in heavy vehicular traffic areas, but in close proximity to large areas of impervious concrete.
- The variation between paired test locations JS-8 and JS-9 was 35 percent and the variation between paired test locations JS-10 and JS-11 was 15 percent. The tests in each pair were approximately four ft apart. JS-8 and JS-10 were located immediately adjacent to the impervious concrete, while JS-9 and JS-11

were located near the midline of the bike path (Photo 13-10). The testing did not indicate a trend in infiltration rates across the width of the bike path.

- The painted location, JS-6, had the lowest infiltration rate of 29.6 in/hr. Following testing, a continuous water stream was applied to the test location. It was observed that water that did not infiltrate within the painted area was infiltrated immediately in to the non-painted surface around it. Therefore, certain areas that are less permeable do not appear to significantly affect the infiltration capability of the surface as a whole.
- It is recommended that periodic visual inspections of the BMP be completed during winter months to document accumulation of deicing material on and around the pervious asphalt. The City does not coordinate snow and ice management for the concrete areas adjacent to the bike path, therefore the extent of salt and/or sand application is unknown.

14. SUMMARY & RECOMMENDATIONS

Fifteen stormwater BMPs were evaluated for performance in 2016 to help the City meet its Phase I MS4 Permit monitoring requirements. The BMP systems that were monitored include underground infiltration systems, a rain garden, stormwater ponds, IESF ponds, and pervious pavement. The systems were monitored to determine infiltration rates, volume reduction, and pollutant removal efficiencies. Long-term monitoring data has shown how the effectiveness of these systems change over time.

14.1. Underground Infiltration Systems

Four underground infiltration BMPs (Beacon Bluff, Hillcrest Knoll Park, St. Albans, and Hampden Park) were monitored for flow and level to evaluate infiltration and volume reduction, in addition to water quality at the Beacon Bluff and Hampden Park sites. The runoff data for each site was normalized over equal monitoring periods to compare runoff from the drainage areas. A summary of runoff from the BMP drainage areas is provided in **Table 14-1** below.

Table 14-1: Underground Infiltration System Runoff Summary

BMP Site	Drainage Area (acres)[1]	Total Runoff (cf)	% Runoff Captured	Water Yield (in/acre)[1]	Water Yield (cu-ft/acre)[1]	2016 Rainfall to Runoff Ratio[1]
Beacon Bluff	143.6	3,062,696	46	5.6	20,246	0.19
Hillcrest Knoll Park	37.1	1,318,123	36	9.8	35,528	0.32
St. Albans	22.2	758,754	97	9.4	34,178	0.32
Hampden Park	7.8	458,498	100	16.2	51,788	0.57

1-For the Beacon Bluff and Hampden Park Sites, the drainage area and total runoff presented in the table includes the total for the BMP system. The water yield calculations were generated from the monitored runoff volume and the corresponding drainage area (not including modeled runoff).

Of the four sites, the Hampden Park BMP received the greatest amount of runoff per drainage acre, resulting in a rainfall to runoff coefficient of 0.57. Beacon Bluff received the least amount of runoff per drainage acre, with a rainfall to runoff coefficient of 0.19, although turbulent flow at that location has created challenges in obtaining accurate flow data. Hillcrest Knoll Park and St. Albans BMPs both had rainfall to runoff coefficients of 0.32.

TSS and TP loads captured by the four-flow monitored BMPs are summarized in **Table 14-2.** TSS and TP loads for Hillcrest Knoll Park and St. Albans were generated using 2016 flow data and flow-weighted averages from the last year of water quality monitoring at each site, which was 2014 and 2015, respectively. The total TSS load and

TP load captured by the four systems was 17,098 pounds and 67.4 pounds, respectively.

Table 14-2: Underground Infiltration System Pollutant Capture Summary

BMP Site	TSS Captured (pounds)	TP Captured (pounds)
Beacon Bluff	7,046	33
Hillcrest Knoll Park	5,204	21.9
St. Albans	4,236	9.2
Hampden Park	612	3.3
Total	**17,098**	**67.4**

A summary of the 2016 infiltration rates for the underground infiltration systems is provided below. In addition to the flow monitored BMPs described above, infiltration rates were calculated for the Arundel, Montreal and Wordsworth BMPs:

- The infiltration rate for the Beacon Bluff underground system was 0.15 in/hr, which is 5% of the post-construction infiltration rate. The underground system no longer drains to empty and groundwater mounding doesn't not appear to be the cause of standing water, based on groundwater elevation data. This suggests that clogging of the construction material within the trench is restricting flow. The site should be evaluated further to identify the nature and extent of the flow restriction.
- Groundwater intrusion into the Hillcrest Knoll BMP has been observed every year since 2013. The mounding that occurs at the site is the limiting factor for infiltration. The 2016 infiltration rate of 0.58 in/hr is 145 percent of the post-construction rate, although all rates calculated for the Site have been below the design and MSWM infiltration rates developed for the Site.
- Infiltration rates for the St. Albans system have exceeded the system design rate every year since 2012. The infiltration rate of 36.2 in/hr calculated for 2016 was 94% of the post-construction rate, and it is the greatest rate of all the sites monitored in 2016.
- The infiltration rate for the Hampden Park BMP was 14.4 in/hr, which exceeded the design rate of 1.8 in/hr.
- The infiltration rate for the Arundel BMP was 0.16 in/hr, which is 2% of the post-construction infiltration rate. It took 13 days for the BMP to drain empty in 2016.
- The Montreal Trench was a new monitoring site in 2016. The infiltration rate was 7.5 in/hr, which exceeds the design rate of 0.6 in/hr.
- The Wordsworth Trench was a new monitoring site in 2016. The infiltration rate was 4.35 in/hr, which exceeds the design rate of 0.6 in/hr.

14.2. Rain Garden & Stormwater Ponds

In 2016, the Beacon Bluff rain garden and the Flandrau-Hoyt and Sackett Park stormwater ponds were monitored for water level. Infiltration within the Beacon Bluff rain garden has decreased from 2.9 in/hr to 0.43 in/hr since 2012, primarily due to sediment accumulation within the basin.

Level data collected at Flandrau-Hoyt and Sackett Park Ponds is primarily used for evaluating future improvements at those locations. The maximum level increase at Flandrau-Hoyt Pond was 14.8 ft, and all runoff events in 2016 resulted in excess water draining within 15 hours of the event. Water levels at Sackett Park Pond exceeded the outlet control structure on eight occasions in 2016, and it took less than six hours for water levels to drop back below that elevation.

14.3. Iron-Enhanced Sand Filtration Ponds

Maryland, Magnolia, and Jenks IESF Pond were evaluated in 2016 for phosphorus removal efficiency. Maryland Pond demonstrated negative load reductions for TP and SRP in 2016. This contrasted with 2015 data, which showed a 54 percent and 69 percent removal efficiencies for TP & SRP, respectively. Baseflow was observed at Maryland Pond in 2016, which resulted in continuous flow through the IESF benches. Maryland Pond will be evaluated further in 2017, to identify and characterize the baseflow.

Magnolia Pond had TP and SRP removal efficiencies of 49 percent and 35 percent, respectively, in 2016 which is an increase in removal effectives calculated for 2015. A total of 1.73 pounds of TP and 0.31 pounds of SRP was captured by the Magnolia IESF system.

Jenks Pond showed no change in TP and SRP, overall. Treatment through the IESF at Jenks Pond was limited by the lack of flow that was diverted to the basin. Modifications to the diversion structure were completed in Spring 2017 to increase the amount of runoff diverted to, and treated by, Jenks Pond.

14.4. Pervious Pavement

Infiltration testing was conducted at the Victoria Street permeable pavers, and the Hamline-Midway Library and Jackson Street pervious asphalt sites in 2016. The Victoria and Hamline Midway Library 2016 infiltration rates are both 2% of post-construction monitored infiltration rates (3.33 in/hr and 3.44 in/hr, respectively). Rehabilitative maintenance efforts at Hamline-Midway Library did not result in an increase in infiltration at the Site. Major sediment loading from adjacent properties has been observed at the Site.

The Jackson Street Pervious Asphalt Bike path was a new Site in 2016. Initial infiltration testing showed an average infiltration rate of 178.3 in/hr.

14.5. 2017 Recommendations

The recommendations for the 2017 Monitoring Program include:

- Continue to perform regular maintenance on all stormwater BMPs.
- Collect and analyze baseflow at the TBNS Maryland Pond site. Collect additional QA/QC samples to confirm negative pollutant reductions
- Confirm modifications to Jenks diversion structure are effectively diverting greater runoff volumes to the basin
- Complete additional infiltration testing at Jackson Street Pervious Bike Path
- On-going review of composite sampling methodologies and flow pacing

Figures

City of St. Paul
2016 Water Quantity & Quality Monitoring Program

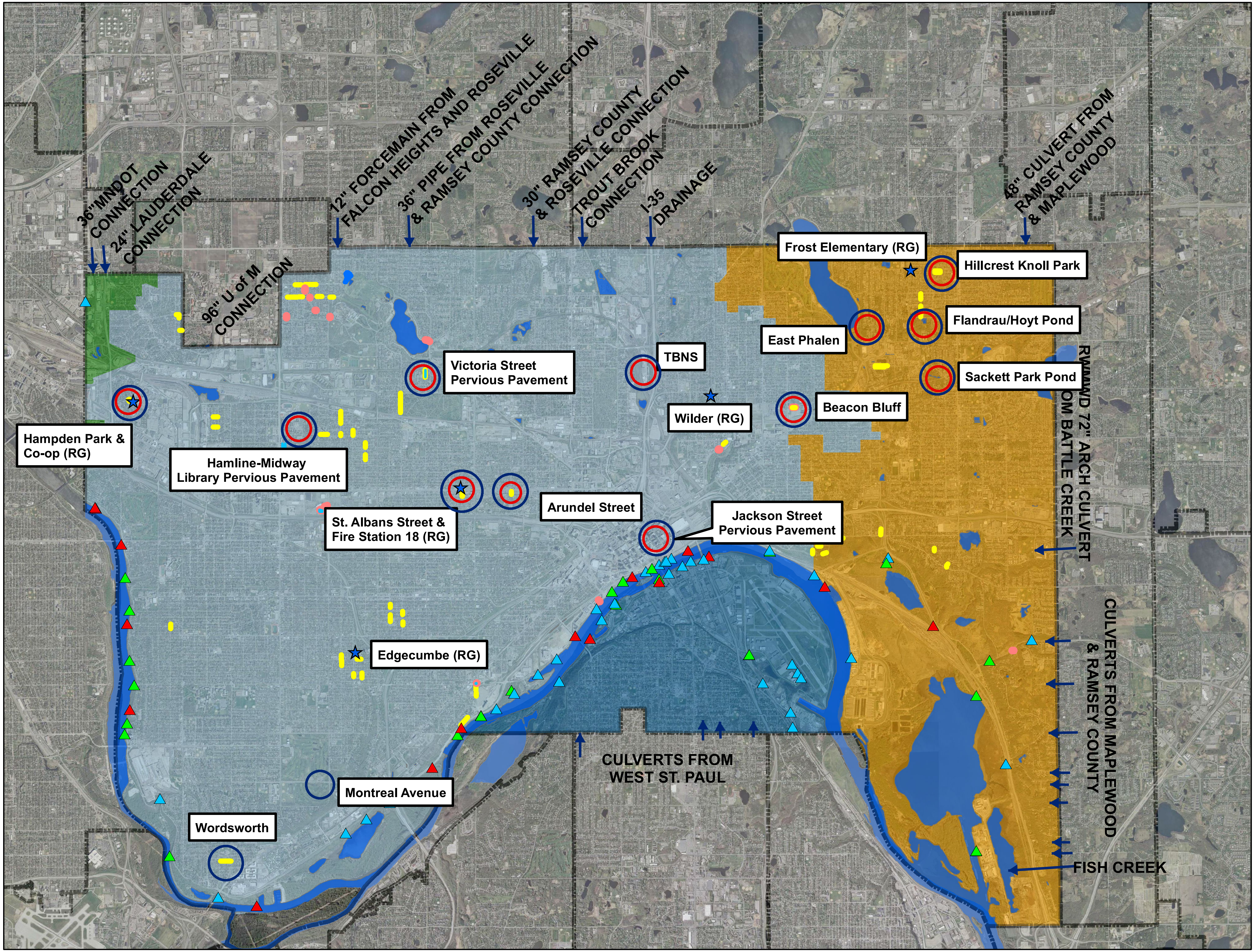


Figure 1-1

2016 Monitoring Site Locations

N W E S

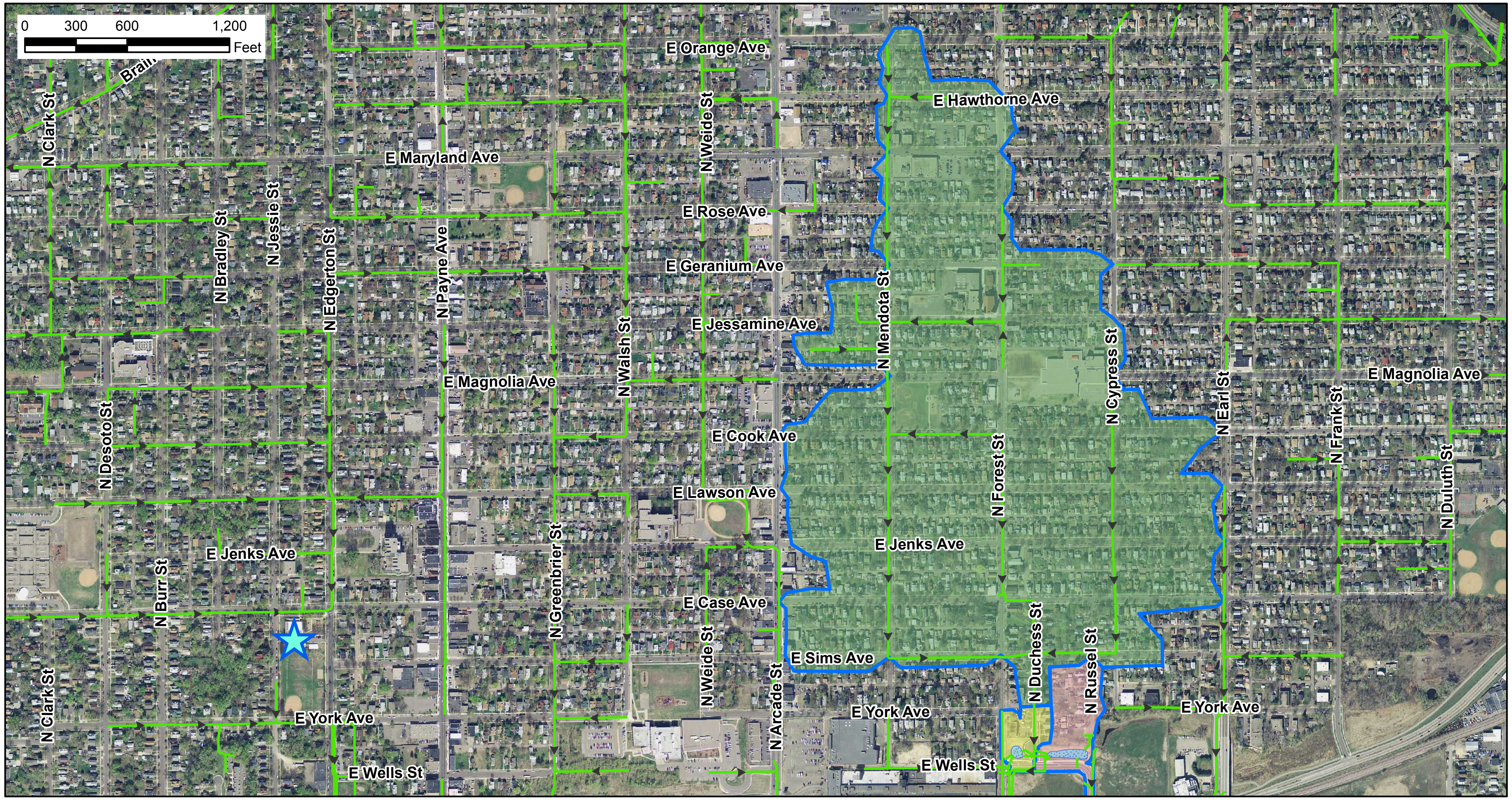
0 2,500 5,000 10,000 Feet

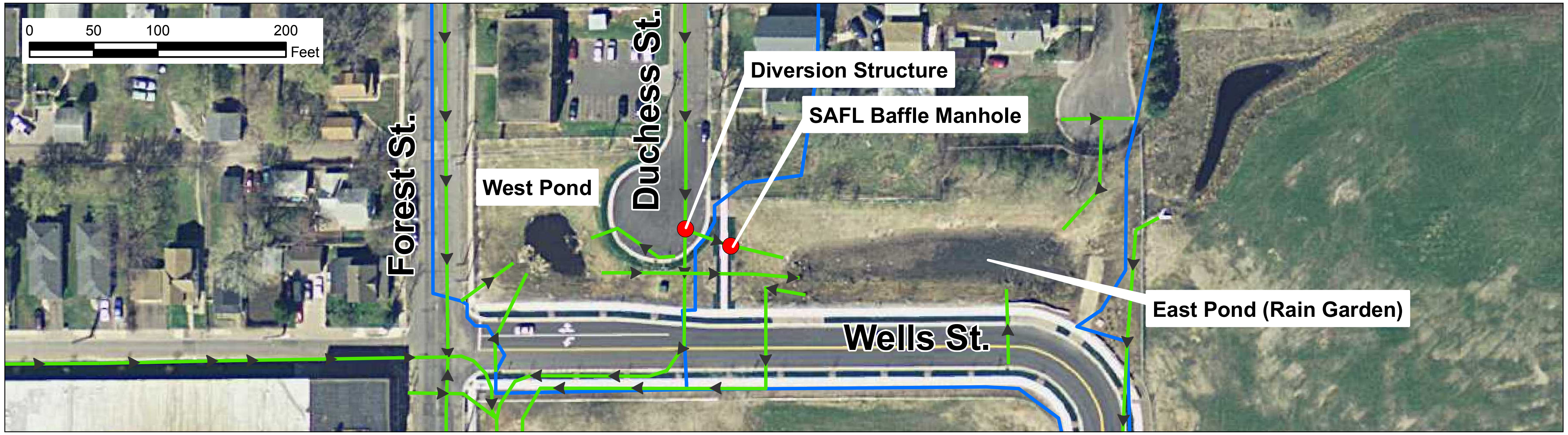
Legend

- Raingarden/Infiltration Basin
- Infiltration Trench
- Pervious Pavement
- Capitol Region Watershed District
- Lower Mississippi River WMO
- Mississippi WMO
- Ramsey/Washington/Metro WD
- 2015 Monitoring Locations
- 2016 Monitoring Locations
- Rain Gauge Locations
- Inflows

Outfalls

- 30" - 48"
- 50" - 72"
- > 72"





City of St. Paul

2016 Water Quantity and Quality Monitoring Program

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FIGURE 3-1
Beacon Bluff Infiltration BMP Drainage Areas

N
W E
S

Legend

- Underground Chamber
- Storm Pipe
- Rain Gauge Location

Drainage Areas

- Subwatershed A - Diversion Structure (136.8 ac)
- Suwatershed B - East Pond (4.7 ac)
- Subwatershed C - West Pond (2.1 ac)

WSB

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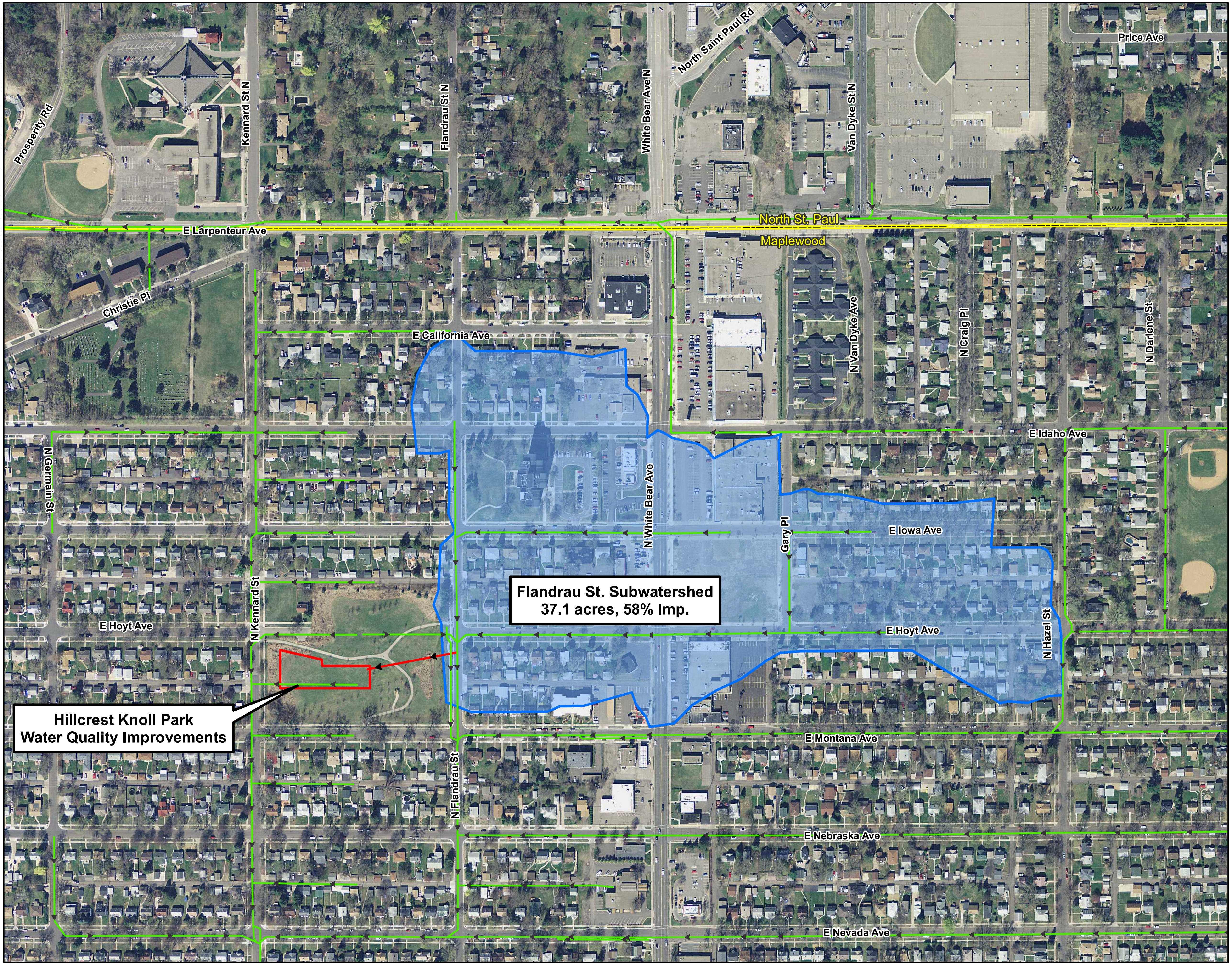
FIGURE 4 - 1

Hillcrest Knoll Park Infiltration BMP Drainage Area



N
W E
S

0 150 300 600 Feet

Legend

- Ex. Storm Sewer
- City Boundaries
- Subwatershed
- Infiltration BMP

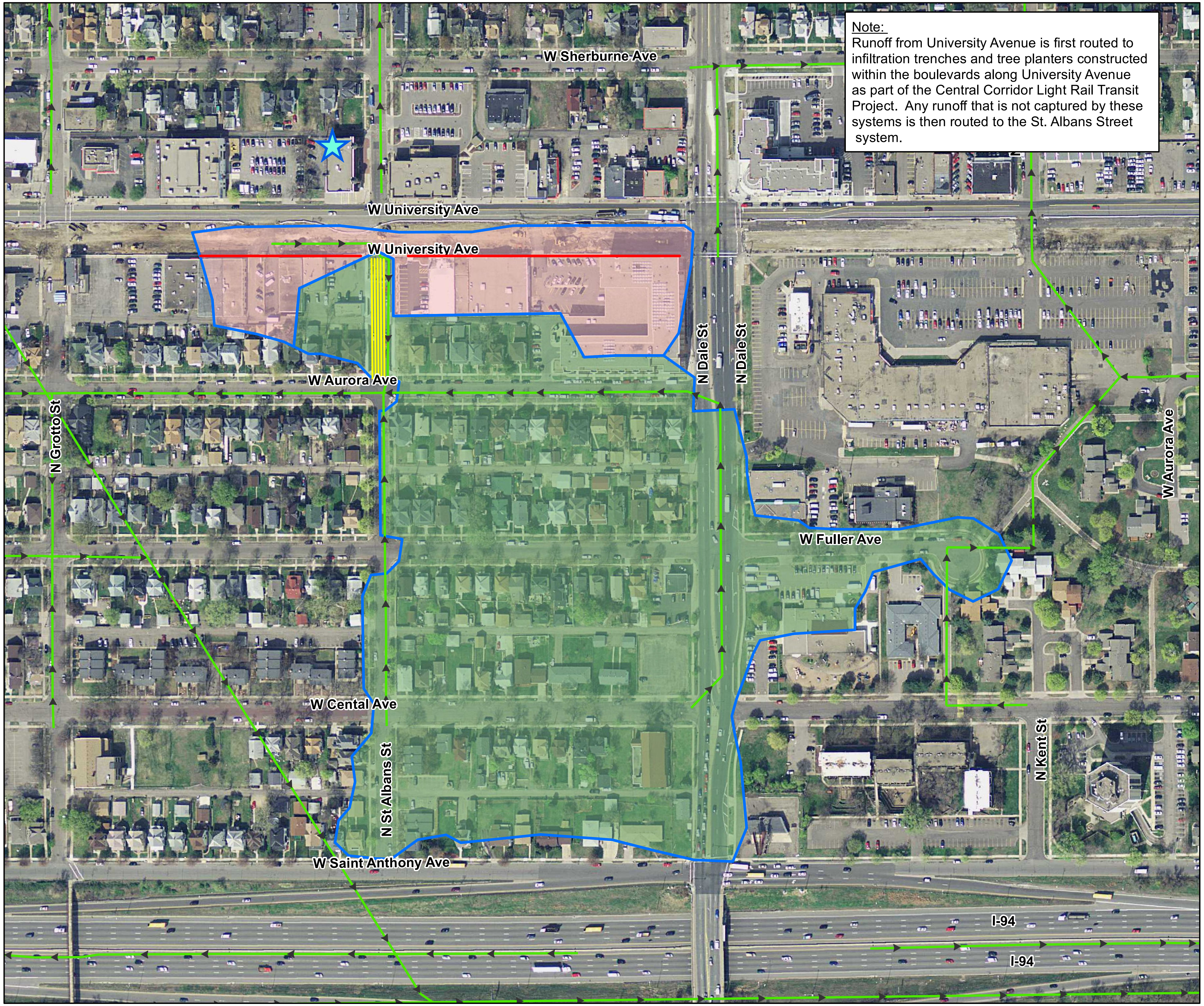
WSB

City of St. Paul

2016 Water Quantity and Quality Monitoring Program

FIGURE 5-1

St. Albans Street Infiltration BMP Drainage Areas



N W E S

0 100 200 400 Feet

Legend

- Infiltration Trench
- CCLRT Infiltration Trench (Not monitored)
- Storm Pipe
- Rain Gauge Location

Drainage Areas

- St. Albans Infiltration System (20.3 ac)
- CCLRT Infiltration Trenches (4.9 acres)

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FIGURE 6-1
Hampden Park Infiltration BMP Drainage Area

N W E S

0 50 100 200 300 400 Feet

Legend

- Storm Pipe
- Rain Gauge Location
- Hampden Park BMP
- Hampden Park BMP Drainage Area

WSB

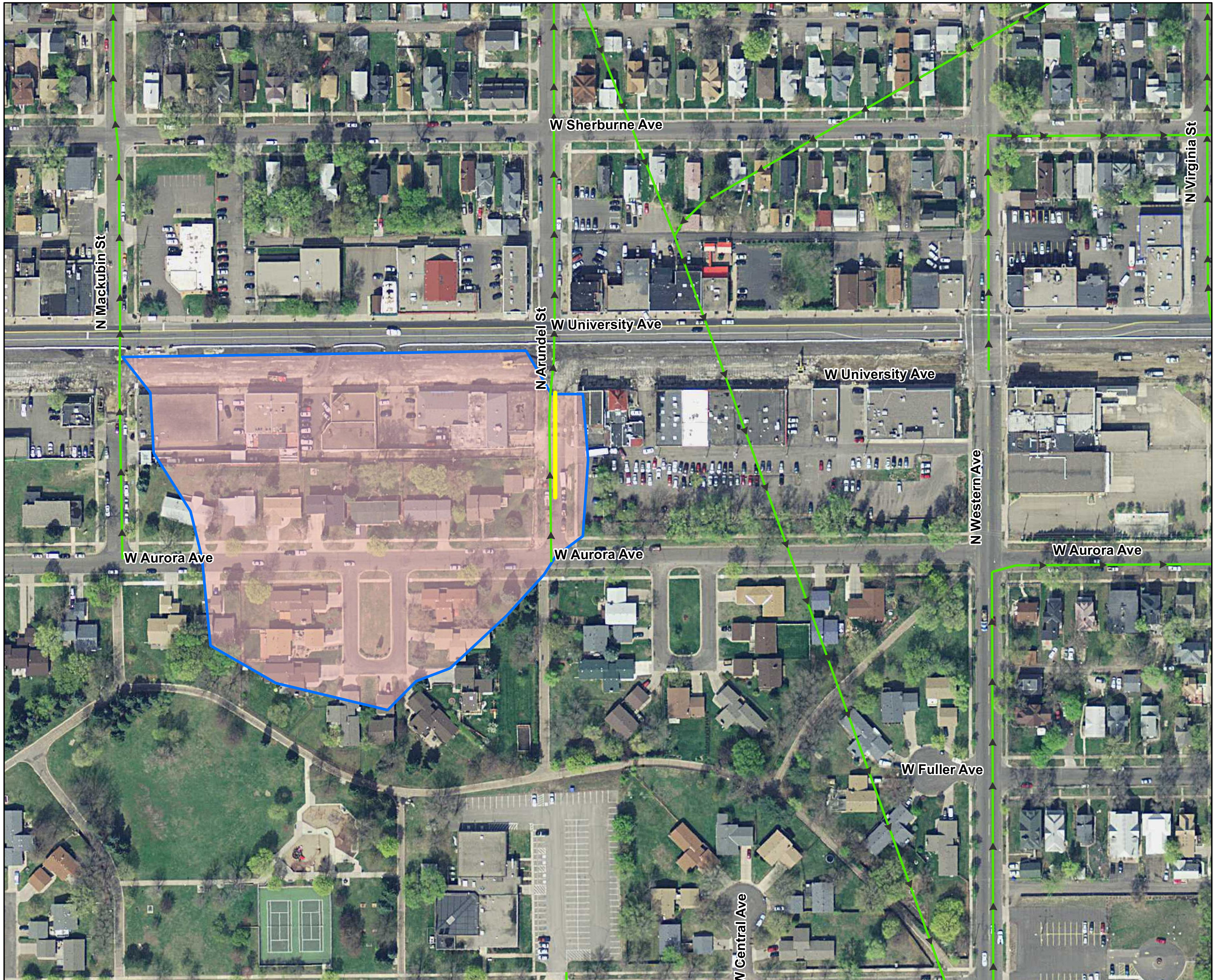

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FIGURE 7-1

Arundel Street Infiltration BMP Drainage Area

N
W E
S

0 75 150 300 Feet

Legend

- Infiltration Trench
- Storm Pipe
- Rain Gauge Location
- Arundel Street System (6.4 ac)

WSB

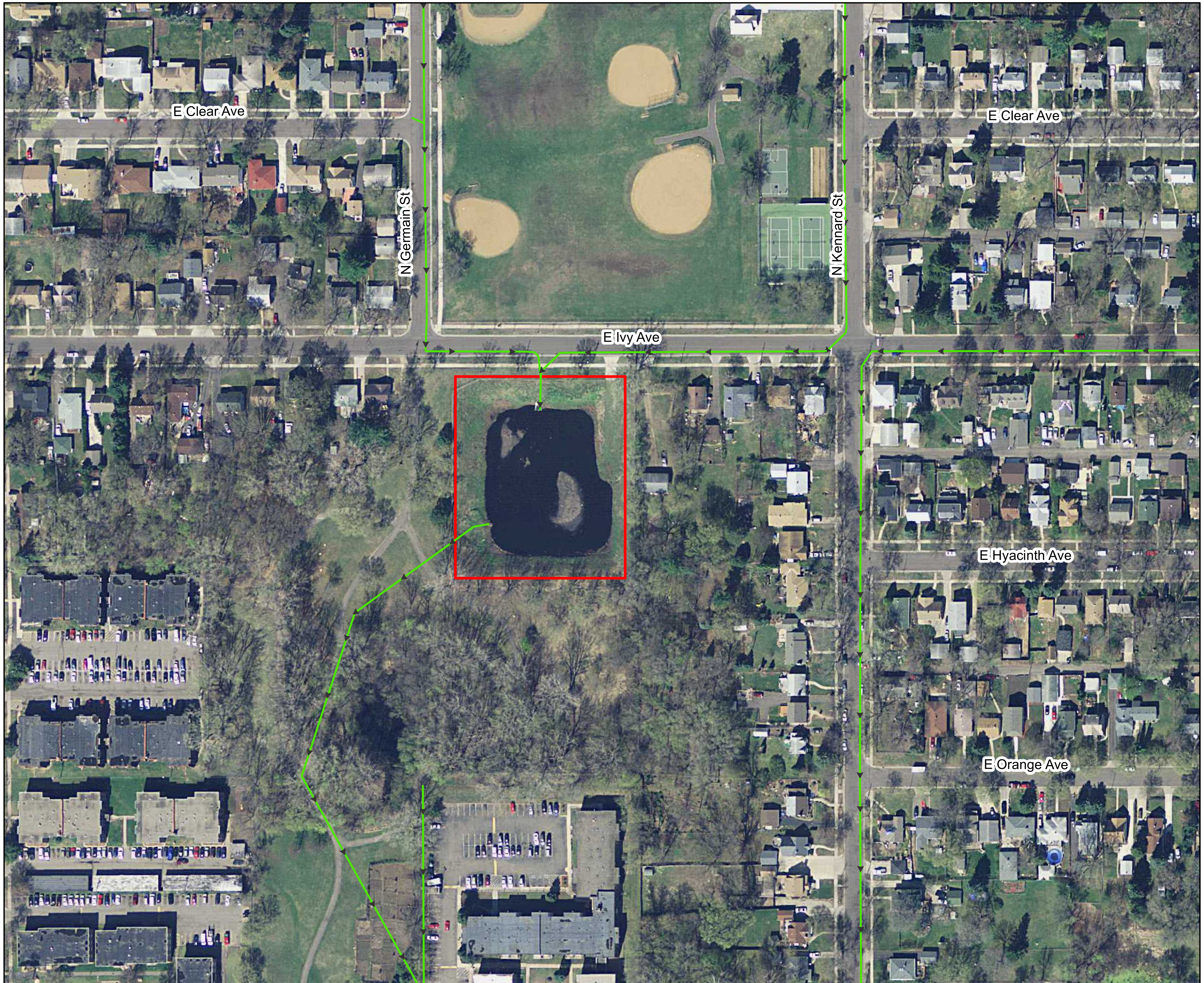

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FIGURE 8-1

Flandrau - Hoyt Pond Site Location

N W E S

0 75 150 300 Feet

Legend

Pond Area

Storm Pipe

WSB

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2016 Water Quantity and Quality Monitoring Program

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FIGURE 9-1

Sackett Park Pond Site Location

N
W E
S

0 100 200 400 Feet

Legend

Pond Area

Storm Pipe

WSB

City of St. Paul

2016 Water Quality & Quantity Program

Figure 10-1 Trout Brook Nature Sanctuary Iron-Enhanced Sand Filtration Ponds Drainage Areas

N
W E
S

0 200 400
Feet

LEGEND

- Storm Pipe
- Subwatershed to BMP
- Iron Enhanced Sand Filtration Ponds

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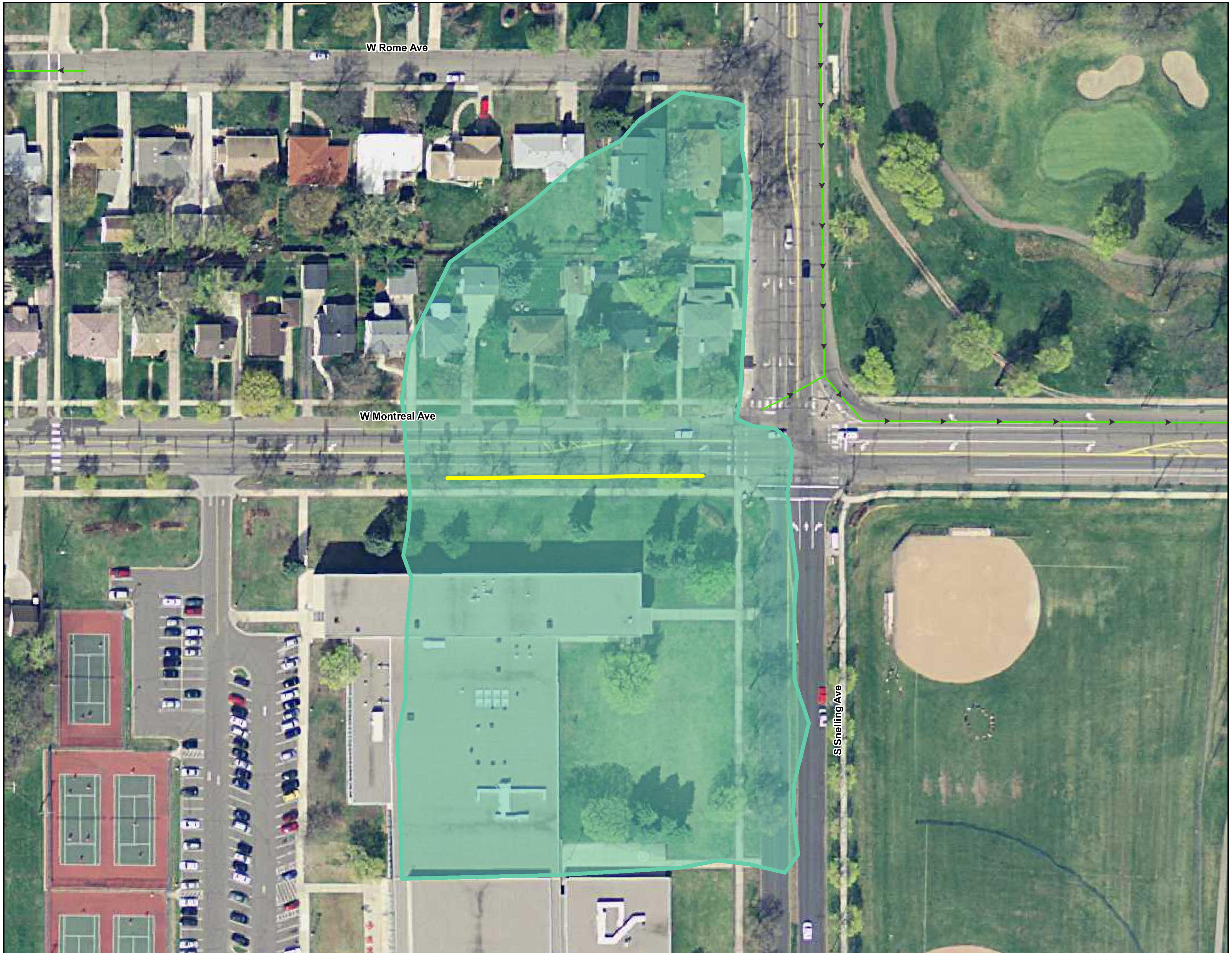
WSB



City of St. Paul

2016 Water Quantity and Quality Monitoring Program

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FIGURE 11 - 1

Montreal Infiltration BMP Drainage Area

N
W E
S

0 80 160 Feet

Legend

- Infiltration Trench
- Drainage Area
- Ex. Storm Sewer
- City Boundaries

WSB

City of St. Paul

2016 Water Quantity and Quality Monitoring Program

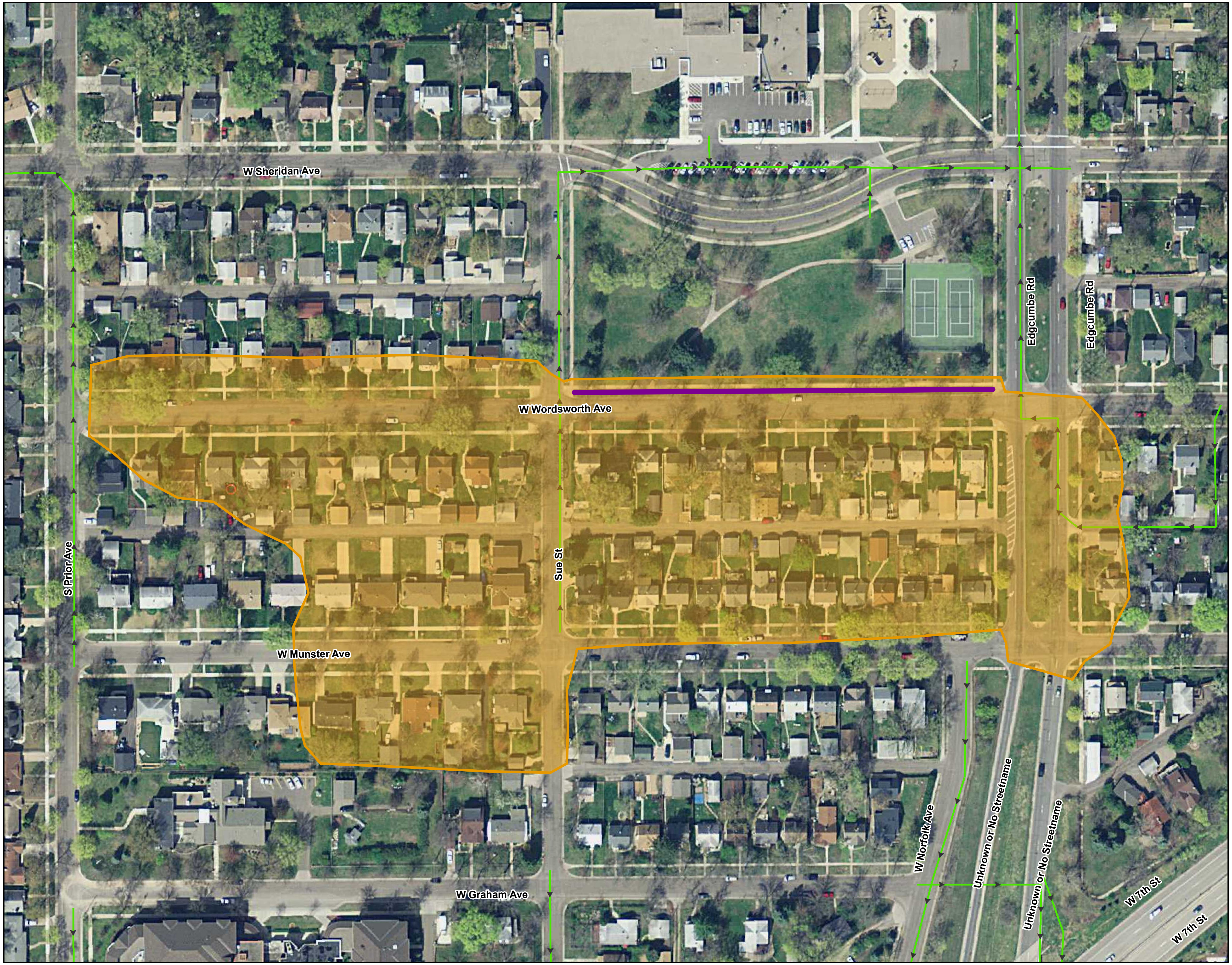


FIGURE 12 - 1

Wordsworth Infiltration BMP Drainage Area

N
W E
S

0 125 250 Feet

Legend

- Infiltration Trench
- Drainage Area
- Ex. Storm Sewer
- City Boundaries

WSB

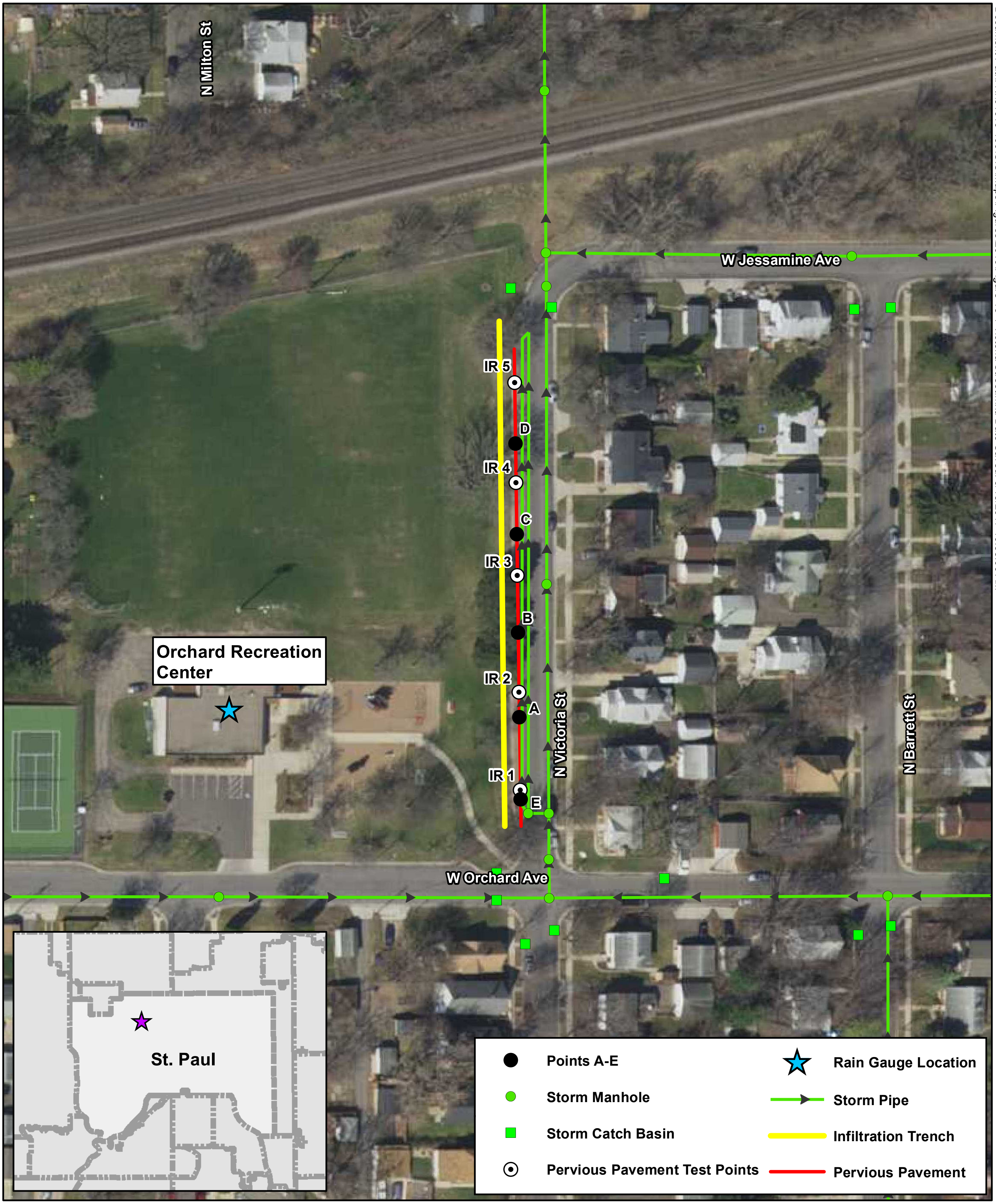


Figure 13-1 - Victoria Street Pervious Pavement Test Locations

2016 Water Quantity and Quality Monitoring Program
City of St Paul, MN

N
0 100 Feet
1 inch = 100 feet

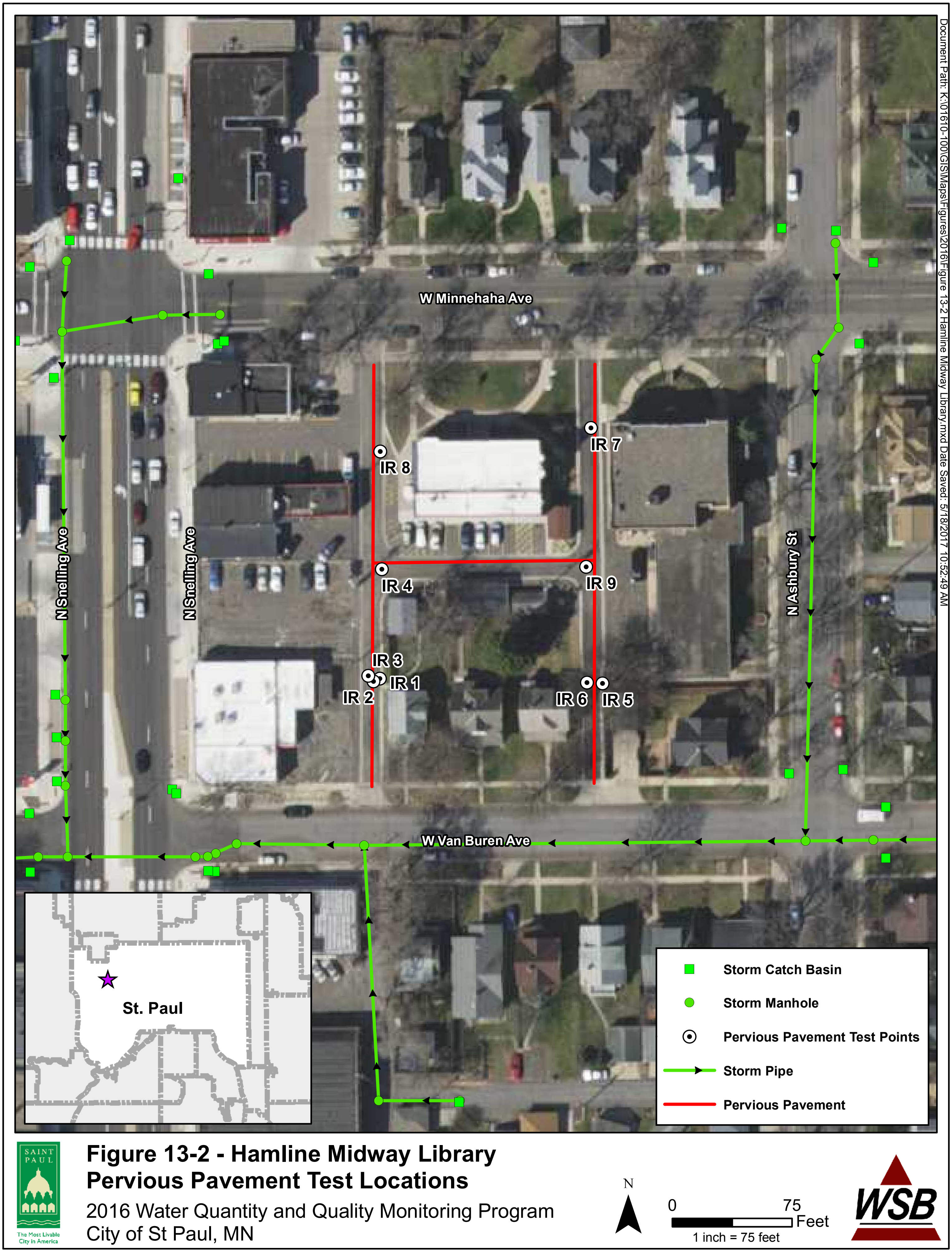


Figure 13-2 - Hamline Midway Library
Pervious Pavement Test Locations

2016 Water Quantity and Quality Monitoring Program
City of St Paul, MN

Figure 13-3 Jackson Street
Pervious Pavement Test Locations

2016 Water Quantity and Quality Monitoring Program
City of St. Paul, MN

Appendix A – Infiltration/Water Level Charts

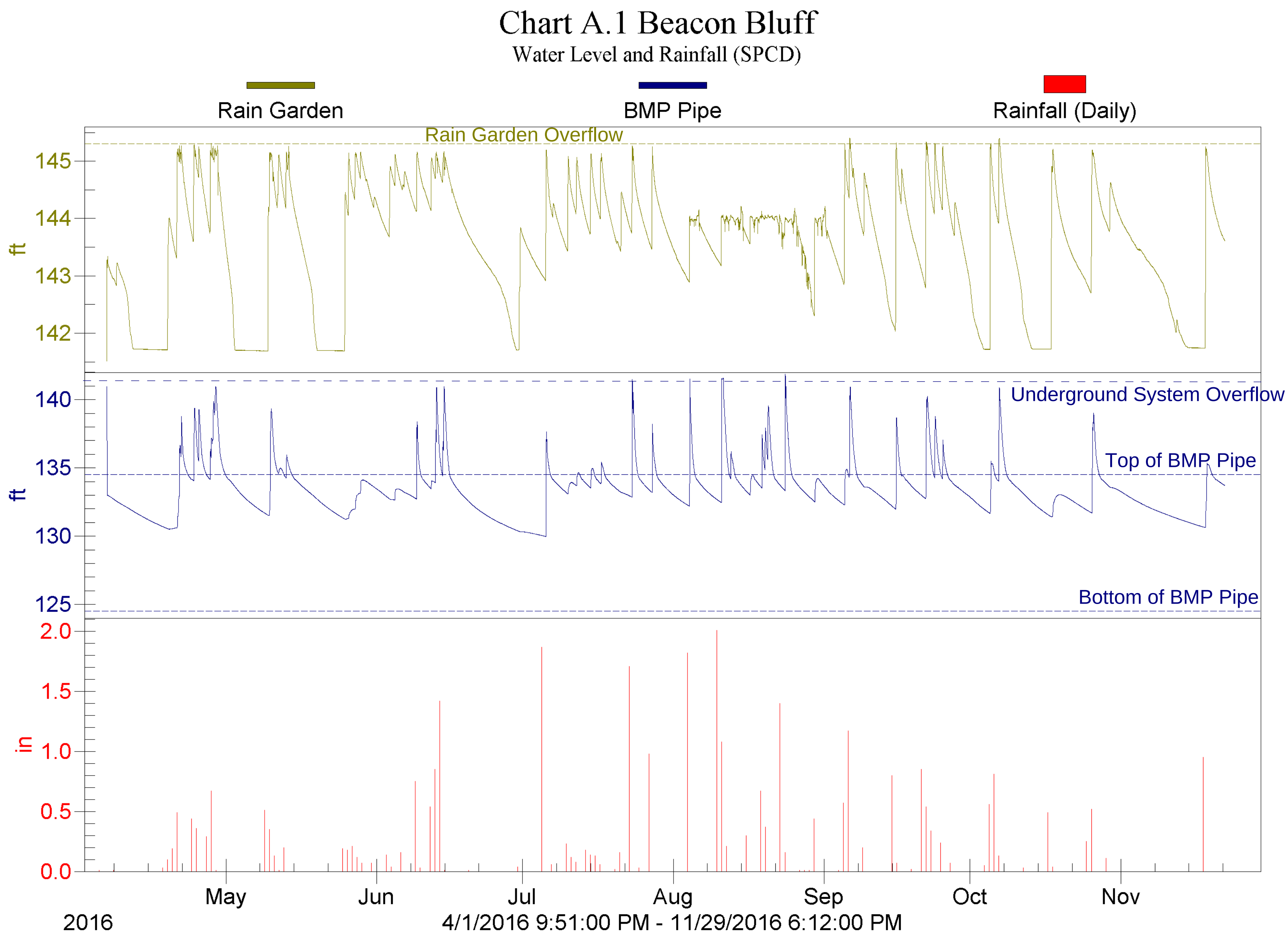
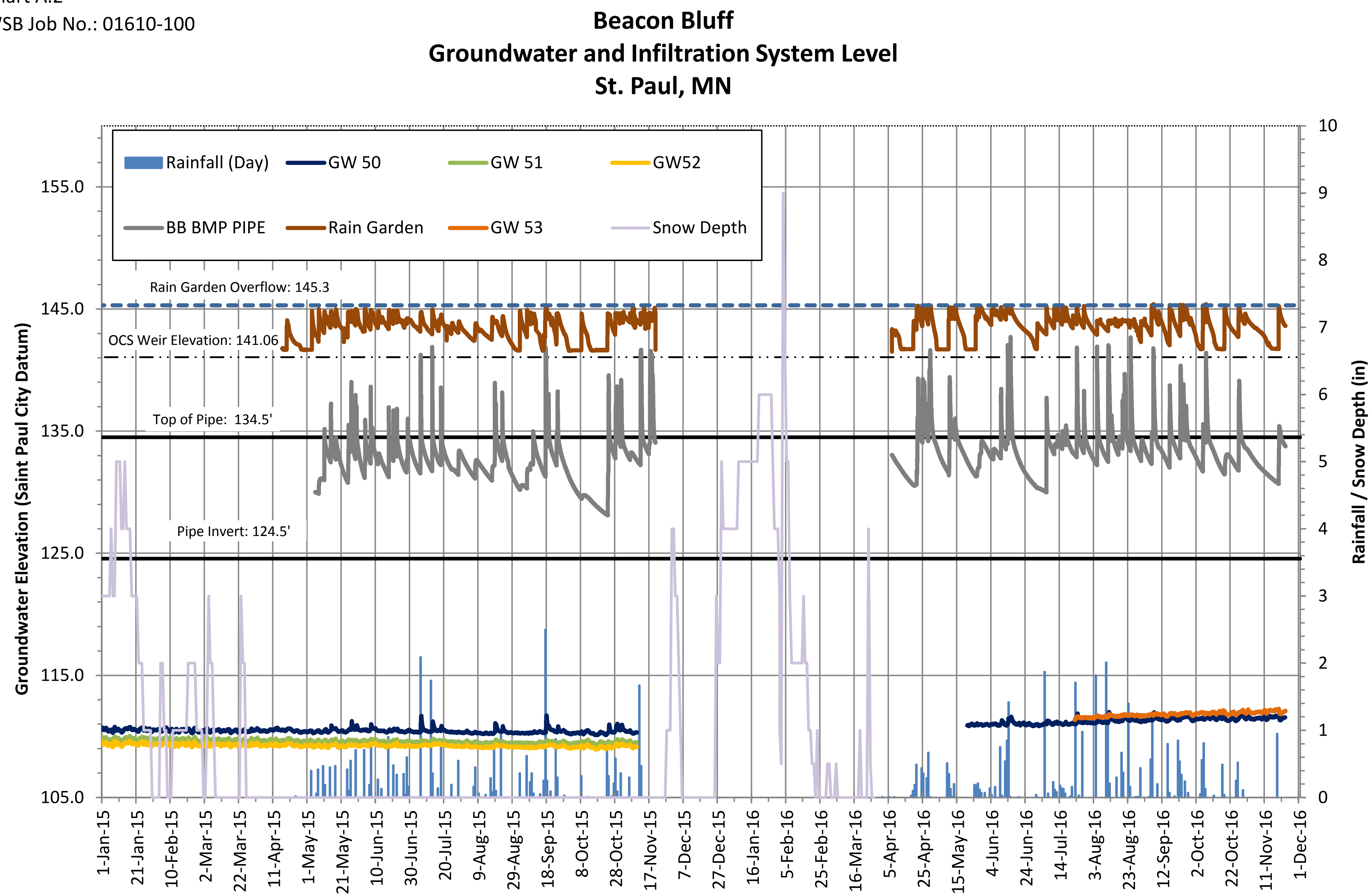
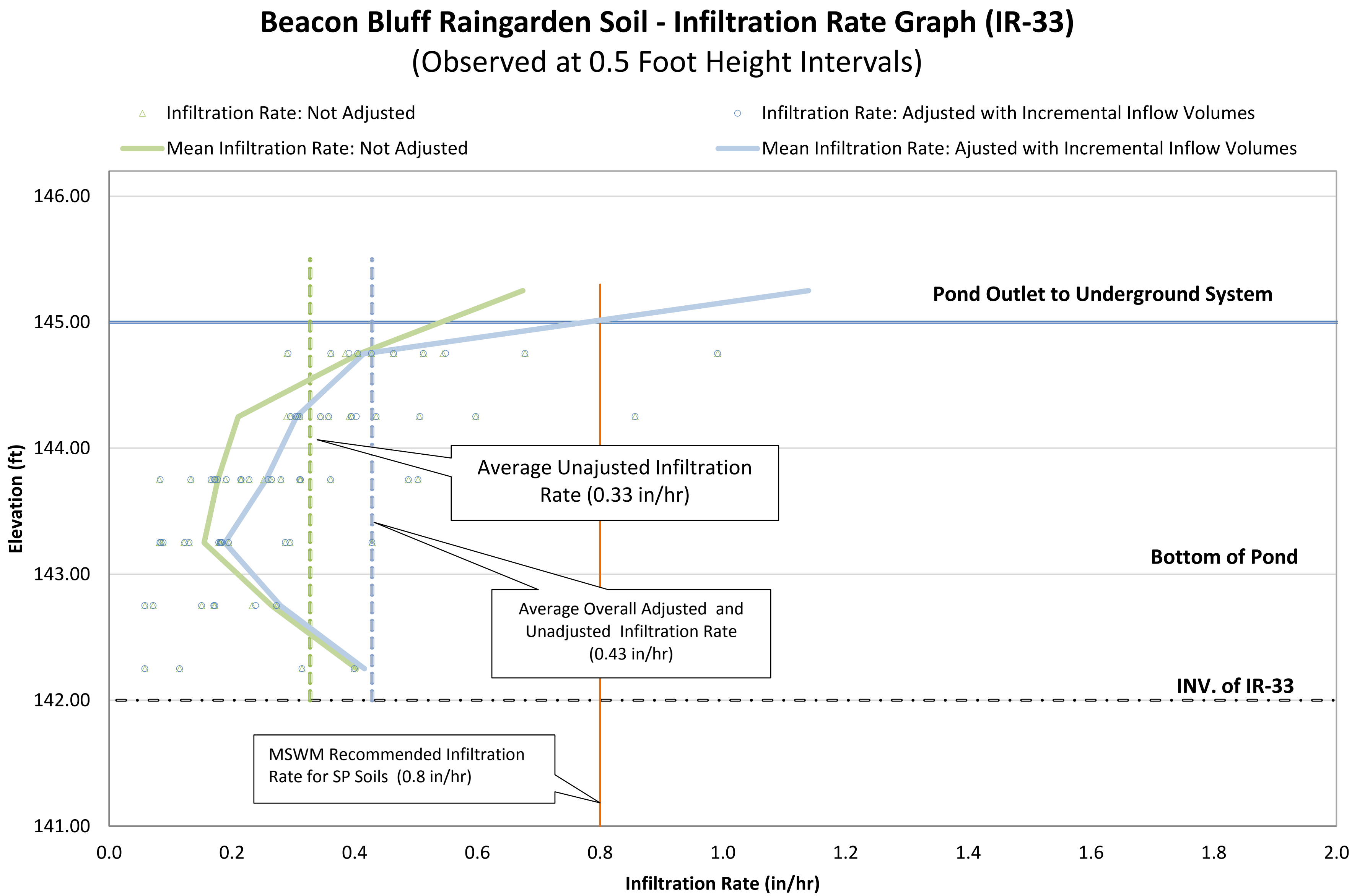


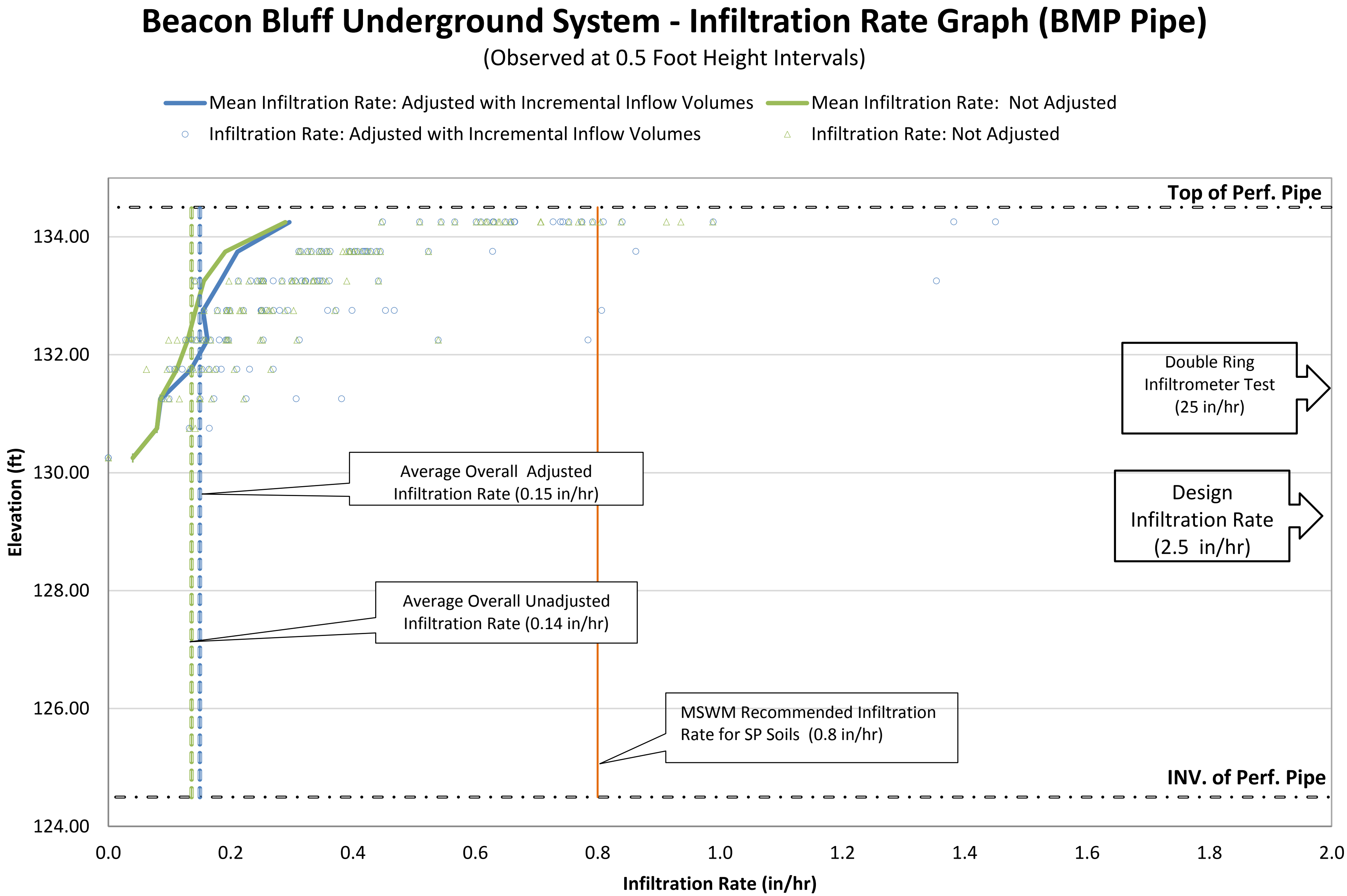
Chart A.1 Beacon Bluff
Water Level and Rainfall (SPCD)
Rain Garden
BMP Pipe
Rainfall (Daily)
Rain Garden Overflow
145
144
143
142
ft
Underground System Overflow
Top of BMP Pipe
Bottom of BMP Pipe
140
135
130
125
ft
2.0
1.5
1.0
0.5
0.0
in
May
Jun
Jul
Aug
Sep
Oct
Nov
2016
4/1/2016 9:51:00 PM - 11/29/2016 6:12:00 PM

City of Saint Paul
2016 Beacon Bluff Groundwater and System Level
Chart A.2
WSB Job No.: 01610-100

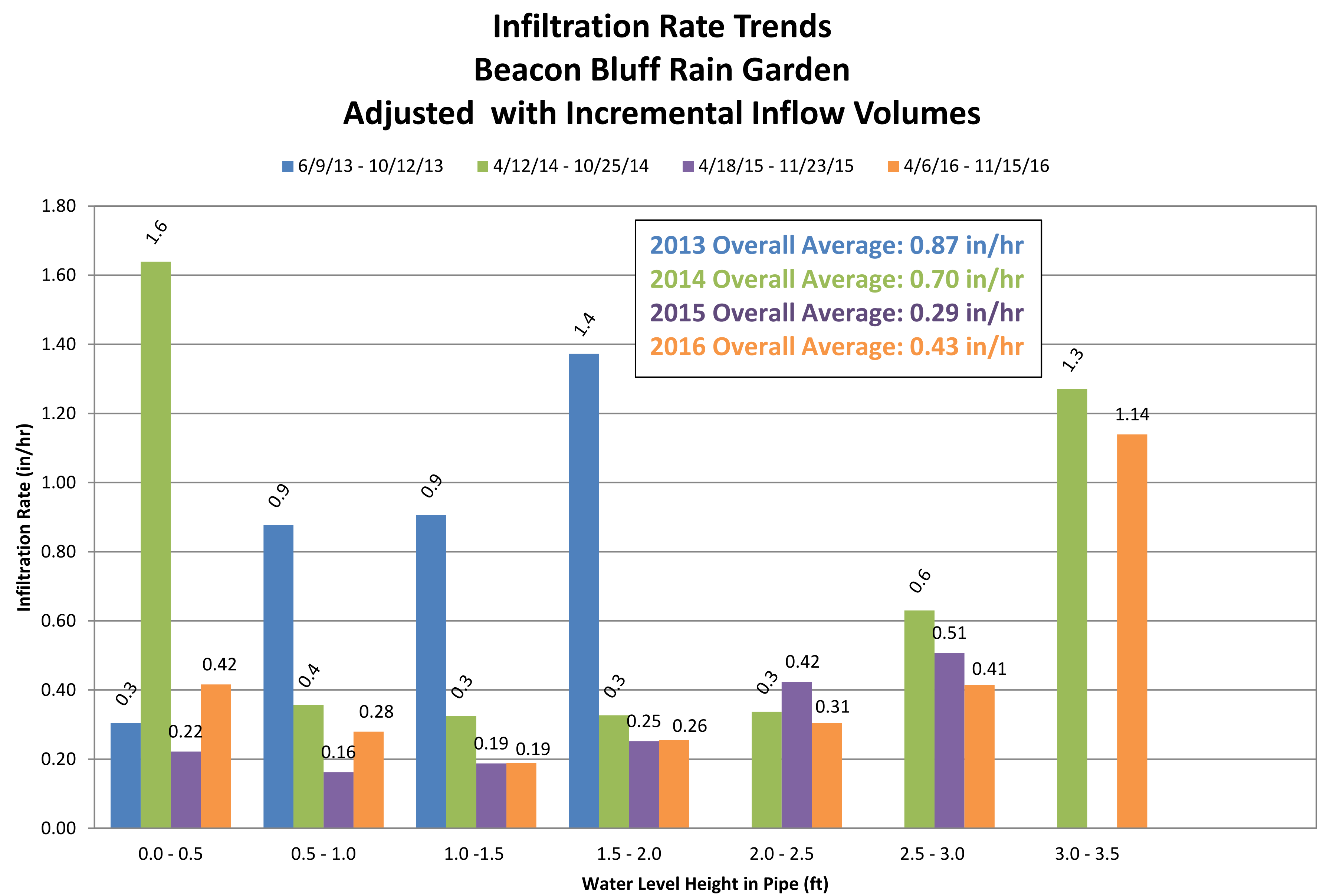


City of Saint Paul
2016 Water Quality and Quantity Monitoring
Chart A.3
WSB Project No.: 01610-100





Note: Pipe Invert is 124.5'
Pipe perforated around circumference of pipe


Infiltration Rate Trends
Beacon Bluff Rain Garden
Adjusted with Incremental Inflow Volumes
6/9/13 - 10/12/13
4/12/14 - 10/25/14
4/18/15 - 11/23/15
4/6/16 - 11/15/16
2013 Overall Average: 0.87 in/hr
2014 Overall Average: 0.70 in/hr
2015 Overall Average: 0.29 in/hr
2016 Overall Average: 0.43 in/hr
Infiltration Rate (in/hr)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0.3
1.6
0.22
0.42
0.9
0.4
0.16
0.28
0.9
0.3
0.19
0.19
1.4
0.3
0.25
0.26
0.3
0.42
0.31
0.6
0.51
0.41
1.3
1.14
0.0 - 0.5
0.5 - 1.0
1.0 -1.5
1.5 - 2.0
2.0 - 2.5
2.5 - 3.0
3.0 - 3.5
Water Level Height in Pipe (ft)

City of Saint Paul
2016 Water Quality and Quantity Report
Chart A.6
WSB Job No.: 01610-100

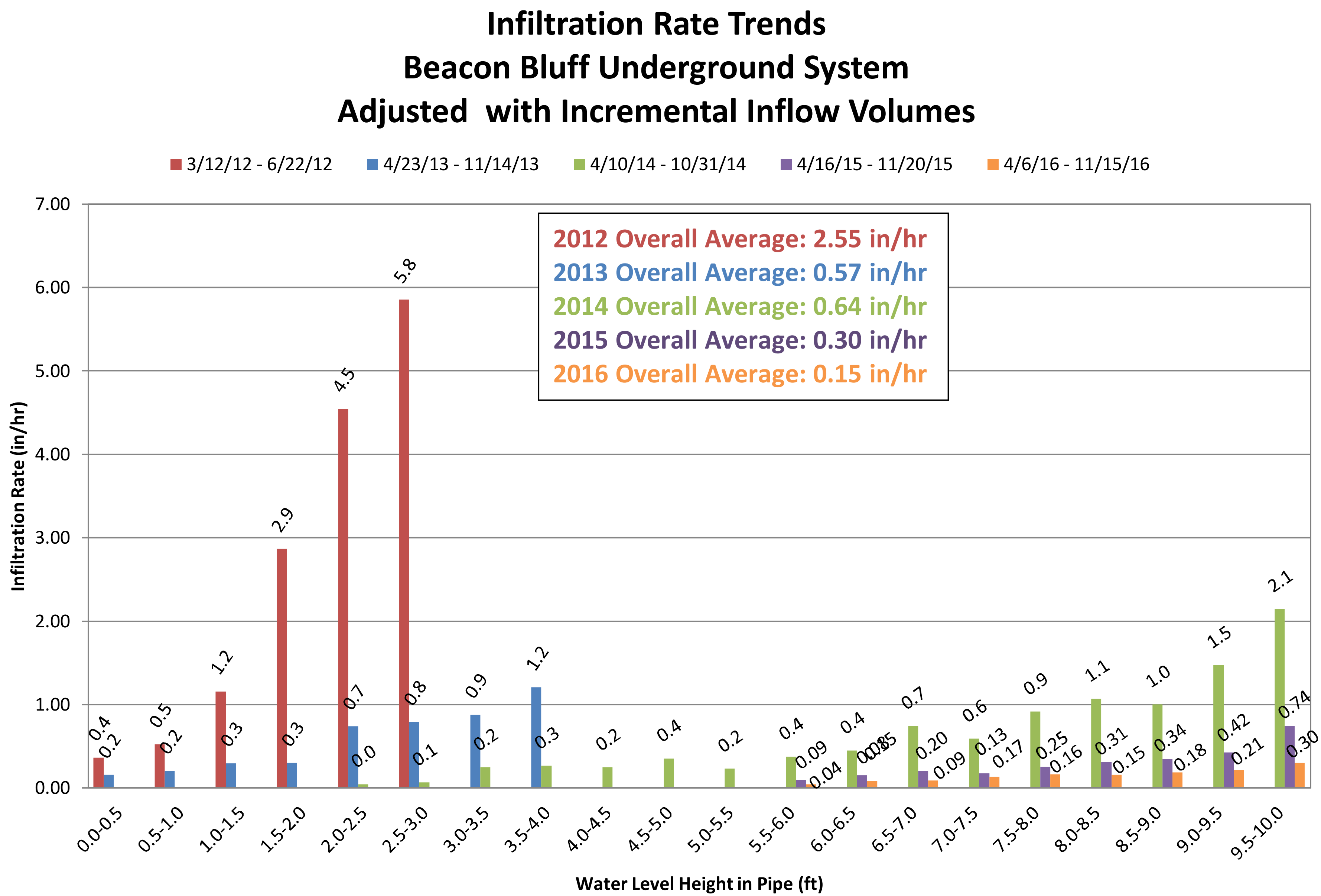
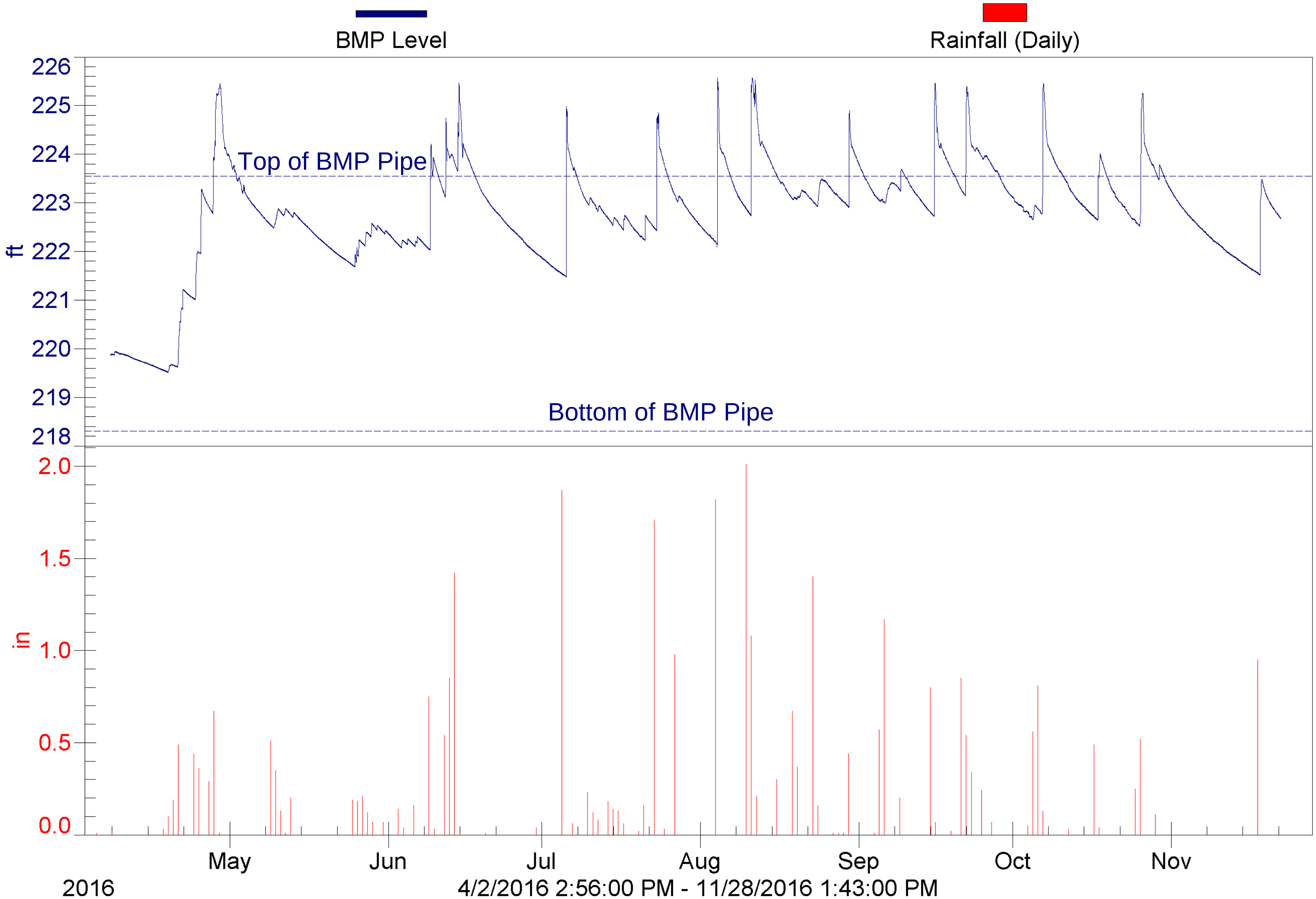
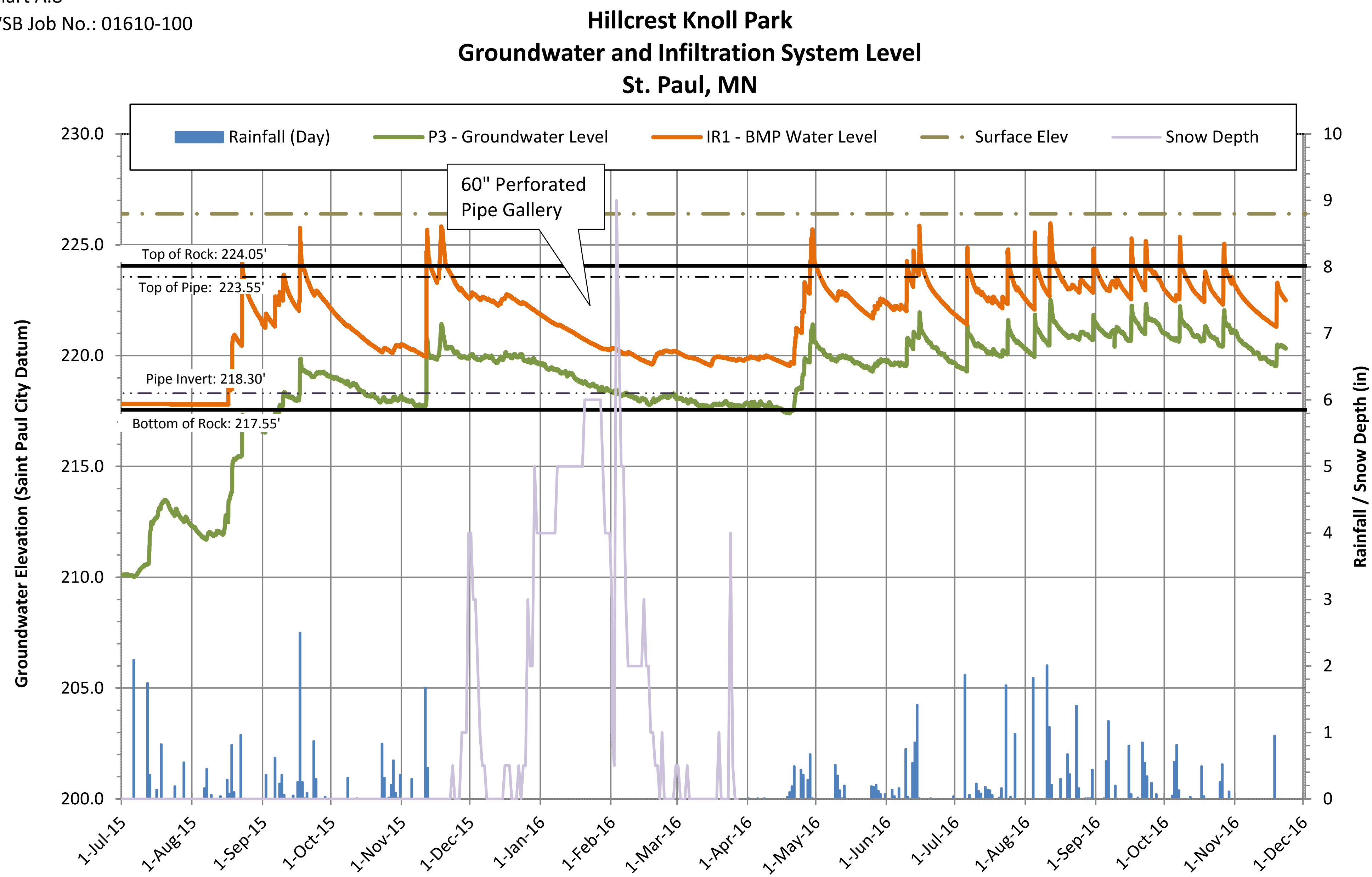


Chart A.7 Hillcrest Knoll Park

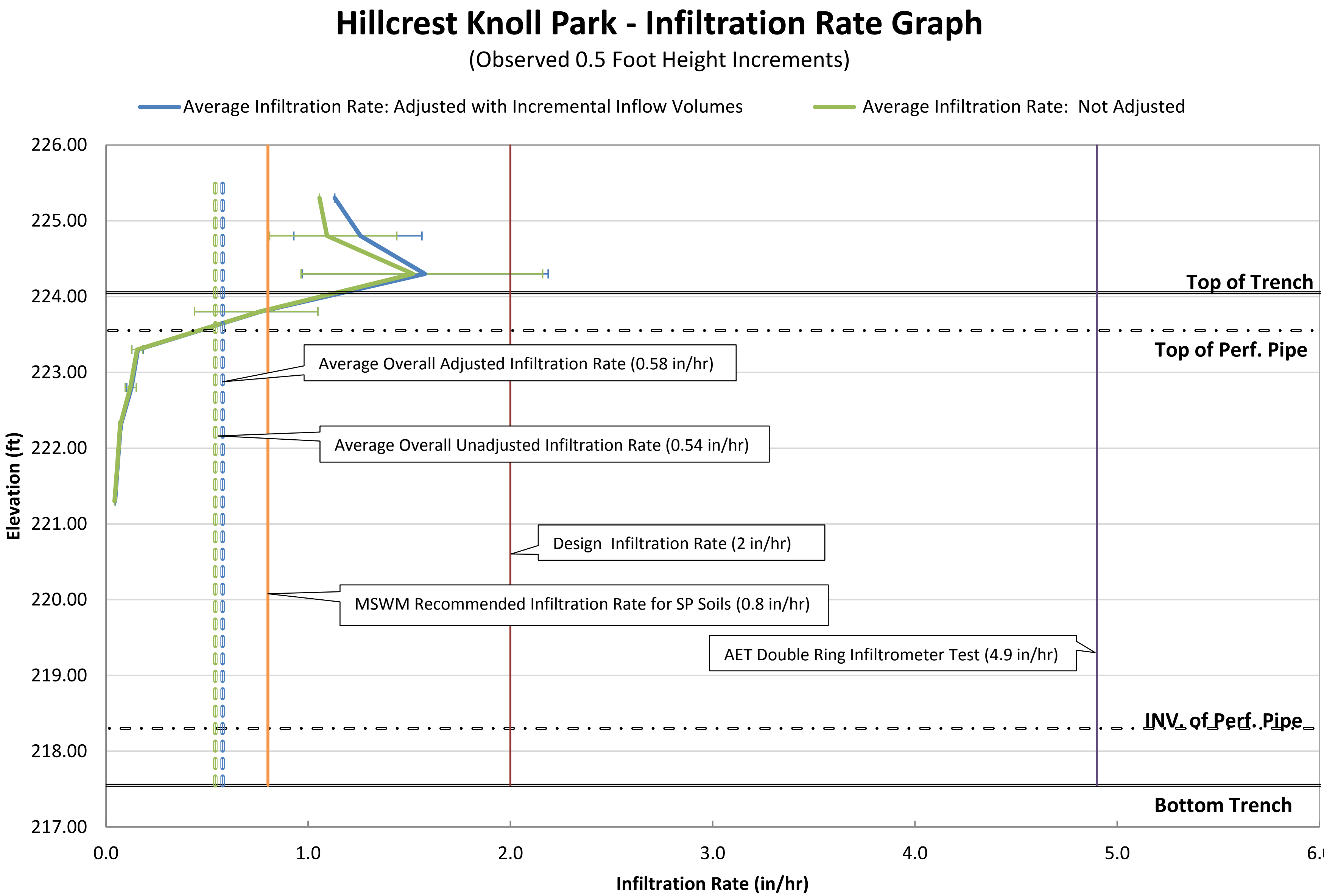
Water Level and Rainfall (SPCD)



City of Saint Paul
2016 Water Quality and Quantity Report
Chart A.8
WSB Job No.: 01610-100

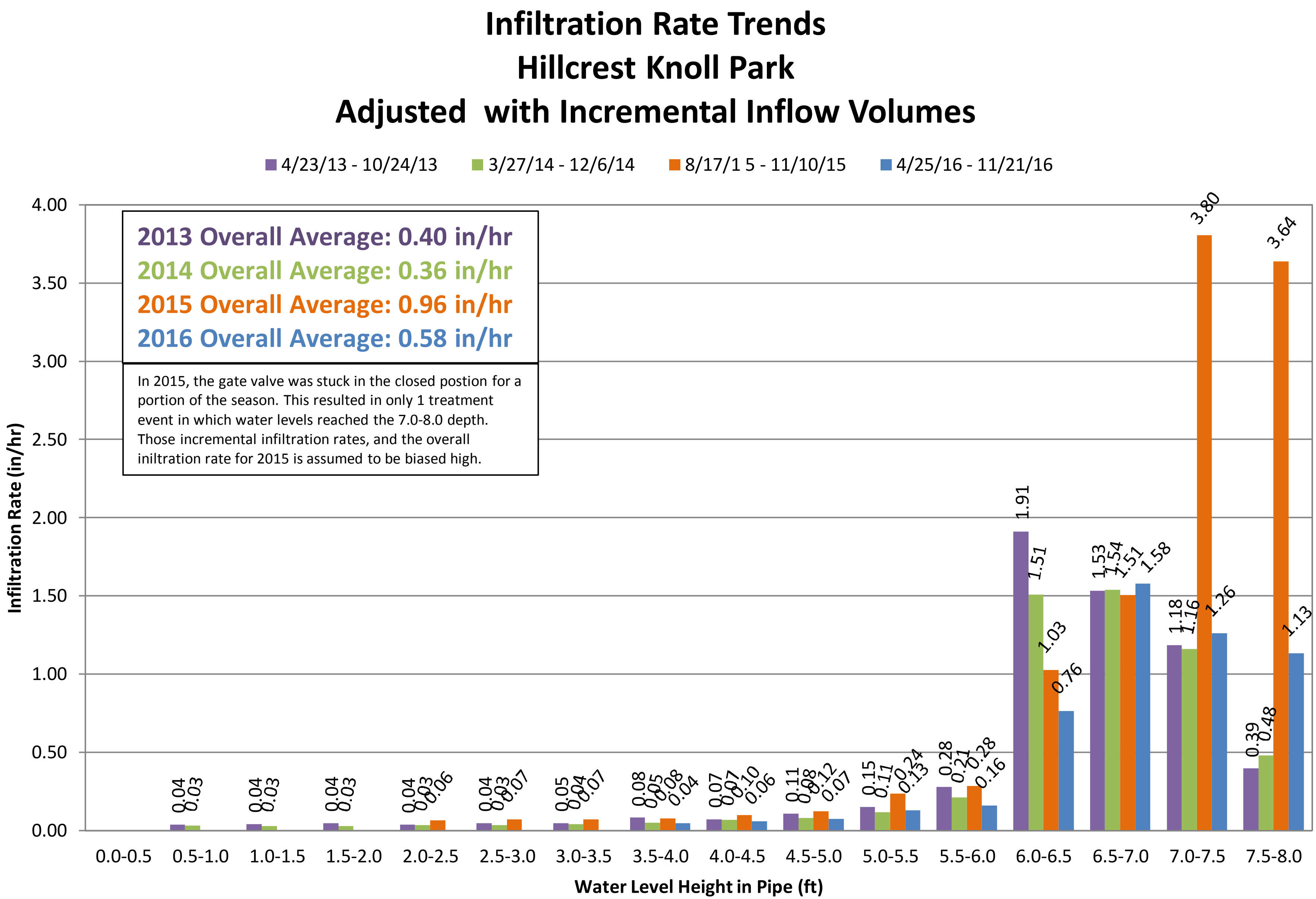


City of Saint Paul
2016 Water Quality and Quantity Report
Chart A.9
WSB Job No.: 01610-100



Note: Pipe Invert is 218.30'
Pipe perforated around circumference of pipe
Error Bars Represent 25th and 75th Percentiles

City of Saint Paul
2016 Water Quality and Quantity Report
Chart A.10
WSB Job No.: 01610-100



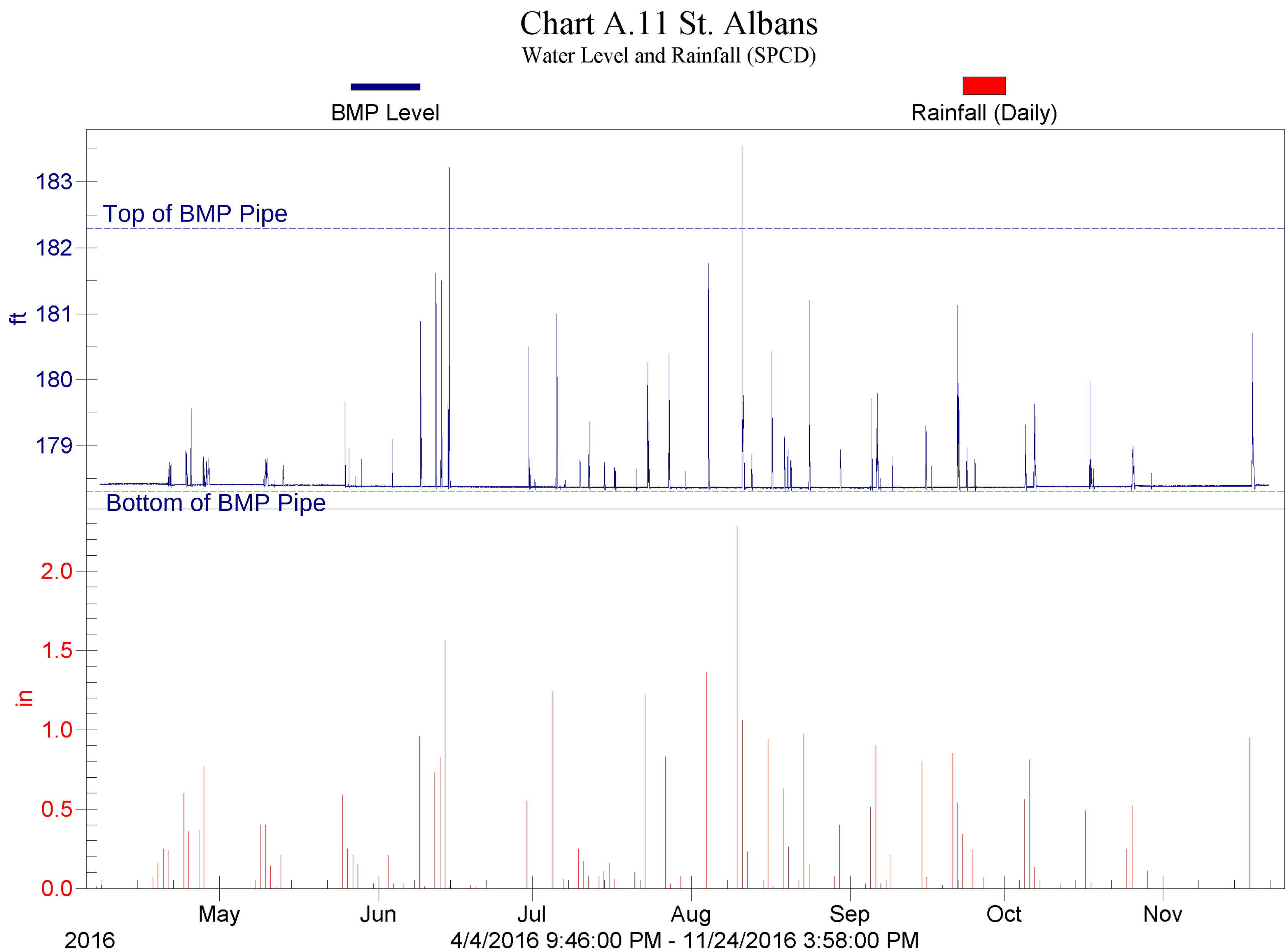
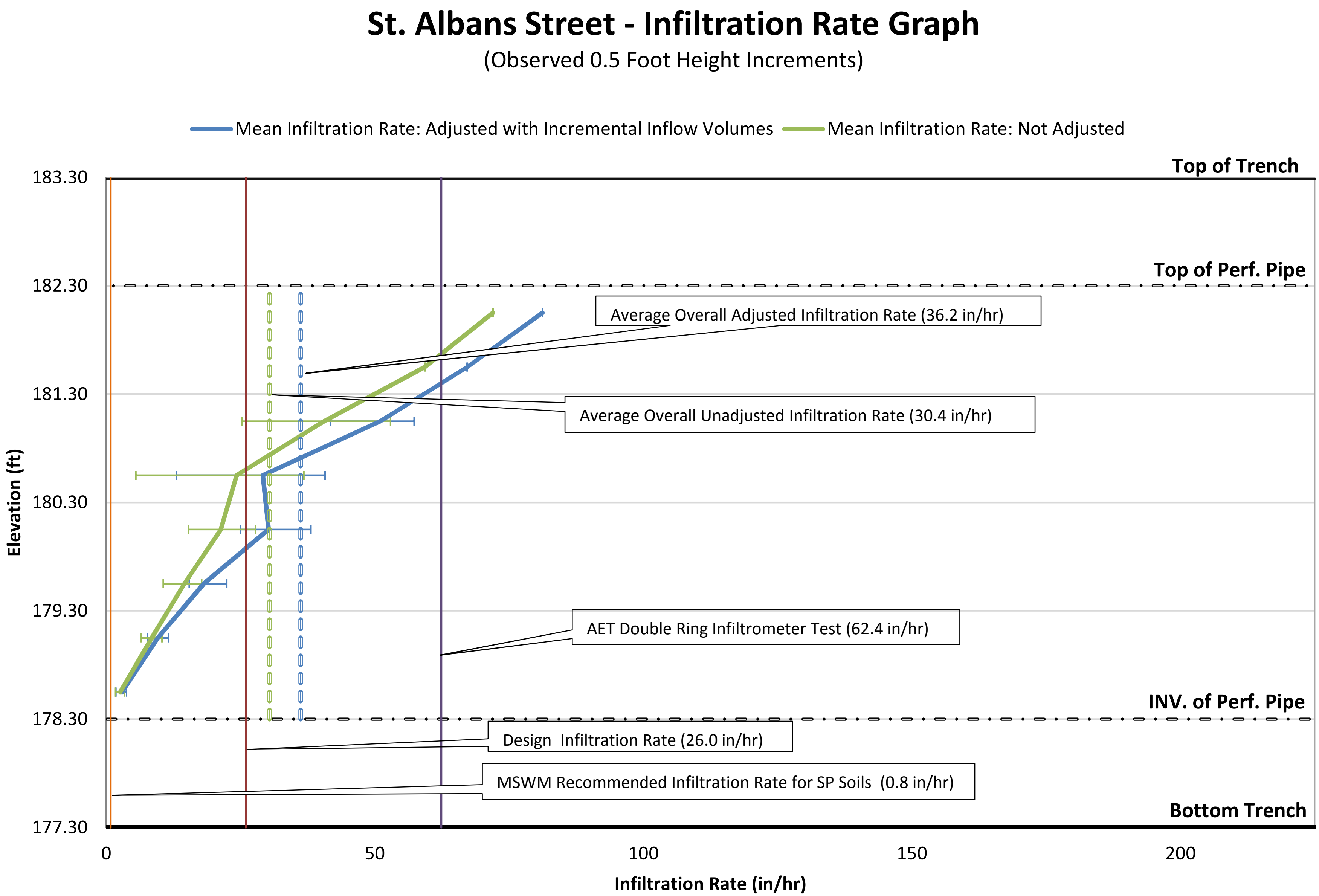


Chart A.11 St. Albans
Water Level and Rainfall (SPCD)
BMP Level
Rainfall (Daily)
Top of BMP Pipe
Bottom of BMP Pipe
ft
183
182
181
180
179
in
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
2016
4/4/2016 9:46:00 PM - 11/24/2016 3:58:00 PM



Note: Pipe Invert is 178.3'
Error Bars Represent 25th and 75th Percentiles
Pipe perforated w/ 2 rows of holes at Elev: 178.9' and 179.2'

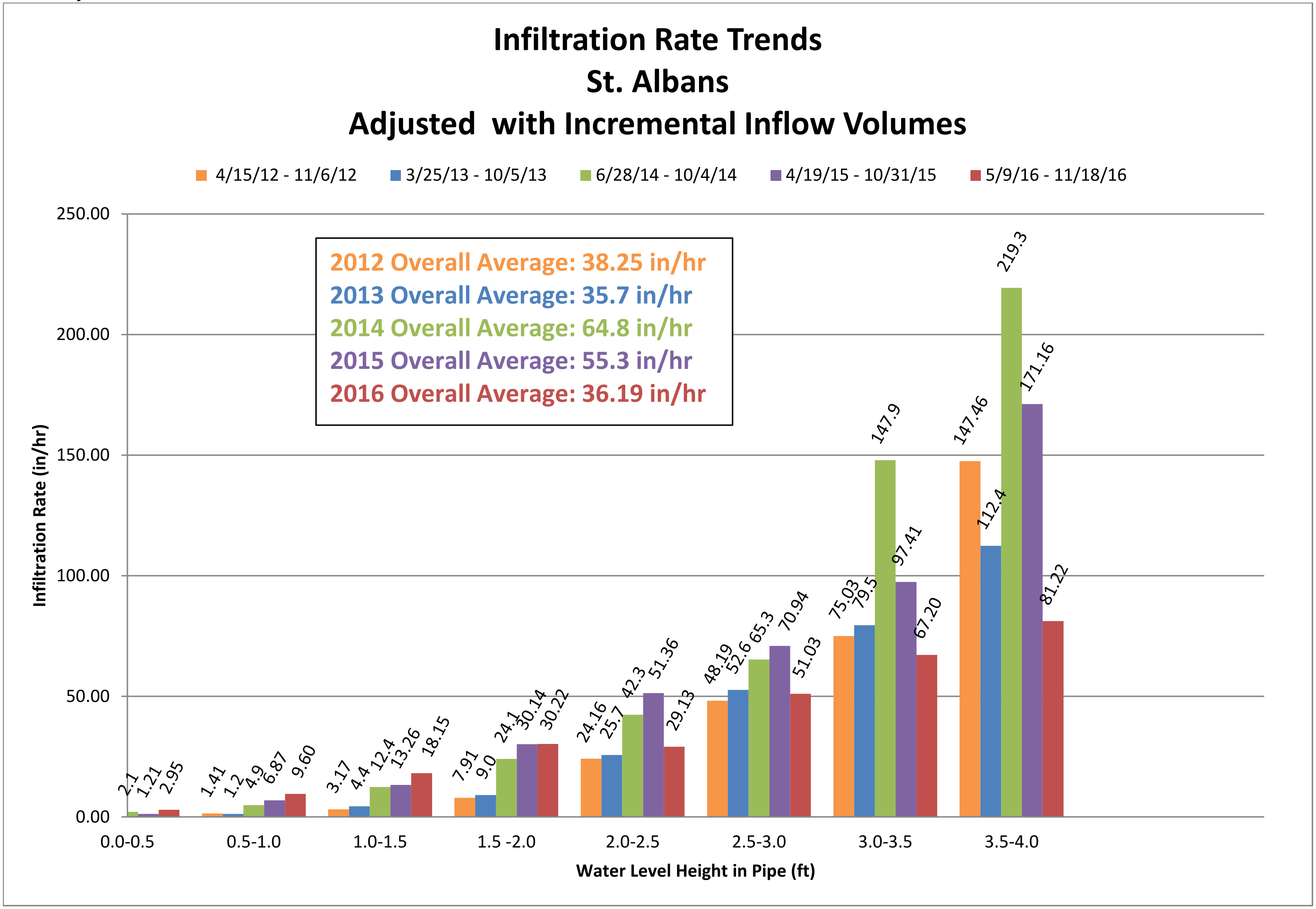
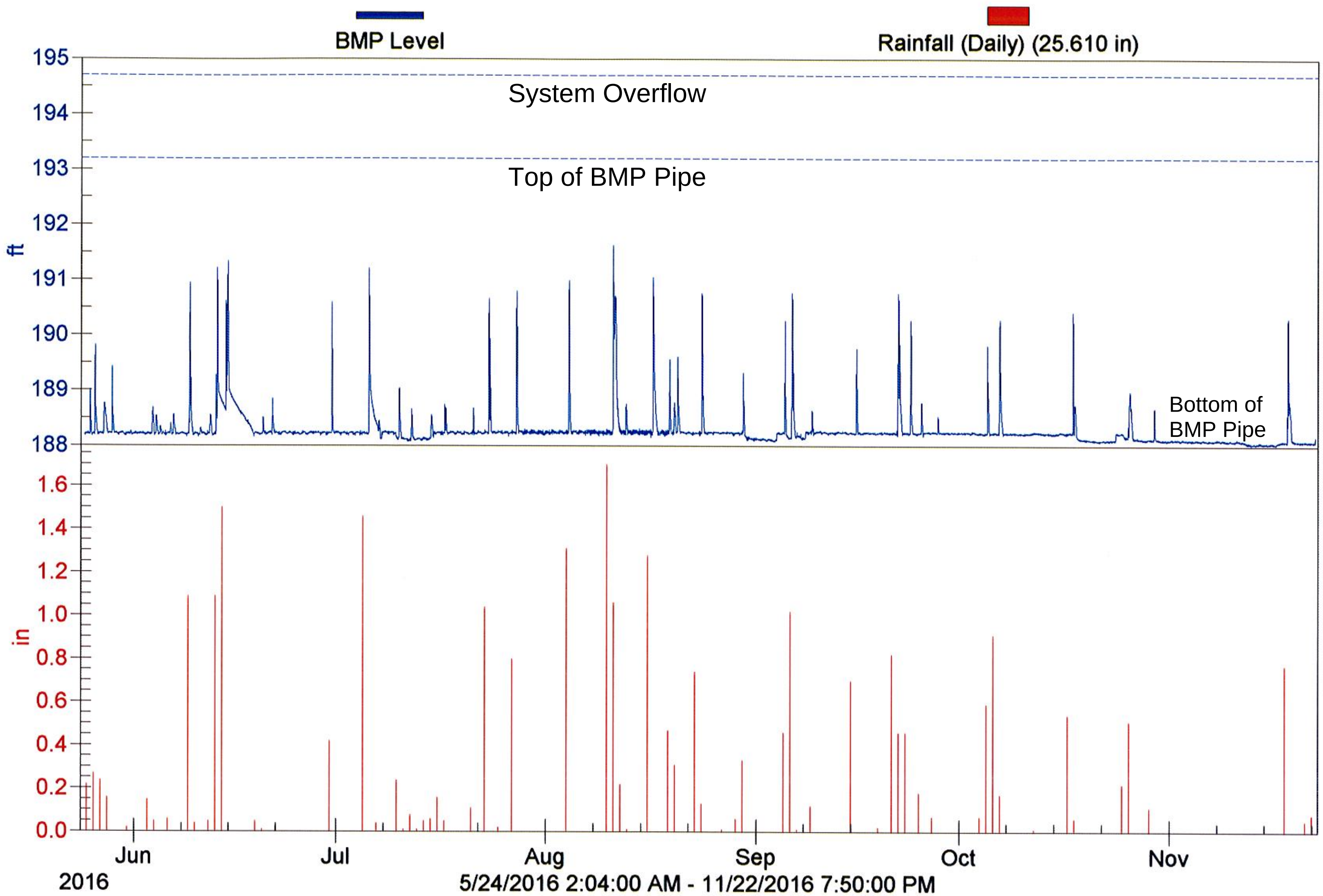
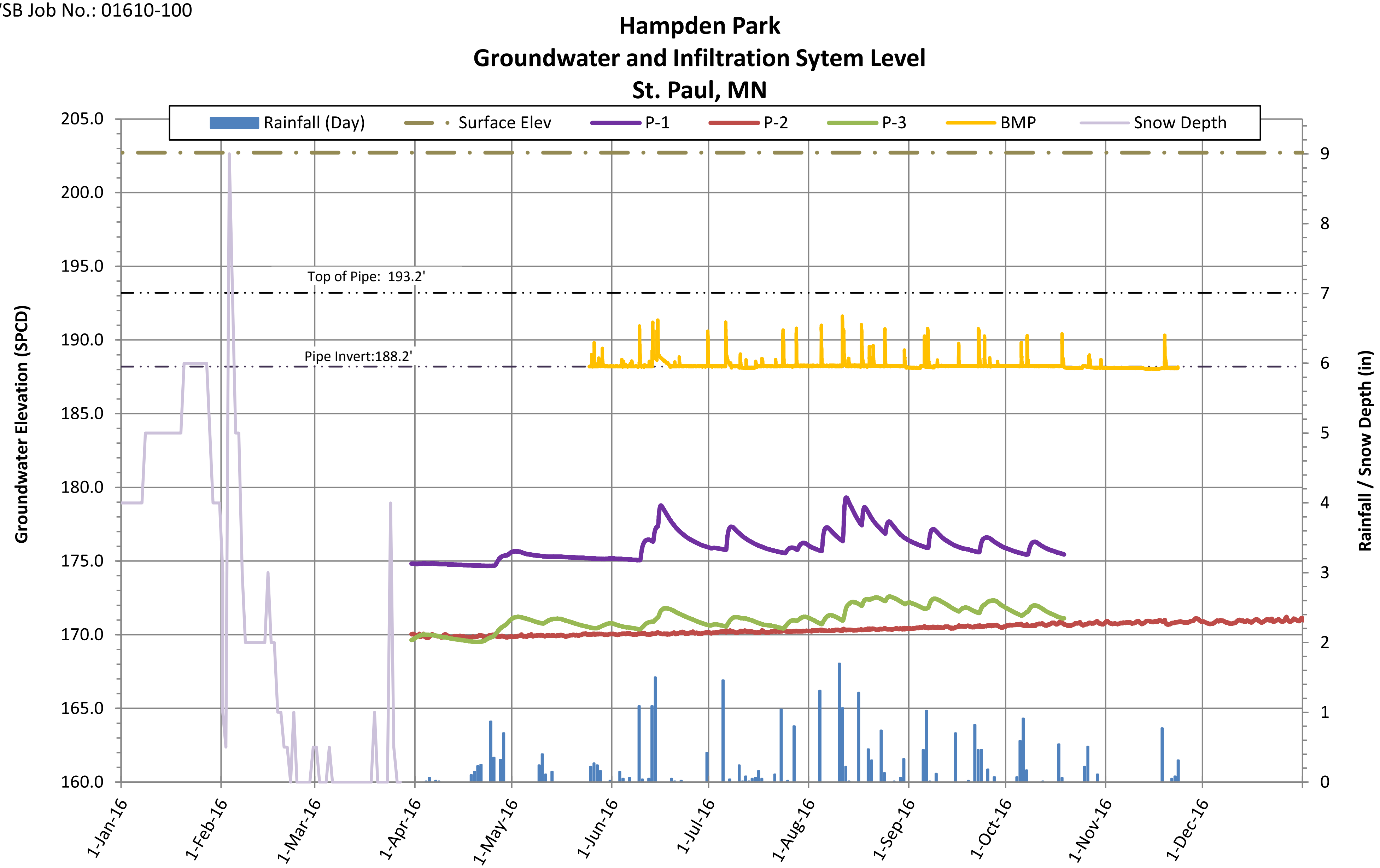

Infiltration Rate Trends
St. Albans
Adjusted with Incremental Inflow Volumes
4/15/12 - 11/6/12
3/25/13 - 10/5/13
6/28/14 - 10/4/14
4/19/15 - 10/31/15
5/9/16 - 11/18/16
2012 Overall Average: 38.25 in/hr
2013 Overall Average: 35.7 in/hr
2014 Overall Average: 64.8 in/hr
2015 Overall Average: 55.3 in/hr
2016 Overall Average: 36.19 in/hr
Infiltration Rate (in/hr)
250.00
200.00
150.00
100.00
50.00
0.00
2.1
1.21
2.95
1.41
1.2
4.9
6.87
9.60
3.17
4.4
12.4
13.26
18.15
7.91
9.0
24.1
30.14
30.22
24.16
25.7
42.3
51.36
29.13
48.19
52.6
65.3
70.94
51.03
75.03
79.5
147.9
97.41
67.20
147.46
112.4
219.3
171.16
81.22
0.0-0.5
0.5-1.0
1.0-1.5
1.5 -2.0
2.0-2.5
2.5-3.0
3.0-3.5
3.5-4.0
Water Level Height in Pipe (ft)

Chart A.14 Hampden Park

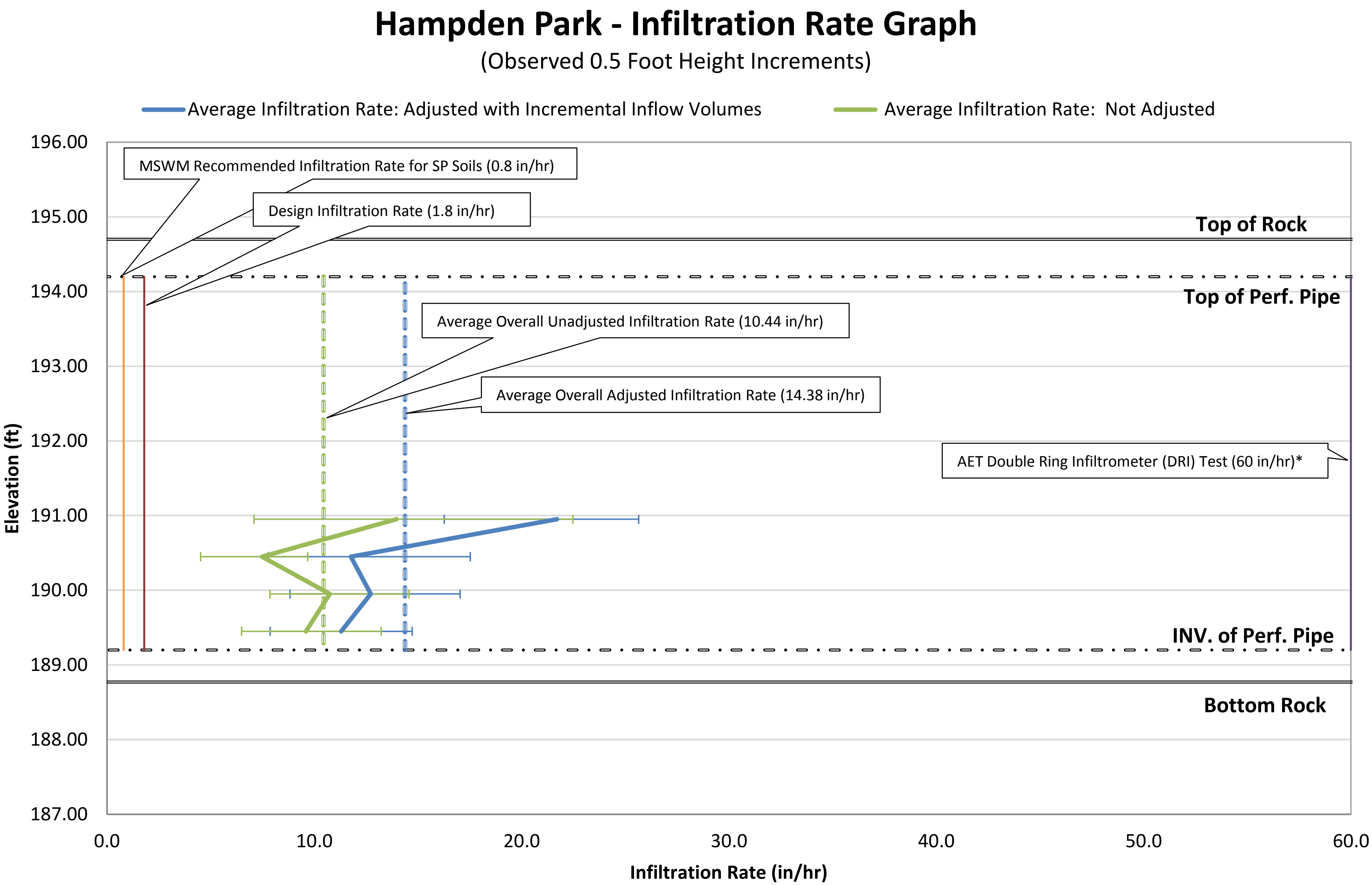
BMP Water Level and Rainfall



City of Saint Paul
2016 Water Quality and Quantity Report
Chart A.15
WSB Job No.: 01610-100



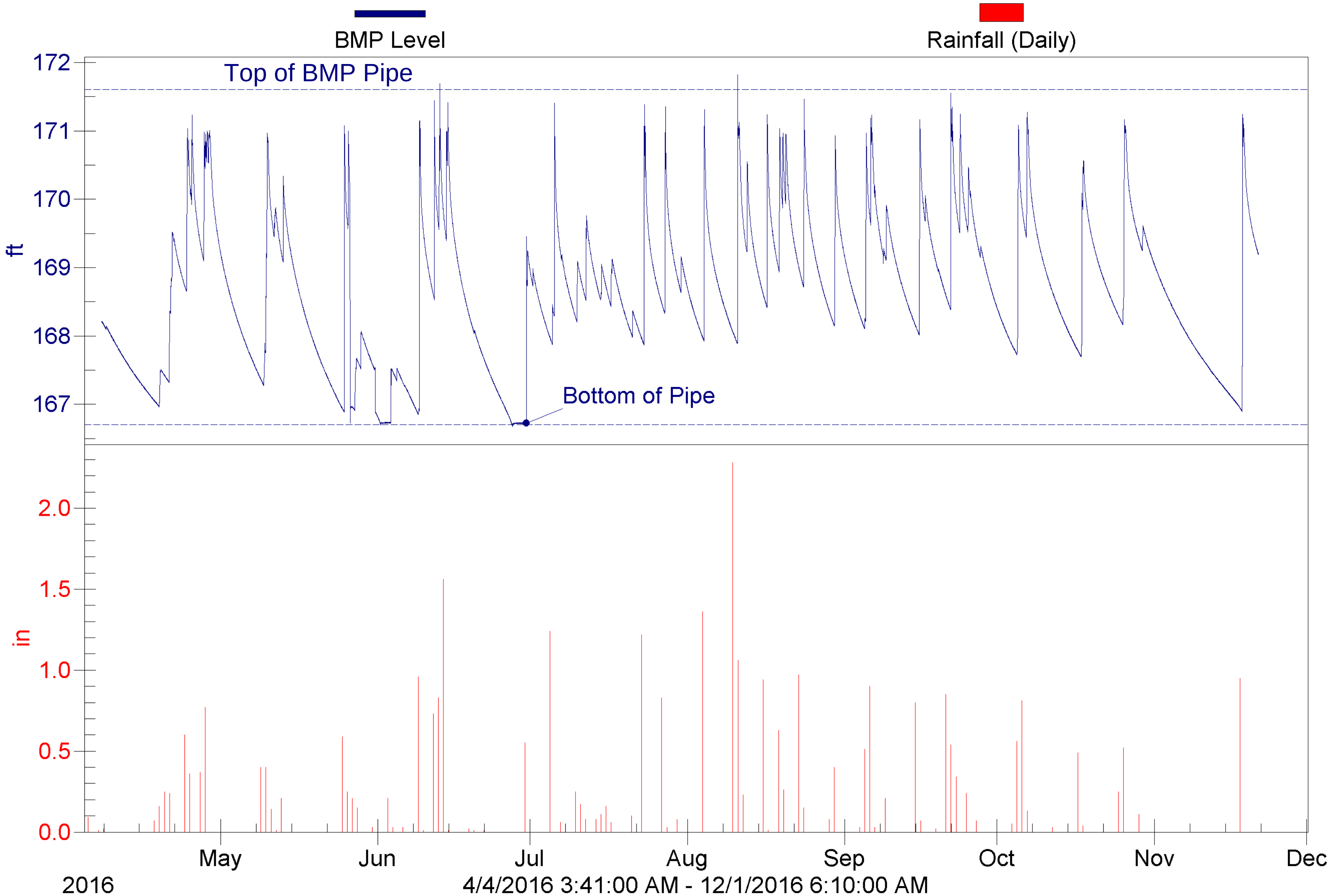
City of Saint Paul
2016 Water Quality and Quantity Monitoring
Chart A.16
WSB Job No.: 01610-100



Note: Pipe Invert is 189.2'
Error Bars Represent 25th and 75th Percentiles
* The DRI testing was completed on top of a 5 ft layer of fine filter aggregate that was constructed above the native soils, per the design.

Chart A. 17 Arundel

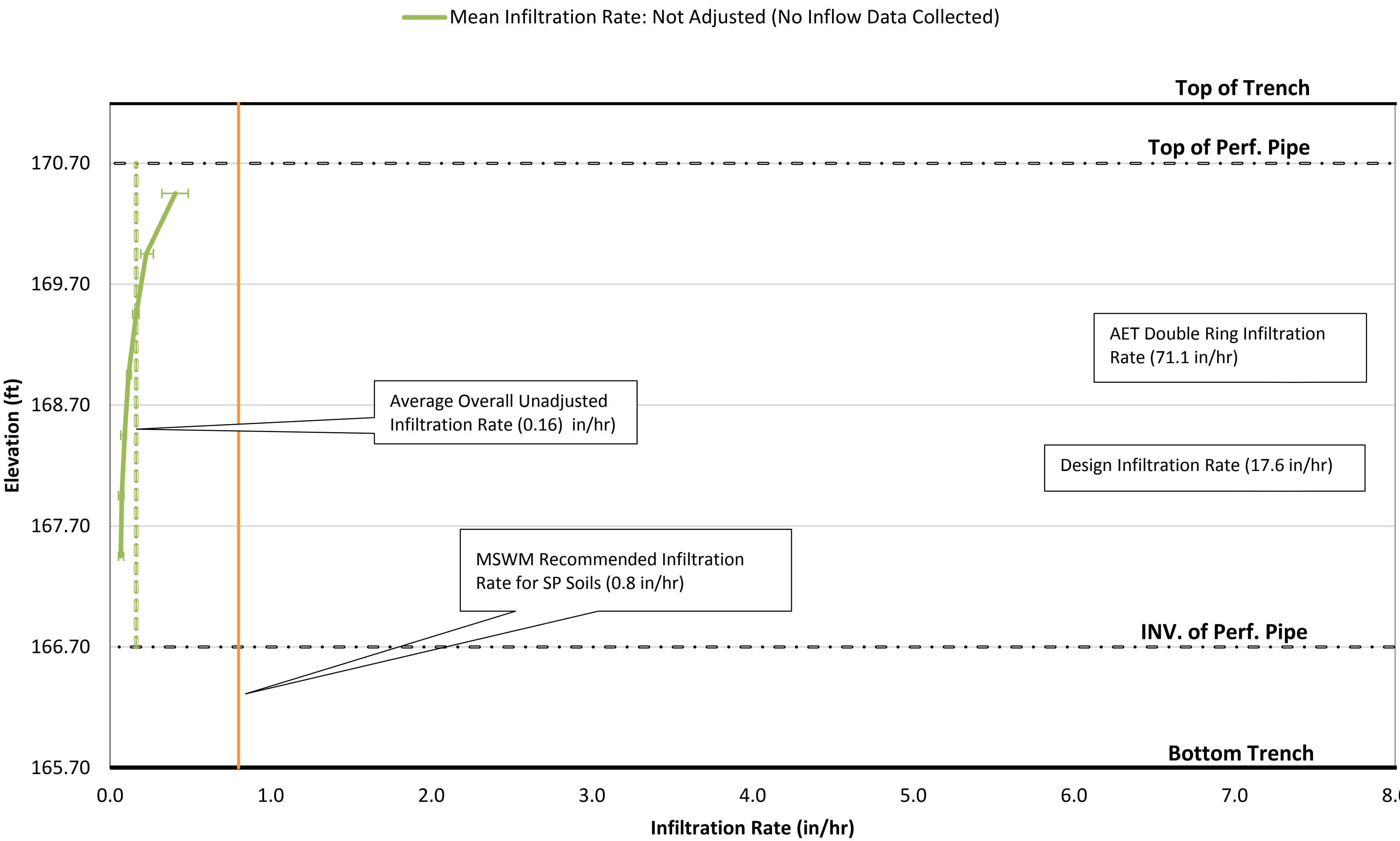
Water Level and Rainfall (SPCD)



City of Saint Paul
2015 Water Quality and Quantity
Chart A.18
WSB Job No.: 01610-100

Arundel Street - Infiltration Rate Graph

(Observed at Incremental 0.5 Foot Elevations)



Note: Pipe Invert is 166.7'
Error Bars Represent 25th and 75th Percentiles
Pipe perforated w/ 2 rows of holes at Elev: 167.3' and 167.6'

City of Saint Paul
2016 Water Quality and Quantity Report
Chart A.19
WSB Job NO.: 01610-100

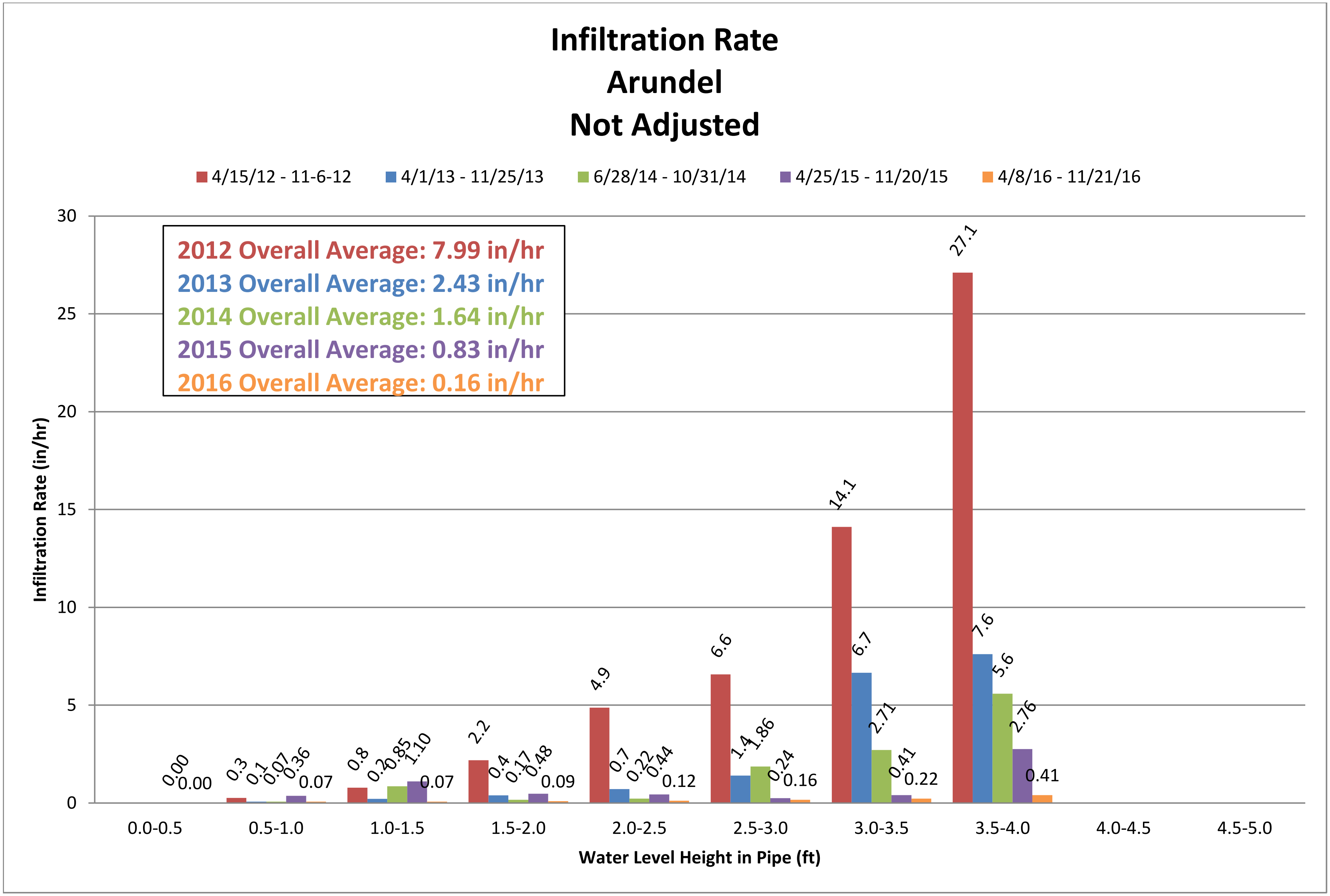


Chart A.20 Flandrau-Hoyt

Pond Level and Rainfall (SPCD)

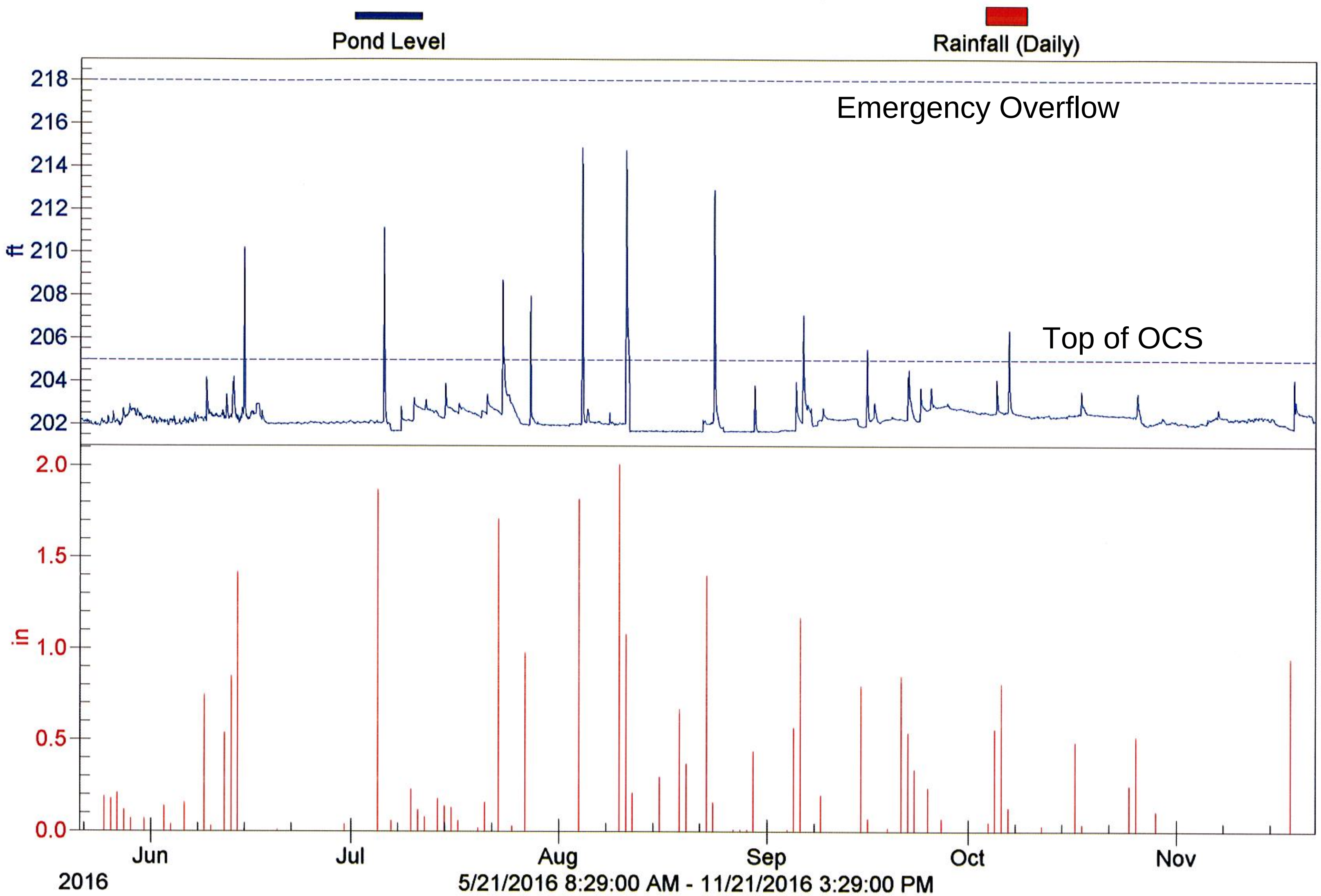


Chart A.21 Sackett Park Pond

Pond Level and Rainfall (SPCD)

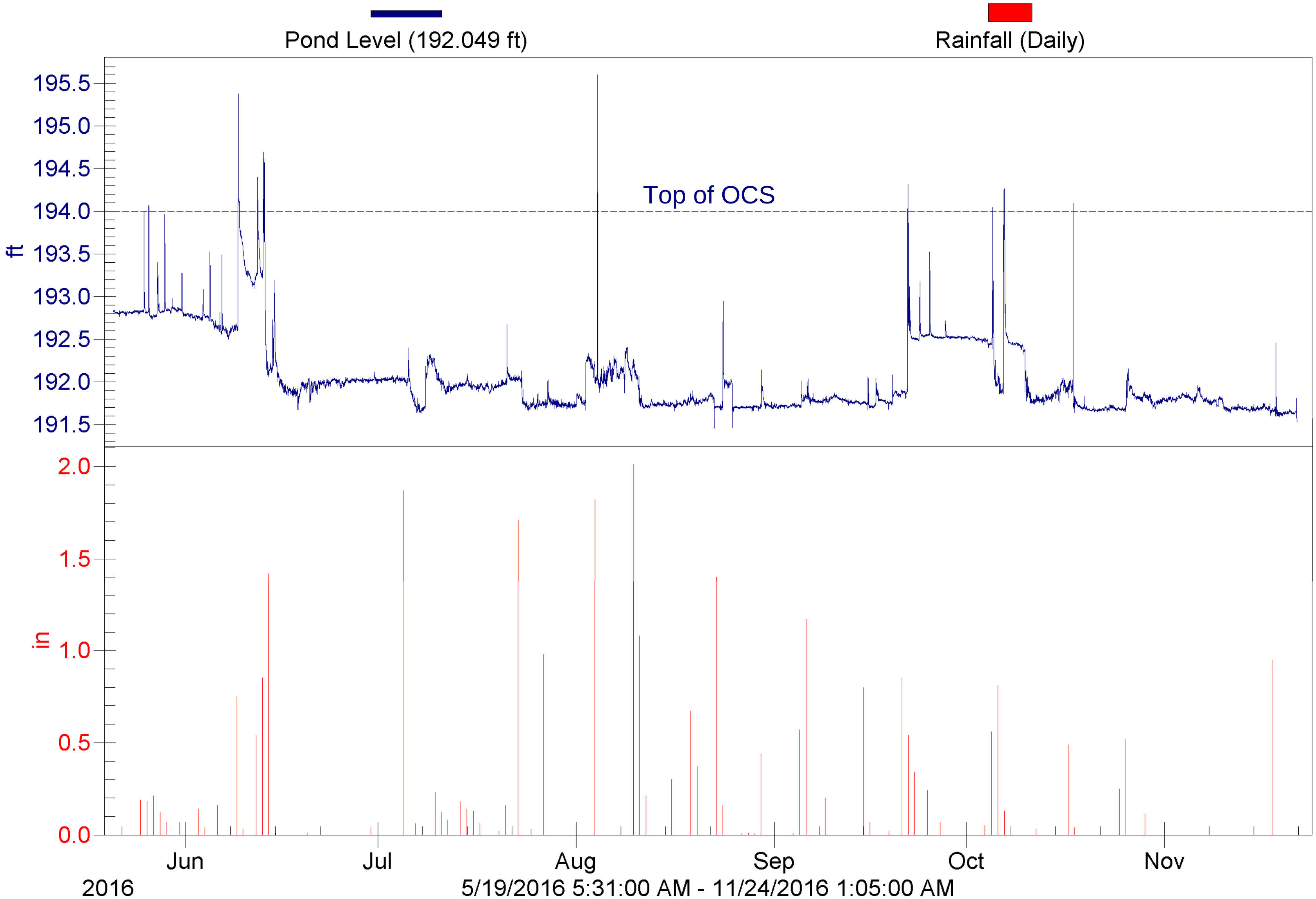


Chart A.22 TBNS - Maryland Pond

Pond Level and Rainfall (SPCD)

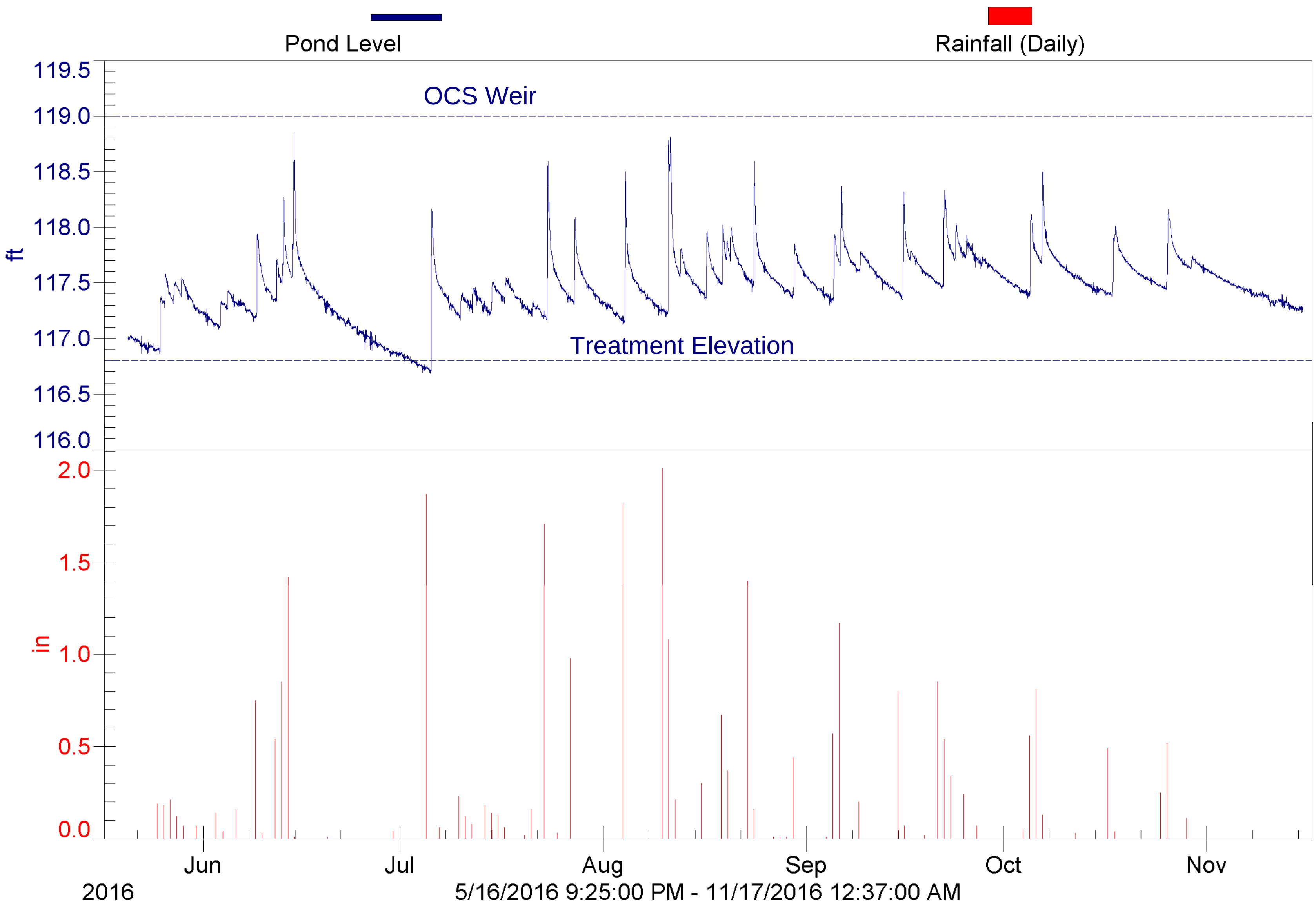
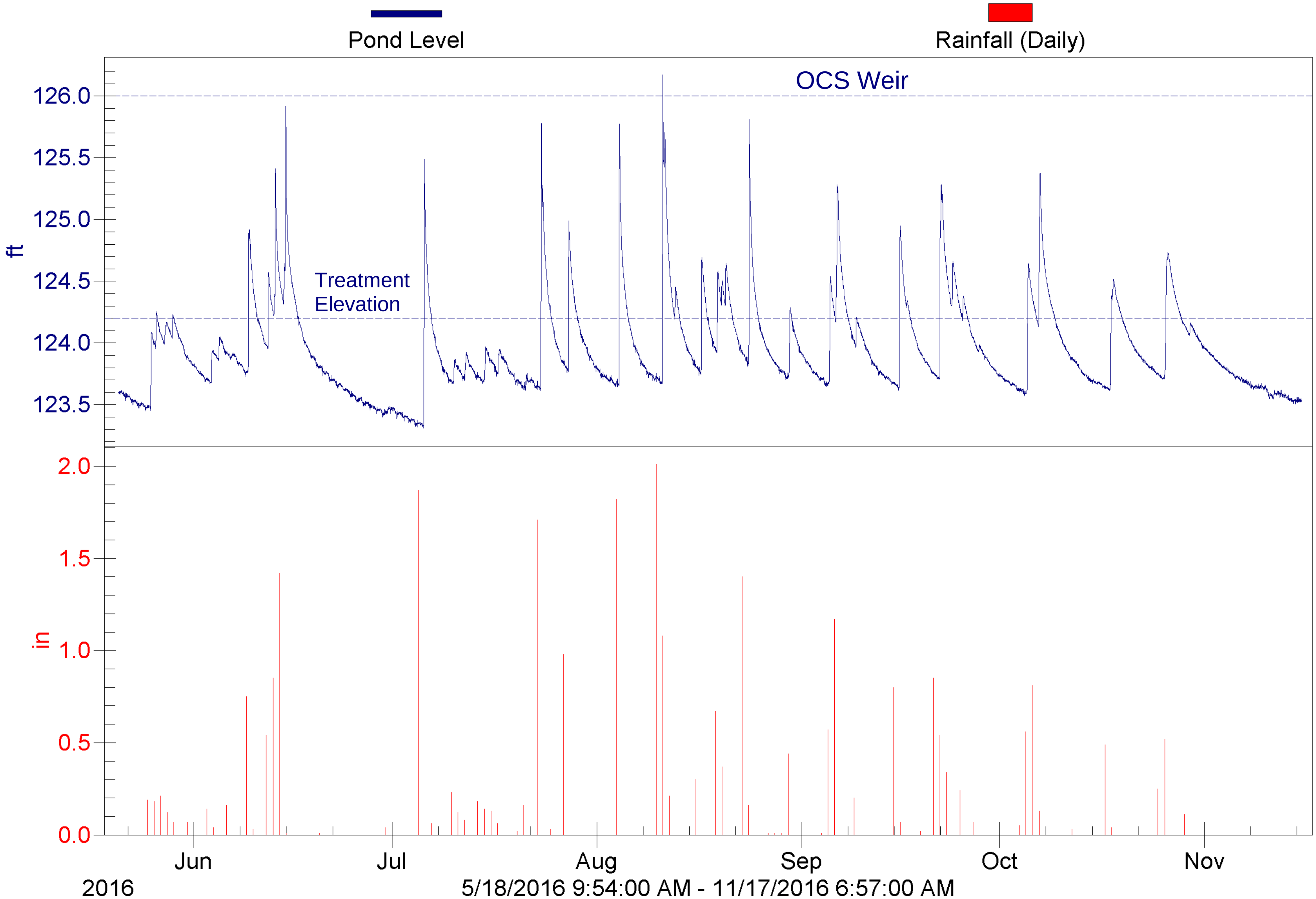


Chart A.23 TBNS - Magnolia

Pond Level and Rainfall (SPCD)



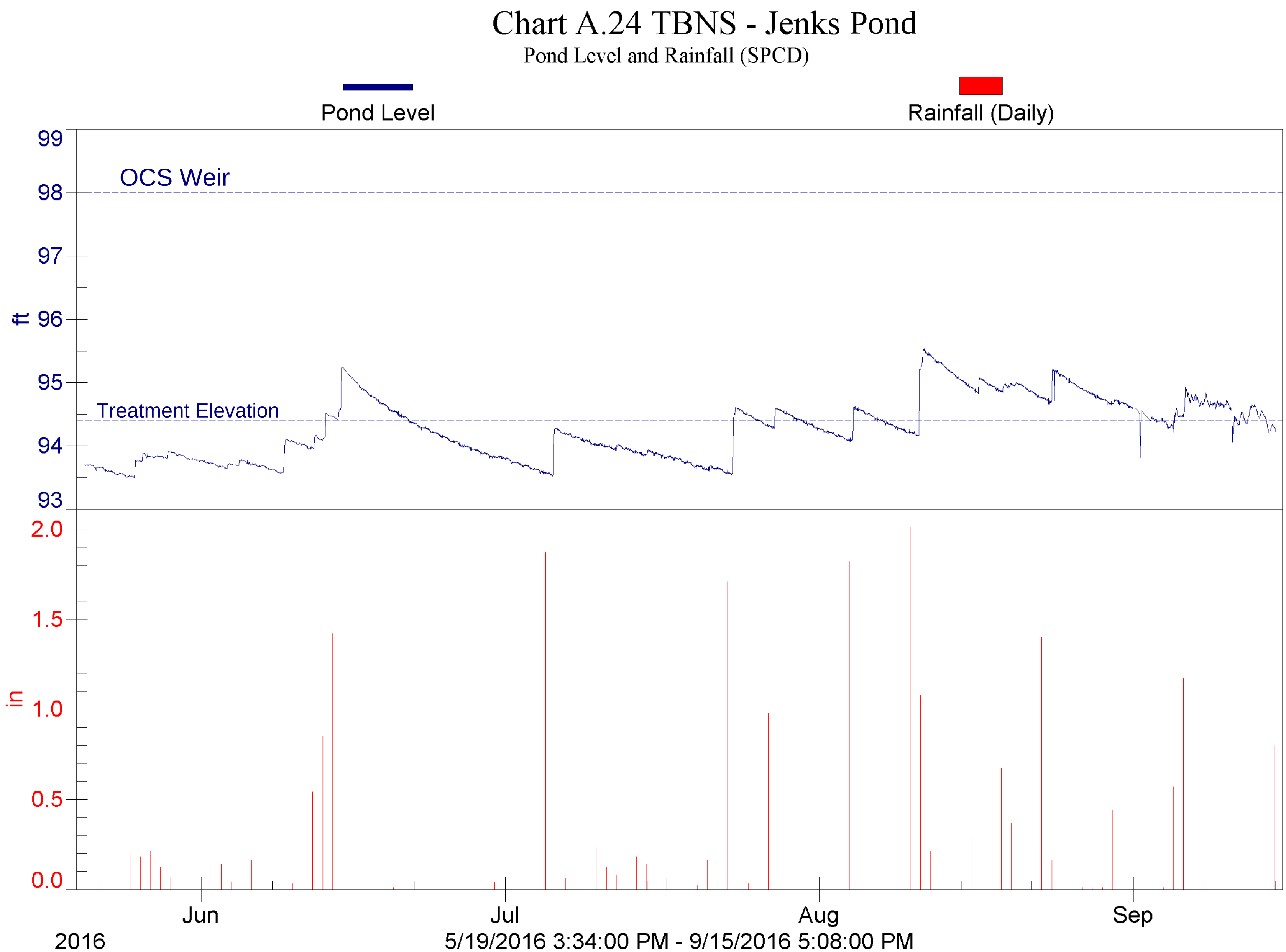
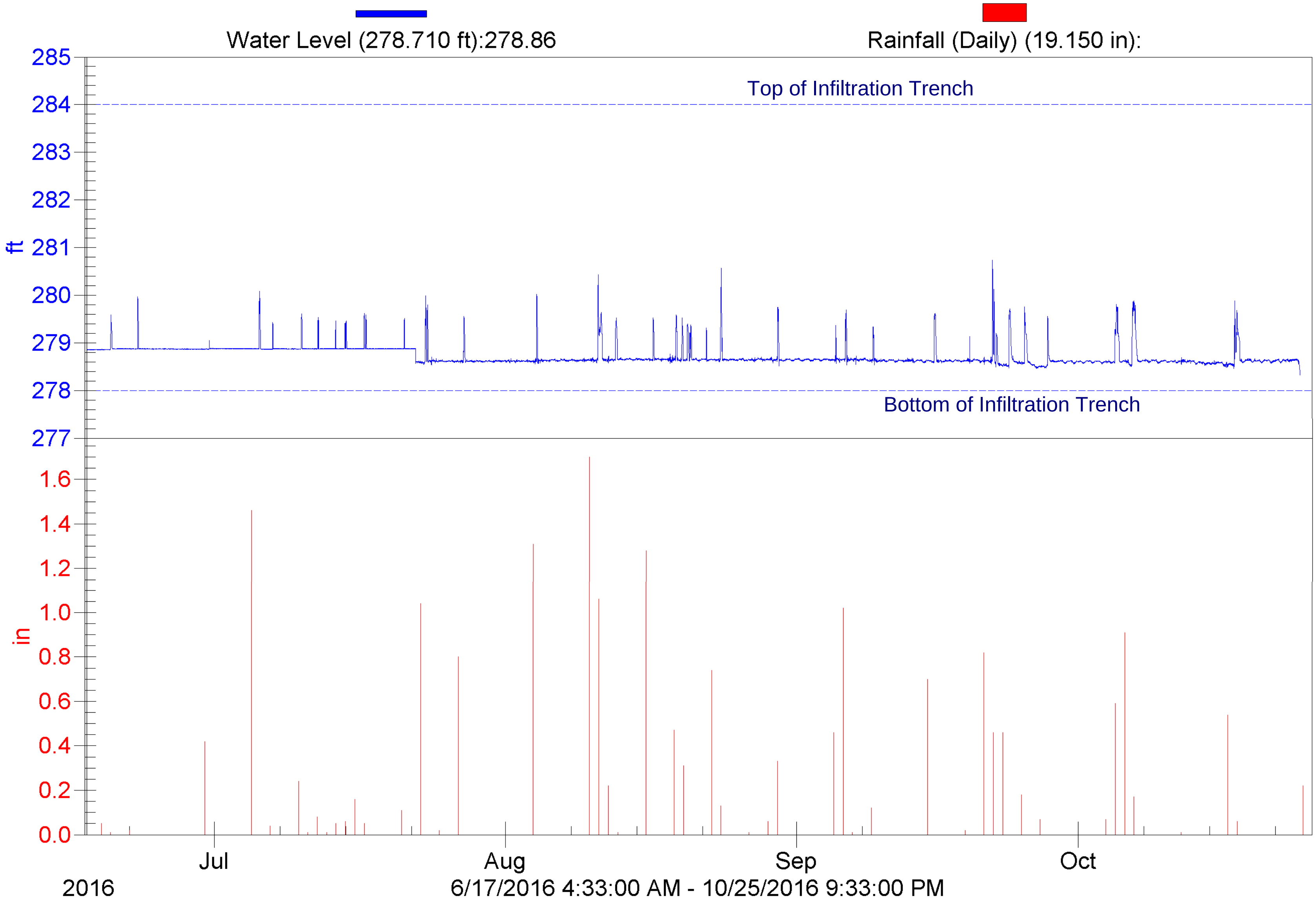


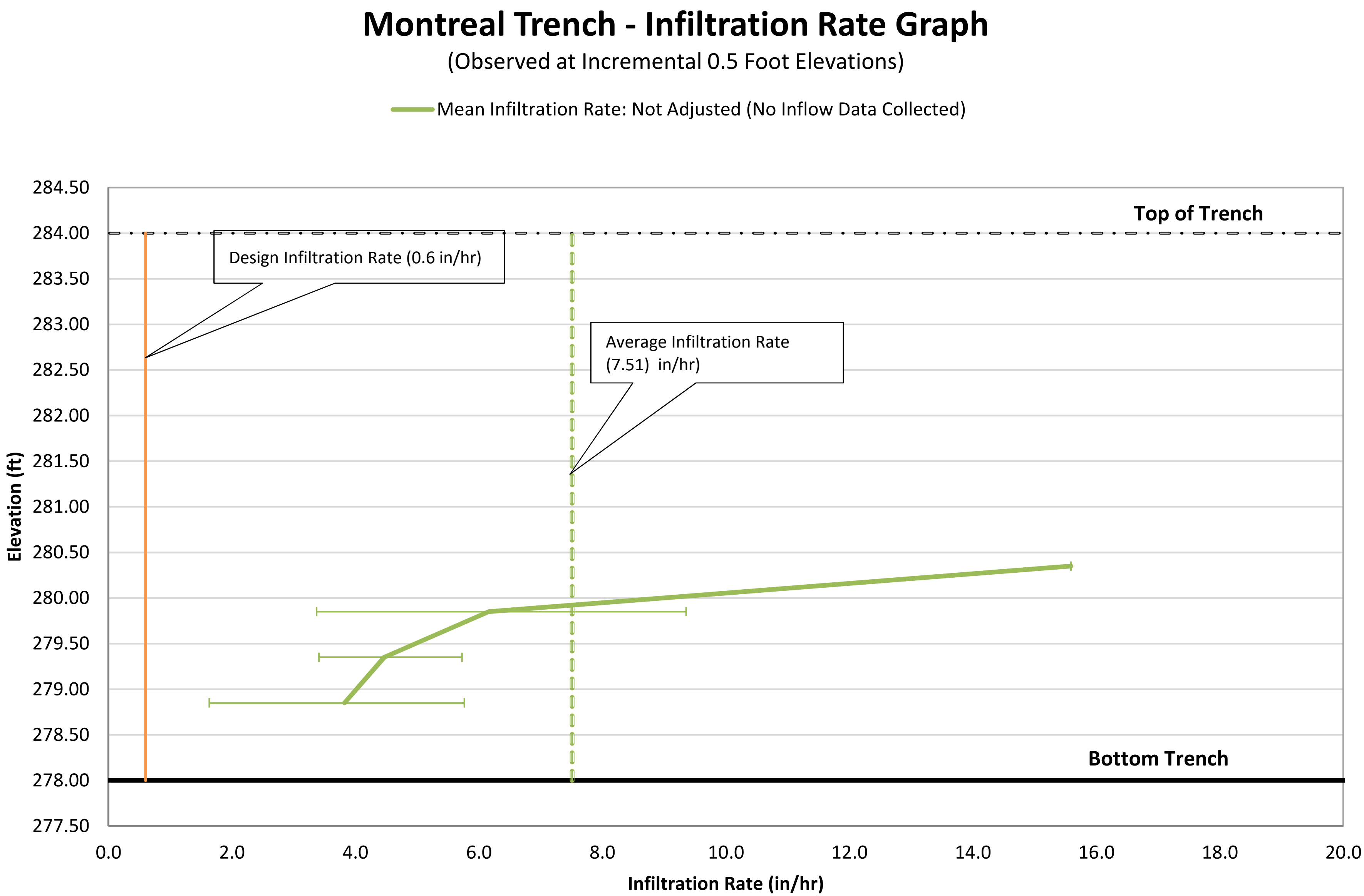
Chart A.24 TBNS - Jenks Pond
Pond Level and Rainfall (SPCD)
Pond Level
Rainfall (Daily)
OCS Weir
Treatment Elevation
ft
99
98
97
96
95
94
93
in
2.0
1.5
1.0
0.5
0.0
Jun
Jul
Aug
Sep
2016
5/19/2016 3:34:00 PM - 9/15/2016 5:08:00 PM

Chart A.25 Montreal Trench

Flowlink 5



City of Saint Paul
2016 Water Quality and Quantity
Chart A.26
WSB Job No.: 01610-100



Error Bars Represent 25th and 75th Percentiles

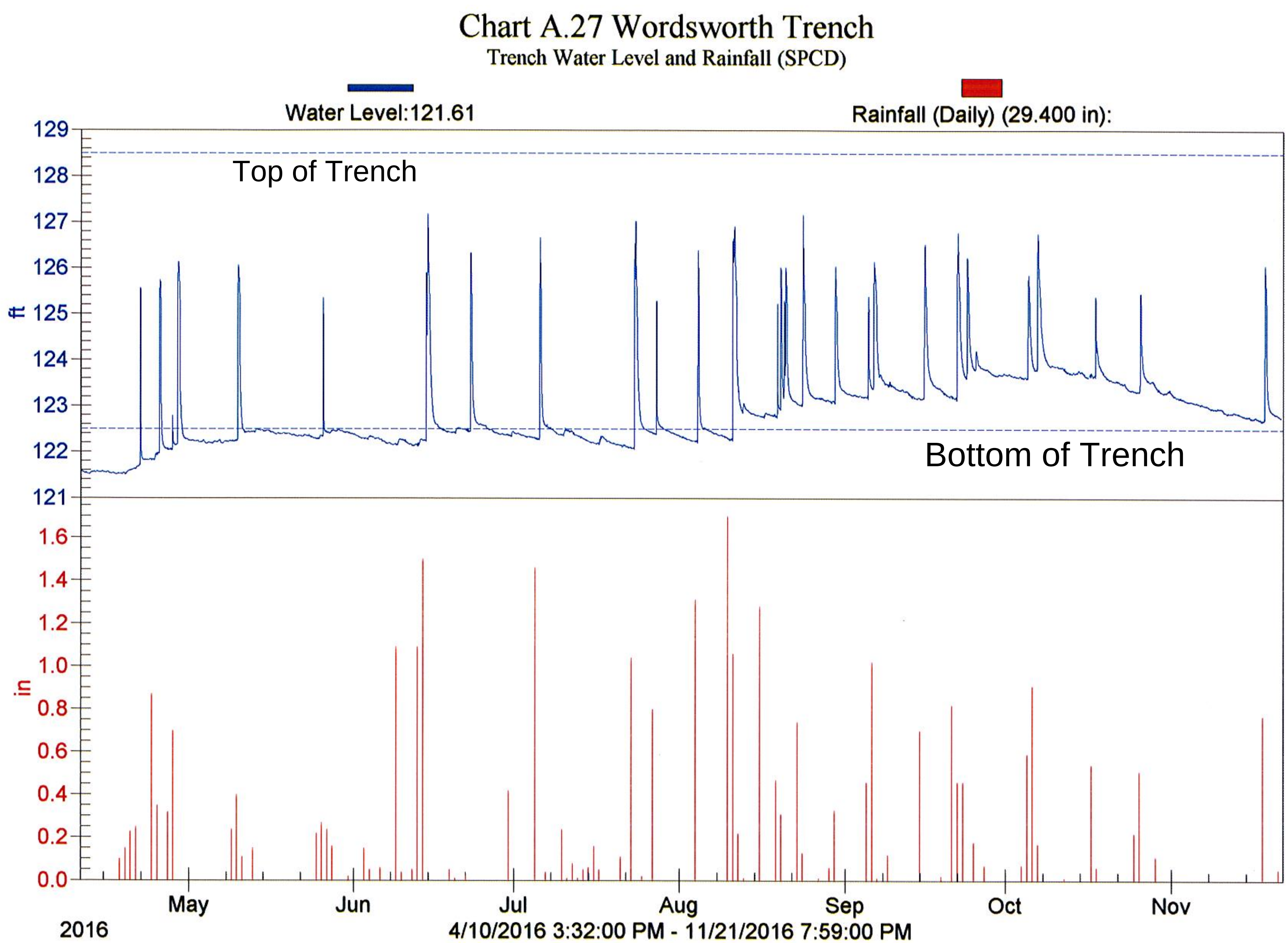
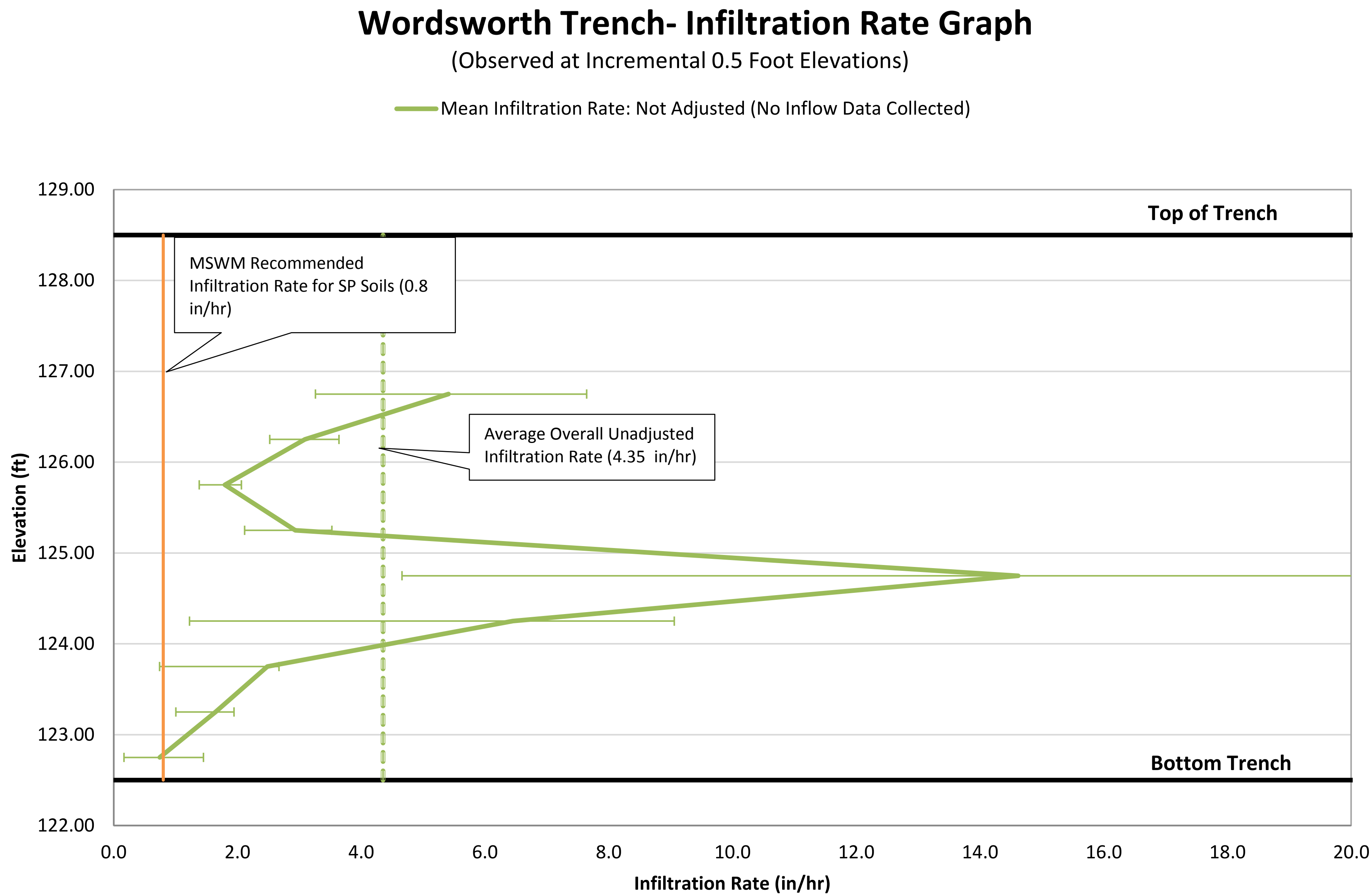


Chart A.27 Wordsworth Trench
Trench Water Level and Rainfall (SPCD)
Water Level:121.61
Rainfall (Daily) (29.400 in):
Top of Trench
Bottom of Trench
ft
in
129
128
127
126
125
124
123
122
121
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
2016
4/10/2016 3:32:00 PM - 11/21/2016 7:59:00 PM

City of Saint Paul
2016 Water Quality and Quantity
Chart A.28
WSB Job No.: 01610-100



Note:
Error Bars Represent 25th and 75th Percentiles

Appendix B – Flow Rate Charts

Chart B.1 Beacon Bluff

Flow Rates and Rainfall

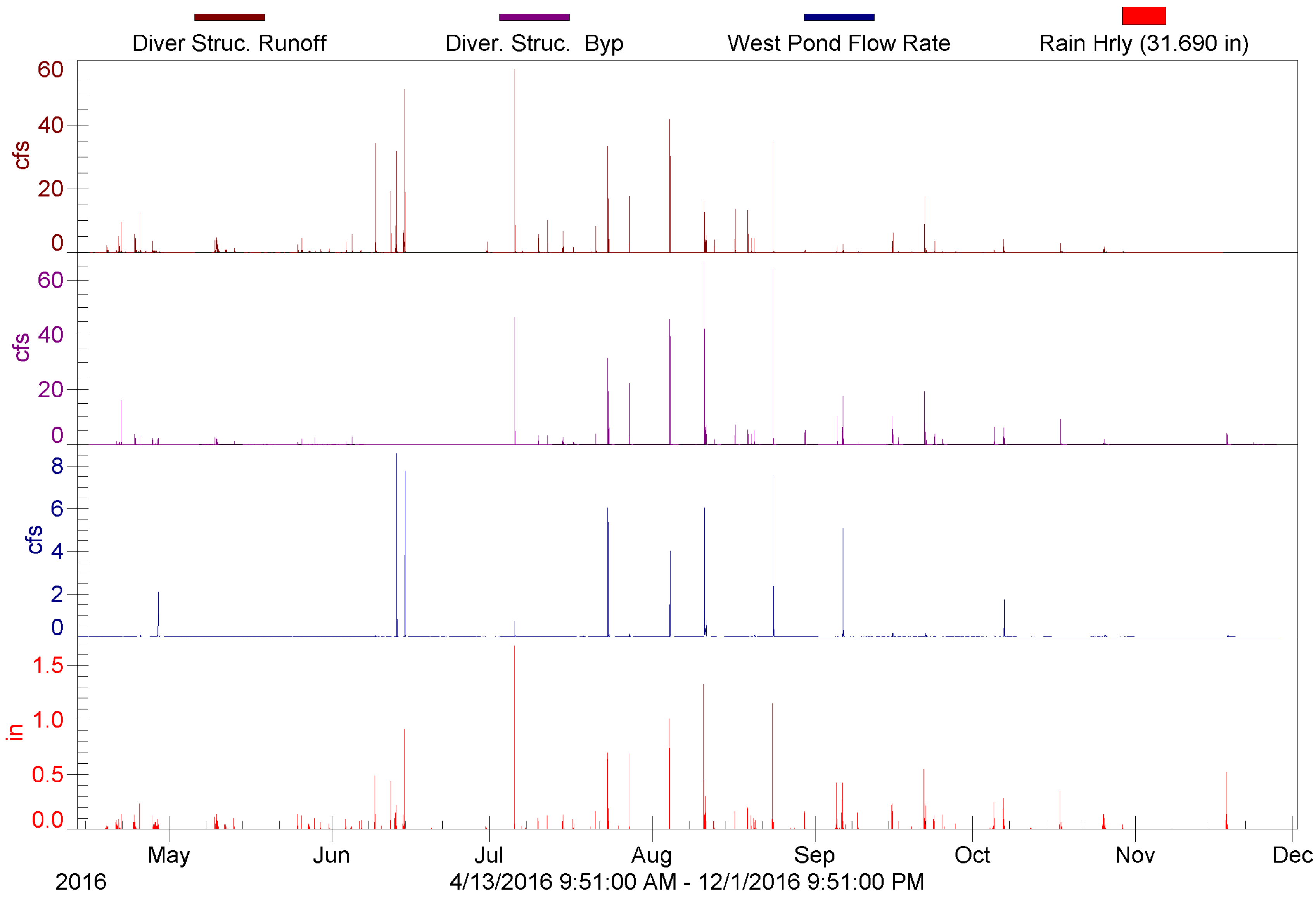
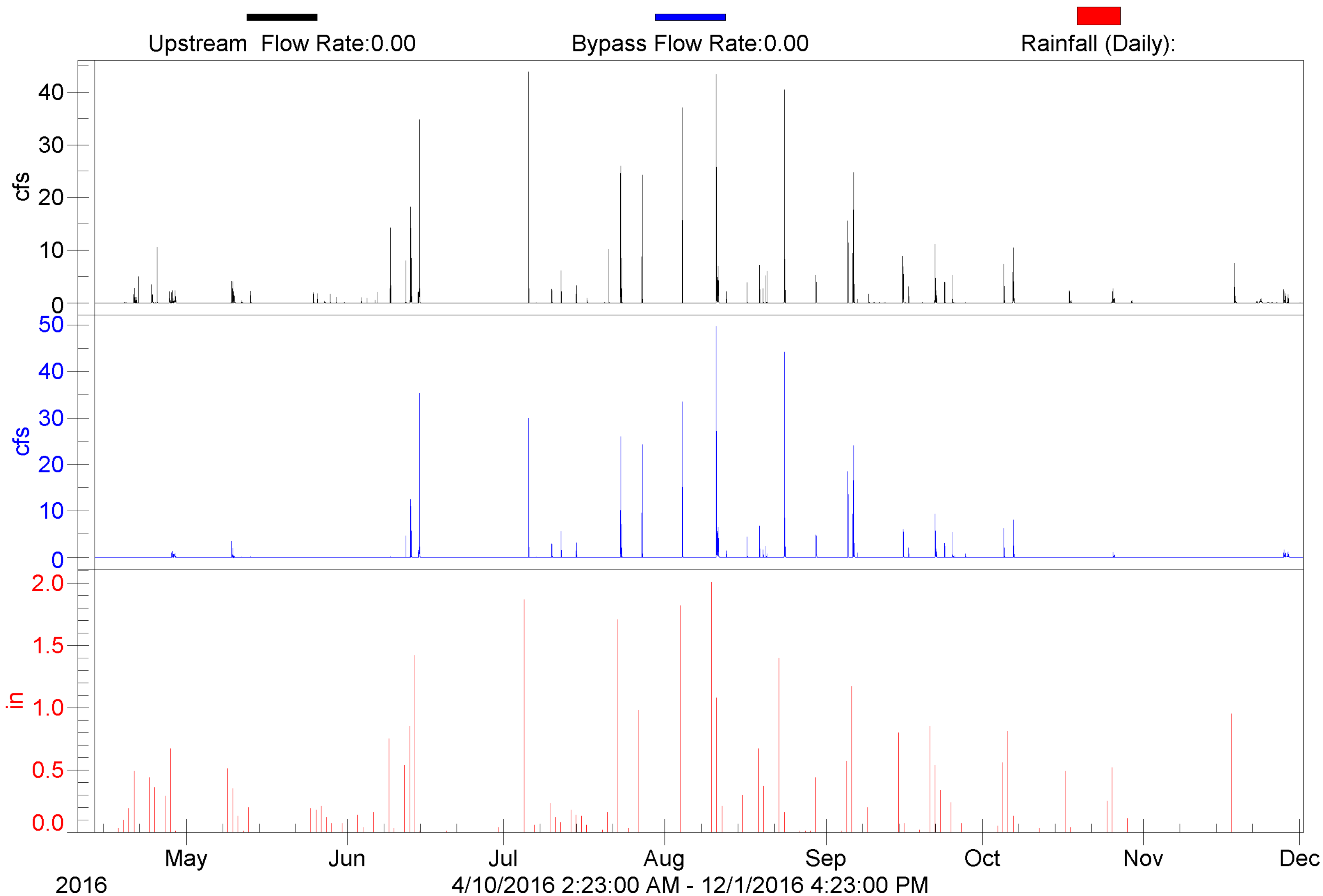


Chart B.2 Hillcrest Knoll Park

Flow Rates and Rainfall



HILLCREST KNOLL PARK INFILTRATION SYSTEM FLOW EVENT SUMMARY

Rain				Flow						
Start	End	Duration	Amount	Start	End	Duration	Flandrau St. Runoff Volume (Upstream of Diversion) (1)	Flandrau St. Bypass Volume (Downstream of Diversion) (2)	Total Inflow to BMP (1 -2)	Percent Captured
		(hr)	(in)			(hr)	(cf)	(cf)	(cf)	(%)
4/20/2016 20:31	4/21/2016 0:59	4.47	0.23	4/20/2016 20:55	4/21/2016 6:45	9.83	10218.8	0.0	10218.8	100.0%
4/21/2016 1:47	4/21/2016 19:27	17.67	0.45	4/21/2016 9:30	4/21/2016 22:30	13.00	7903.1	0.0	7903.1	100.0%
4/24/2016 6:39	4/24/2016 16:07	9.47	0.43	4/24/2016 6:52	4/24/2016 18:30	11.63	14549.3	0.0	14549.3	100.0%
4/25/2016 8:16	4/25/2016 9:47	1.52	0.33	4/25/2016 2:30	4/25/2016 14:45	12.25	15249.1	0.0	15249.1	100.0%
4/27/2016 16:57	4/28/2016 1:49	8.87	0.31	4/27/2016 17:15	4/28/2016 3:30	10.25	10375.1	0.0	10375.1	100.0%
4/28/2016 4:16	4/28/2016 10:31	6.25	0.26	4/28/2016 4:15	4/28/2016 12:00	7.75	12963.9	7031.4	5932.6	45.8%
4/28/2016 13:10	4/28/2016 22:58	9.80	0.39	4/28/2016 13:30	4/29/2016 6:00	16.50	23268.6	7359.0	15909.6	68.4%
5/9/2016 13:17	5/9/2016 16:07	2.83	0.15	5/9/2016 13:45	5/9/2016 17:45	4.00	6343.0	3275.2	3067.9	48.4%
5/9/2016 19:54	5/10/2016 8:38	12.73	0.71	5/9/2016 20:15	5/10/2016 12:00	15.75	32494.1	4603.0	27891.0	85.8%
5/11/2016 13:01	5/11/2016 19:34	6.55	0.13	5/11/2016 13:15	5/12/2016 0:15	11.00	1576.3	187.7	1388.5	88.1%
5/13/2016 7:14	5/13/2016 10:17	3.05	0.20	5/13/2016 7:38	5/13/2016 12:15	4.62	6098.7	445.6	5653.1	92.7%
5/25/2016 9:58	5/25/2016 12:08	2.17	0.19	5/25/2016 10:15	5/25/2016 15:15	5.00	3079.5	0.0	3079.5	100.0%
5/26/2016 2:48	5/26/2016 4:58	2.17	0.18	5/26/2016 3:30	5/26/2016 9:30	6.00	3621.3	0.0	3621.3	100.0%
5/27/2016 10:41	5/27/2016 18:03	7.37	0.21	5/27/2016 11:00	5/27/2016 21:30	10.50	2432.9	0.0	2432.9	100.0%
5/28/2016 15:32	5/28/2016 16:01	0.48	0.11	5/28/2016 15:42	5/28/2016 21:15	5.55	2702.3	0.0	2702.3	100.0%
5/29/2016 19:18	5/29/2016 19:25	0.12	0.06	5/29/2016 19:28	5/29/2016 22:00	2.53	761.2	0.0	761.2	100.0%
5/31/2016 8:07	5/31/2016 9:11	1.07	0.06	5/31/2016 8:20	5/31/2016 11:30	3.17	409.6	0.0	409.6	100.0%
6/3/2016 12:00	6/3/2016 16:23	4.38	0.13	6/3/2016 13:15	6/3/2016 19:15	6.00	1465.5	0.0	1465.5	100.0%
6/4/2016 17:51	6/4/2016 18:01	0.17	0.03	6/4/2016 18:07	6/4/2016 22:15	4.13	457.0	0.0	457.0	100.0%
6/6/2016 6:08	6/6/2016 6:35	0.45	0.07	6/6/2016 6:30	6/6/2016 9:45	3.25	711.3	0.0	711.3	100.0%
6/6/2016 14:30	6/6/2016 14:34	0.07	0.07	6/6/2016 14:39	6/6/2016 19:45	5.10	1052.4	0.0	1052.4	100.0%
6/9/2016 0:26	6/9/2016 7:41	7.25	0.72	6/9/2016 3:30	6/9/2016 10:30	7.00	17188.0	7.4	17180.5	100.0%
6/12/2016 3:07	6/12/2016 5:17	2.17	0.52	6/12/2016 3:30	6/12/2016 9:30	6.00	14448.8	4578.5	9870.3	68.3%
6/12/2016 23:54	6/13/2016 7:24	7.50	0.82	6/13/2016 0:30	6/13/2016 11:30	11.00	47291.5	22172.1	25119.3	53.1%
6/14/2016 12:32	6/14/2016 20:34	8.03	1.41	6/14/2016 13:00	6/15/2016 1:00	12.00	67004.1	56230.8	10773.3	16.1%
6/30/2016 6:38	6/30/2016 12:07	5.48	0.04	6/30/2016 12:30	6/30/2016 14:15	1.75	47.4	0.0	47.4	100.0%
7/5/2016 18:09	7/7/2016 5:11	35.03	1.92	7/5/2016 18:13	7/5/2016 22:45	4.53	61584.4	41469.2	20115.2	32.7%
7/10/2016 5:31	7/10/2016 8:03	2.53	0.23	7/10/2016 5:45	7/10/2016 10:00	4.25	5357.6	4786.7	570.9	10.7%
7/11/2016 23:54	7/12/2016 1:54	2.00	0.20	7/12/2016 0:00	7/12/2016 5:45	5.75	5823.4	4044.9	1778.5	30.5%
7/14/2016 20:39	7/15/2016 0:33	3.90	0.31	7/14/2016 21:15	7/15/2016 3:15	6.00	9293.9	7638.7	1655.2	17.8%
7/16/2016 22:21	7/17/2016 3:39	5.30	0.19	7/16/2016 23:00	7/17/2016 7:15	8.25	3672.1	0.0	3672.1	100.0%
7/20/2016 8:31	7/20/2016 8:33	0.03	0.02	7/20/2016 8:45	7/20/2016 11:00	2.25	363.2	0.0	363.2	100.0%
7/21/2016 4:40	7/21/2016 4:56	0.27	0.16	7/21/2016 4:15	7/21/2016 8:15	4.00	6111.9	0.0	6111.9	100.0%
7/23/2016 11:05	7/23/2016 17:09	6.07	1.69	7/23/2016 11:11	7/23/2016 20:15	9.07	80654.7	59734.3	20920.3	25.9%
7/27/2016 14:03	7/27/2016 16:24	2.35	0.96	7/27/2016 14:13	7/27/2016 18:45	4.53	44486.8	43235.6	1251.3	2.8%
8/4/2016 7:22	8/4/2016 9:38	2.27	1.79	8/4/2016 7:29	8/4/2016 11:15	3.77	89558.7	72378.4	17180.3	19.2%
8/10/2016 20:26	8/11/2016 6:23	9.95	3.08	8/10/2016 20:34	8/11/2016 14:00	17.43	169215.1	151732.7	17482.4	10.3%
8/12/2016 17:07	8/12/2016 19:27	2.33	0.20	8/12/2016 17:45	8/12/2016 21:15	3.50	4323.3	3039.4	1283.8	29.7%
8/16/2016 17:22	8/16/2016 19:47	2.42	0.30	8/16/2016 17:49	8/17/2016 1:00	7.18	7321.5	7208.5	113.1	1.5%
8/19/2016 2:58	8/19/2016 5:22	2.40	0.45	8/19/2016 3:07	8/19/2016 7:00	3.88	20694.5	17647.2	3047.3	14.7%
8/19/2016 18:32	8/19/2016 22:42	4.17	0.22	8/19/2016 19:40	8/19/2016 22:30	2.83	4229.2	2417.3	1811.9	42.8%
8/20/2016 8:44	8/20/2016 14:45	6.02	0.35	8/20/2016 8:57	8/20/2016 16:45	7.80	14692.6	4458.5	10234.0	69.7%
8/23/2016 20:12	8/24/2016 2:21	6.15	1.53	8/23/2016 21:30	8/24/2016 6:30	9.00	87410.4	83330.6	4079.8	4.7%
8/29/2016 23:56	8/30/2016 3:07	3.18	0.44	8/29/2016 23:52	8/30/2016 6:15	6.38	23867.0	17554.7	6312.3	26.4%
9/5/2016 1:14	9/5/2016 5:59	4.75	0.55	9/5/2016 4:07	9/5/2016 9:15	5.13	19232.4	19034.3	198.1	1.0%
9/6/2016 2:31	9/6/2016 11:01	8.50	1.11	9/6/2016 3:10	9/6/2016 13:30	10.33	58482.2	54405.0	4077.2	7.0%
9/6/2016 20:22	9/6/2016 21:55	1.55	0.05	9/6/2016 21:45	9/6/2016 23:30	1.75	514.1	476.7	37.4	7.3%
9/9/2016 2:58	9/9/2016 7:07	4.15	0.20	9/9/2016 3:30	9/9/2016 12:30	9.00	4020.4	0.0	4020.4	100.0%
9/15/2016 16:10	9/15/2016 20:28	4.30	0.79	9/15/2016 16:30	9/15/2016 23:45	7.25	57220.6	37889.9	19330.7	33.8%
9/16/2016 20:13	9/16/2016 20:35	0.37	0.06	9/16/2016 20:38	9/16/2016 23:45	3.12	3284.1	1761.3	1522.9	46.4%
9/19/2016 10:30	9/19/2016 10:38	0.13	0.02	9/19/2016 11:00	9/19/2016 14:45	3.75	404.8	0.0	404.8	100.0%
9/21/2016 20:30	9/22/2016 5:38	9.13	1.35	9/21/2016 20:00	9/22/2016 8:00	12.00	50753.7	37474.4	13279.3	26.2%
9/23/2016 15:22	9/23/2016 19:37	4.25	0.34	9/23/2016 16:15	9/23/2016 21:15	5.00	14961.3	8918.4	6043.0	40.4%
9/25/2016 6:14	9/25/2016 8:07	1.88	0.17	9/25/2016 7:00	9/25/2016 10:45	3.75	7261.7	6803.4	458.3	6.3%
9/25/2016 8:31	9/25/2016 17:28	8.95	0.06	9/25/2016 16:45	9/25/2016 18:00	1.25	118.5	117.8	0.7	0.6%
9/27/2016 17:04	9/27/2016 18:08	1.07	0.06	9/27/2016 17:30	9/28/2016 3:00	9.50	215.1	198.8	16.3	7.6%
10/4/2016 21:54	10/5/2016 5:46	7.87	0.60	10/5/2016 2:41	10/5/2016 9:15	6.57	25229.5	14693.4	10536.0	41.8%
10/6/2016 19:02	10/7/2016 3:16	8.23	0.93	10/6/2016 19:22	10/7/2016 6:30	11.13	66668.1	32988.5	33679.6	50.5%
10/17/2016 15:06	10/18/2016 1:18	10.20	0.52	10/17/2016 16:00	10/18/2016 9:15	17.25	8201.6	0.0	8201.6	100.0%
10/25/2016 17:18	10/26/2016 8:14	14.93	0.76	10/25/2016 20:15	10/26/2016 17:30	21.25	29423.0	3178.7	26244.3	89.2%
10/29/2016 14:14	10/29/2016 17:03	2.82	0.10	10/29/2016 14:45	10/29/2016 22:30	7.75	3082.9	0.0	3082.9	100.0%
11/18/2016 8:37	11/18/2016 14:27	5.83	0.92	11/18/2016 10:09	11/18/2016 21:30	11.35	26675.3	0.0	26675.3	100.0%
Subtotals:			**30.8**				**1318123**	**844508**	**473615**	**36%**

Flow to the BMP is monitored at a flow diversion structure along Flandrau St.

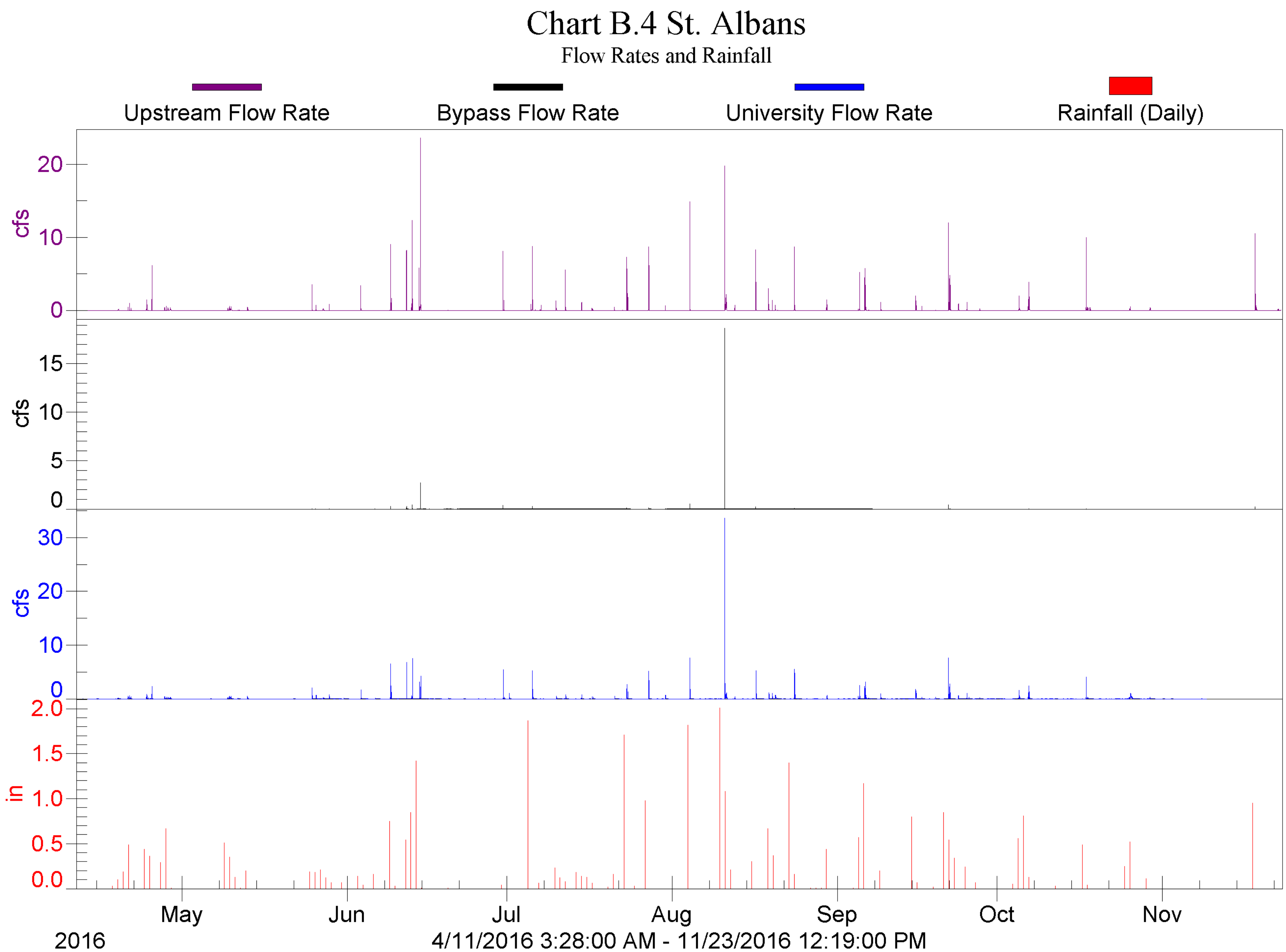


Chart B.4 St. Albans
Flow Rates and Rainfall
Upstream Flow Rate
Bypass Flow Rate
University Flow Rate
Rainfall (Daily)
cfs
20
10
0
cfs
15
10
5
0
cfs
30
20
10
0
in
2.0
1.5
1.0
0.5
0.0
May
Jun
Jul
Aug
Sep
Oct
Nov
2016
4/11/2016 3:28:00 AM - 11/23/2016 12:19:00 PM

City of Saint Paul
2016 Water Quality and Quantity Report
Chart B.5
WSB Project Number 01610-100

SAINT ALBANS INFILTRATION SYSTEM FLOW EVENT SUMMARY

Rain				Flow								
Start	End	Duration	Amount	Start	End	Duration	Aurora Avenue Runoff Volume (Upstream of Diversion) (1)	University Avenue Runoff Volume (2)	Aurora Avenue Bypass Volume (Downstream of Diversion) (3)	Total BMP Drainage Area Runoff (1+2)	Total Inflow to BMP (1 + 2 - 3)	Percent Captured
		(hr)	(in)			(hr)	(cf)	(cf)	(cf)	(cf)	(cf)	(%)
5/9/2016 12:57	5/10/2016 10:00	21.05	0.80	5/9/2016 11:45	5/10/2016 12:45	25.00	6138.7	7622.8	0.0	13761.49	13761.5	100.0%
5/11/2016 12:50	5/11/2016 20:31	7.68	0.14	5/11/2016 12:00	5/11/2016 20:30	8.50	479.8	1119.0	0.0	1598.84	1598.8	100.0%
5/13/2016 7:25	5/13/2016 10:23	2.97	0.21	5/13/2016 6:41	5/13/2016 11:00	4.32	1386.7	1634.8	0.0	3021.47	3021.5	100.0%
		0.00	0.00	5/21/2016 21:15	5/22/2016 6:45	9.50	0.0	112.1	0.0	112.13	112.1	100.0%
5/25/2016 9:41	5/25/2016 12:25	2.73	0.54	5/25/2016 8:51	5/25/2016 15:30	6.65	6866.6	5701.5	0.0	12568.33	12568.1	100.0%
5/26/2016 2:29	5/26/2016 4:42	2.22	0.25	5/26/2016 1:45	5/26/2016 7:30	5.75	2223.0	2677.8	0.0	4900.82	4900.8	100.0%
5/27/2016 10:24	5/27/2016 17:26	7.03	0.21	5/27/2016 9:45	5/27/2016 21:00	11.25	1704.3	2028.5	0.0	3732.79	3732.8	100.0%
5/28/2016 15:20	5/28/2016 16:02	0.70	0.15	5/28/2016 14:30	5/28/2016 20:15	5.75	1108.7	1767.5	0.0	2876.23	2876.2	100.0%
5/31/2016 8:23	5/31/2016 8:49	0.43	0.03	5/31/2016 7:45	5/31/2016 12:30	4.75	22.6	244.0	0.0	266.63	266.6	100.0%
6/3/2016 11:34	6/3/2016 16:12	4.63	0.21	6/3/2016 11:45	6/3/2016 19:45	8.00	2506.6	2400.6	0.0	4907.21	4907.2	100.0%
6/4/2016 2:46	6/4/2016 3:04	0.30	0.02	6/4/2016 3:00	6/4/2016 7:30	4.50	12.8	124.3	0.0	137.10	137.1	100.0%
6/6/2016 6:07	6/6/2016 6:14	0.12	0.02	6/6/2016 6:15	6/6/2016 14:15	8.00	0.4	266.8	0.0	267.25	267.3	100.0%
6/6/2016 17:15	6/6/2016 17:30	0.25	0.01	6/6/2016 17:00	6/7/2016 1:30	8.50	0.2	78.5	0.0	78.67	78.7	100.0%
6/9/2016 0:11	6/9/2016 0:22	0.18	0.03	6/9/2016 0:15	6/9/2016 1:00	0.75	10.0	302.9	0.0	312.91	312.9	100.0%
6/9/2016 3:07	6/9/2016 7:28	4.35	0.93	6/9/2016 2:15	6/9/2016 10:45	8.50	14826.5	10044.5	0.0	25127.68	24870.9	99.0%
6/12/2016 3:22	6/12/2016 3:59	0.62	0.73	6/12/2016 2:15	6/12/2016 8:30	6.25	10620.5	7004.5	0.0	17879.10	17625.0	98.6%
6/13/2016 0:24	6/13/2016 2:27	2.05	0.18	6/12/2016 23:45	6/13/2016 3:45	4.00	1706.2	1642.1	0.0	3348.28	3348.3	100.0%
6/13/2016 5:02	6/13/2016 7:23	2.35	0.64	6/13/2016 4:21	6/13/2016 9:45	5.40	10974.7	7160.3	0.0	18542.47	18135.0	97.8%
6/14/2016 12:16	6/14/2016 13:24	1.13	0.32	6/14/2016 11:30	6/14/2016 14:15	2.75	4560.0	2857.3	0.0	7421.97	7417.3	99.9%
6/14/2016 16:15	6/15/2016 2:00	9.75	1.24	6/14/2016 16:36	6/15/2016 0:15	7.65	48138.9	13825.1	2866.4	64870.76	61964.0	95.5%
		0.00	0.00	6/17/2016 11:30	6/17/2016 13:15	1.75	0.0	67.0	0.0	66.99	67.0	100.0%
6/19/2016 23:20	6/20/2016 0:35	1.25	0.03	6/19/2016 22:00	6/20/2016 3:15	5.25	84.6	242.8	0.0	327.91	327.4	99.9%
6/22/2016 20:00	6/22/2016 20:15	0.25	0.01	6/22/2016 20:00	6/23/2016 2:15	6.25	0.0	157.8	0.0	158.85	157.8	99.3%
		0.00	0.00	6/26/2016 21:30	6/26/2016 23:00	1.50	0.0	22.7	0.0	23.16	22.7	98.1%
		0.00	0.00	6/28/2016 15:00	6/28/2016 18:00	3.00	0.0	177.9	0.0	178.67	177.9	99.6%
6/30/2016 6:19	6/30/2016 6:51	0.53	0.48	6/30/2016 5:15	6/30/2016 7:30	2.25	5869.8	3387.7	0.0	9619.46	9257.5	96.2%
6/30/2016 10:48	6/30/2016 12:11	1.38	0.07	6/30/2016 9:45	6/30/2016 14:45	5.00	848.9	693.2	0.0	1543.57	1542.1	99.9%
				7/1/2016 10:45	7/1/2016 13:45	3.00	0.0	803.2	0.0	803.72	803.2	99.9%
7/5/2016 17:59	7/5/2016 21:11	3.20	1.24	7/5/2016 12:00	7/5/2016 22:15	10.25	18506.8	14113.7	0.0	32996.72	32620.5	98.9%
				7/6/2016 7:00	7/6/2016 7:45	0.75	30.6	3.7	0.0	34.59	34.3	99.1%
7/7/2016 4:18	7/7/2016 5:10	0.87	0.05	7/7/2016 4:00	7/7/2016 7:00	3.00	251.7	207.4	0.0	460.01	459.1	99.8%
7/7/2016 19:00	7/7/2016 19:15	0.25	0.01	7/7/2016 10:15	7/7/2016 11:30	1.25	199.9	0.0	0.0	200.32	199.9	99.8%
7/10/2016 5:27	7/10/2016 8:02	2.58	0.25	7/10/2016 4:30	7/10/2016 10:15	5.75	1710.3	1775.0	0.0	3487.49	3485.2	99.9%
7/11/2016 23:47	7/12/2016 1:45	1.97	0.24	7/11/2016 22:51	7/12/2016 4:45	5.90	2965.2	1806.4	0.0	4777.42	4771.7	99.9%
				7/13/2016 20:30	7/13/2016 23:15	2.75	0.0	56.1	0.0	57.08	56.1	98.3%
7/14/2016 20:53	7/15/2016 4:16	7.38	0.19	7/14/2016 20:30	7/15/2016 4:00	7.50	1073.1	1436.8	0.0	2512.83	2509.9	99.9%
7/16/2016 22:12	7/16/2016 23:53	1.68	0.16	7/16/2016 10:00	7/17/2016 0:30	14.50	1037.9	1272.6	0.0	2315.27	2310.4	99.8%
7/17/2016 2:50	7/17/2016 3:42	0.87	0.06	7/17/2016 2:00	7/17/2016 5:15	3.25	428.9	739.3	0.0	1169.02	1168.2	99.9%
7/21/2016 4:27	7/21/2016 5:16	0.82	0.09	7/21/2016 3:36	7/21/2016 7:30	3.90	762.9	776.5	0.0	1540.87	1539.4	99.9%
				7/22/2016 13:00	7/22/2016 16:45	3.75	152.3	0.0	0.0	153.27	152.3	99.4%
7/23/2016 10:54	7/23/2016 13:10	2.27	0.97	7/23/2016 10:00	7/23/2016 14:15	4.25	16869.5	8588.2	0.0	25583.76	25457.7	99.5%
7/23/2016 15:44	7/23/2016 16:56	1.20	0.23	7/23/2016 15:00	7/23/2016 18:00	3.00	3085.4	2312.2	0.0	5402.59	5397.6	99.9%
7/27/2016 12:53	7/27/2016 15:58	3.08	0.82	7/27/2016 12:30	7/27/2016 19:00	6.50	14659.9	8928.2	0.0	23745.87	23588.1	99.3%
7/30/2016 17:52	7/30/2016 17:58	0.10	0.08	7/30/2016 16:58	7/30/2016 20:00	3.03	309.8	934.6	0.0	1244.56	1244.4	100.0%
8/4/2016 7:17	8/4/2016 10:33	3.27	1.34	8/4/2016 6:30	8/4/2016 12:30	6.00	23648.1	13811.7	0.0	38430.58	37459.8	97.5%
8/10/2016 20:24	8/11/2016 7:26	11.03	3.34	8/10/2016 19:28	8/11/2016 8:00	12.53	48259.1	35617.3	16806.9	102380.32	83876.5	81.9%
8/12/2016 16:55	8/12/2016 19:25	2.50	0.23	8/12/2016 16:15	8/12/2016 21:00	4.75	1803.8	1402.7	0.0	3208.14	3206.5	99.9%
8/16/2016 16:57	8/16/2016 19:10	2.22	0.92	8/16/2016 16:00	8/16/2016 20:15	4.25	14398.2	10738.9	0.0	25345.11	25137.0	99.2%
8/19/2016 2:45	8/19/2016 5:28	2.72	0.44	8/19/2016 1:45	8/19/2016 7:00	5.25	5097.5	5711.7	0.0	10815.69	10809.1	99.9%
8/19/2016 18:24	8/19/2016 23:24	5.00	0.19	8/19/2016 18:00	8/19/2016 23:24	5.40	1659.0	1869.3	0.0	3529.86	3528.4	100.0%
8/20/2016 8:37	8/20/2016 11:21	2.73	0.23	8/20/2016 7:45	8/20/2016 13:00	5.25	1842.0	2742.9	0.0	4587.02	4584.9	100.0%
8/20/2016 13:29	8/20/2016 19:26	5.95	0.03	8/20/2016 18:45	8/20/2016 20:45	2.00	50.7	180.4	0.0	231.67	231.1	99.8%
				8/21/2016 21:45	8/22/2016 3:45	6.00	0.0	62.5	0.0	64.47	62.5	97.0%
8/23/2016 20:53	8/24/2016 3:19	6.43	1.12	8/23/2016 20:15	8/24/2016 3:30	7.25	19955.0	13195.9	0.0	33297.03	33151.0	99.6%
8/29/2016 23:21	8/30/2016 3:07	3.77	0.48	8/29/2016 22:45	8/30/2016 5:00	6.25	5121.3	3528.0	0.0	8652.38	8649.3	100.0%
9/4/2016 22:08	9/5/2016 6:06	7.97	0.54	9/4/2016 22:00	9/5/2016 9:00	11.00	7116.2	6640.7	0.0	13764.06	13757.0	99.9%
9/6/2016 2:48	9/6/2016 10:26	7.63	0.84	9/6/2016 1:45	9/6/2016 12:30	10.75	12652.7	10645.3	0.0	23303.61	23298.0	100.0%
9/6/2016 6:15	9/6/2016 21:38	15.38	0.55	9/6/2016 19:30	9/6/2016 23:15	3.75	154.3	525.0	0.0	680.56	679.3	99.8%
9/7/2016 0:10	9/7/2016 10:23	10.22	0.03	9/7/2016 8:30	9/7/2016 13:15	4.75	2.5	159.9	0.0	163.80	162.3	99.1%
9/9/2016 0:45	9/9/2016 7:07	6.37	0.21	9/9/2016 1:00	9/9/2016 9:30	8.50	1925.2	2521.5	0.0	4446.74	4446.7	100.0%
9/15/2016 16:10	9/15/2016 20:28	4.30	0.79	9/15/2016 16:15	9/15/2016 22:15	6.00	8236.8	10510.0	0.0	18746.81	18746.8	100.0%
9/16/2016 20:13	9/16/2016 20:35	0.37	0.06	9/16/2016 20:15	9/16/2016 22:30	2.25	317.6	395.6	0.0	713.27	713.3	100.0%
9/19/2016 10:30	9/19/2016 10:38	0.13	0.02	9/19/2016 10:30	9/19/2016 15:45	5.25	93.3	475.4	0.0	568.71	568.7	100.0%
9/21/2016 0:16	9/21/2016 0:30	0.23	0.01	9/21/2016 0:16	9/21/2016 3:30	3.23	0.0	115.1	0.0	115.14	115.1	100.0%
9/21/2016 20:30	9/22/2016 5:38	9.13	1.35	9/21/2016 20:30	9/22/2016 6:45	10.25	23754.5	20894.9	0.0	45186.67	44649.4	98.8%
9/23/2016 15:22	9/23/2016 19:37	4.25	0.34	9/23/2016 15:30	9/23/2016 20:45	5.25	4013.6	3110.0	0.0	7123.51	7123.5	100.0%
9/25/2016 6:14	9/25/2016 8:37	2.38	0.19	9/25/2016 5:45	9/25/2016 11:45	6.00	1869.1	2248.3	0.0	4117.45	4117.4	100.0%
9/25/2016 16:04	9/25/2016 17:28	1.40	0.04	9/25/2016 16:15	9/25/2016 19:15	3.00	24.0	353.5	0.0	377.52	377.5	100.0%
9/27/2016 17:04	9/27/2016 18:47	1.72	0.07	9/27/2016 14:00	9/27/2016 21:45	7.75	731.3	658.0	0.0	1389.35	1389.3	100.0%
10/4/2016 8:45	10/4/2016 9:00	0.25	0.01	10/4/2016 11:15	10/4/2016 18:00	6.75	0.0	235.7	0.0	235.65	235.7	100.0%
10/4/2016 21:54	10/5/2016 5:46	7.87	0.60	10/4/2016 20:15	10/5/2016 9:45	13.50	5864.4	7514.2	0.0	13378.57	13378.6	100.0%
10/6/2016 19:02	10/7/2016 3:16	8.23	0.93	10/6/2016 19:12	10/7/2016 5:30	10.30	16339.8	12524.3	0.0	28864.21	28864.1	100.0%
10/12/2016 1:29	10/12/2016 7:00	5.52	0.03	10/12/2016 1:30	10/12/2016 8:45	7.25	1.5	114.8	0.0	116.33	116.3	100.0%
10/17/2016 15:06	10/17/2016 17:40	2.57	0.40	10/17/2016 15:15	10/17/2016 20:00	4.75	10271.5	4626.3	0.0	14905.63	14897.8	99.9%
10/17/2016 22:06	10/18/2016 1:18	3.20	0.12	10/17/2016 22:15	10/18/2016 3:00	4.75	2717.4	1441.5	0.0	4158.85	4158.8	100.0%
				10/18/2016 9:20	10/18/2016 11:15	1.92	2116.0	10.2	0.0	2126.20	2126.2	100.0%
10/25/2016 17:18	10/26/2016 8:14	14.93	0.76	10/25/2016 17:15	10/26/2016 13:24	20.15	3013.8	16684.5	0.0	19698.22	19698.2	100.0%
10/29/2016 14:14	10/29/2016 18:18	4.07	0.11	10/29/2016 14:30	10/30/2016 7:45	17.25	2007.1	1211.0	0.0	3218.11	3218.1	100.0%
11/18/2016 8:37	11/18/2016 16:58	8.35	0.94	11/18/2016 8:52	11/19/2016 0:15	15.38	19948.8	0.0	0.0	20154.95	19948.8	99.0%
11/22/2016 15:00	11/23/2016 2:00	11.00	0.45	11/22/2016 15:00	11/23/2016 10:00	19.00	2415.5	0.0	0.0	2415.46	2415.5	100.0%
Subtotals			**29.4**				**429556**	**309595**	**19673**	**764648**	**739151**	**97%**

Flow to the BMP is monitored at a flow diversion structure located at the intersection of Aurora Ave. and St. Albans st., and another inlet near University Ave. 83876.5

Flow, No Rain

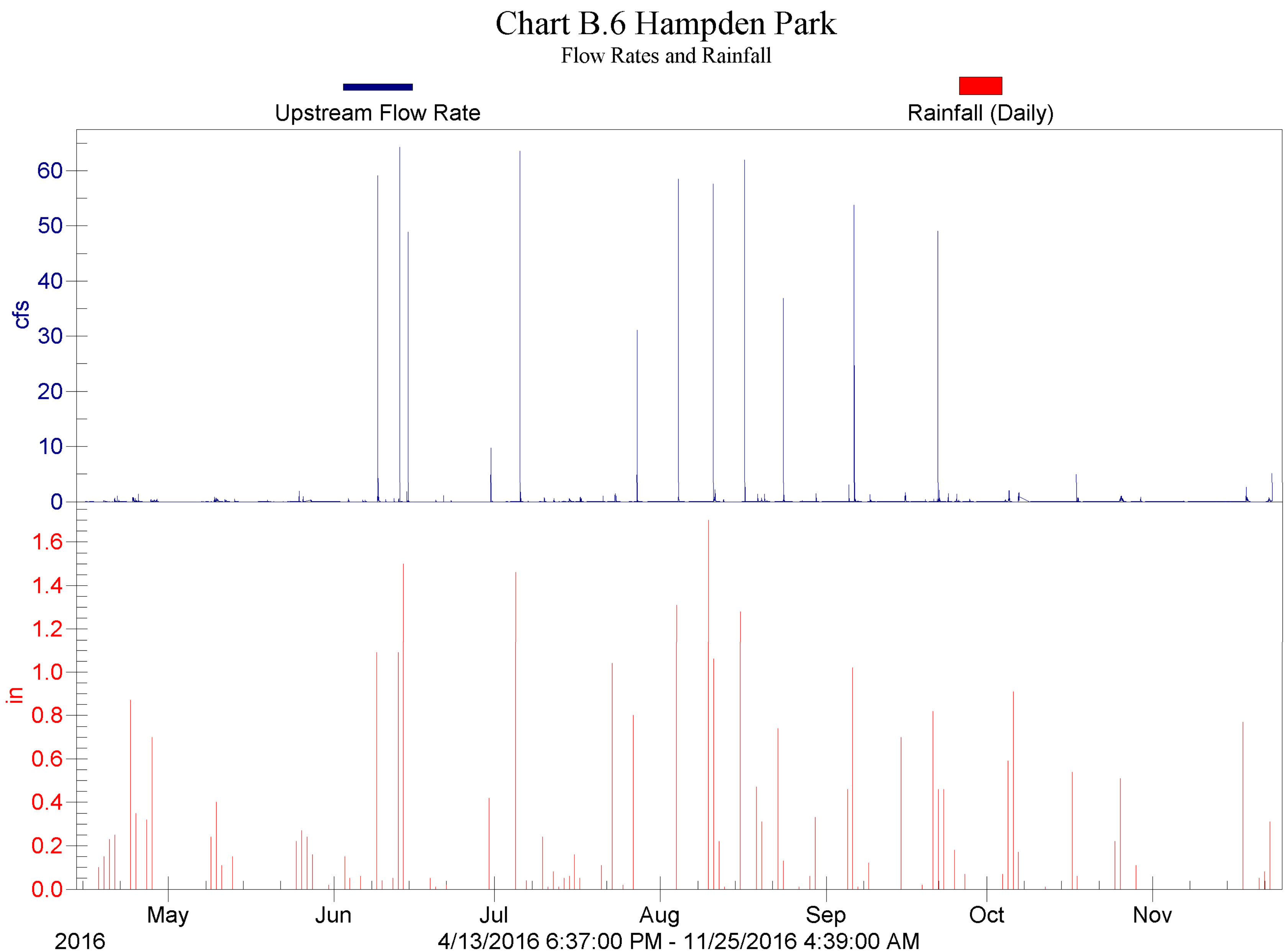


Chart B.6 Hampden Park
Flow Rates and Rainfall
Upstream Flow Rate
Rainfall (Daily)
cfs
0
10
20
30
40
50
60
in
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
May
Jun
Jul
Aug
Sep
Oct
Nov
2016
4/13/2016 6:37:00 PM - 11/25/2016 4:39:00 AM

Chart B.7 TBNS - Maryland Pond

Flow Rates and Rainfall

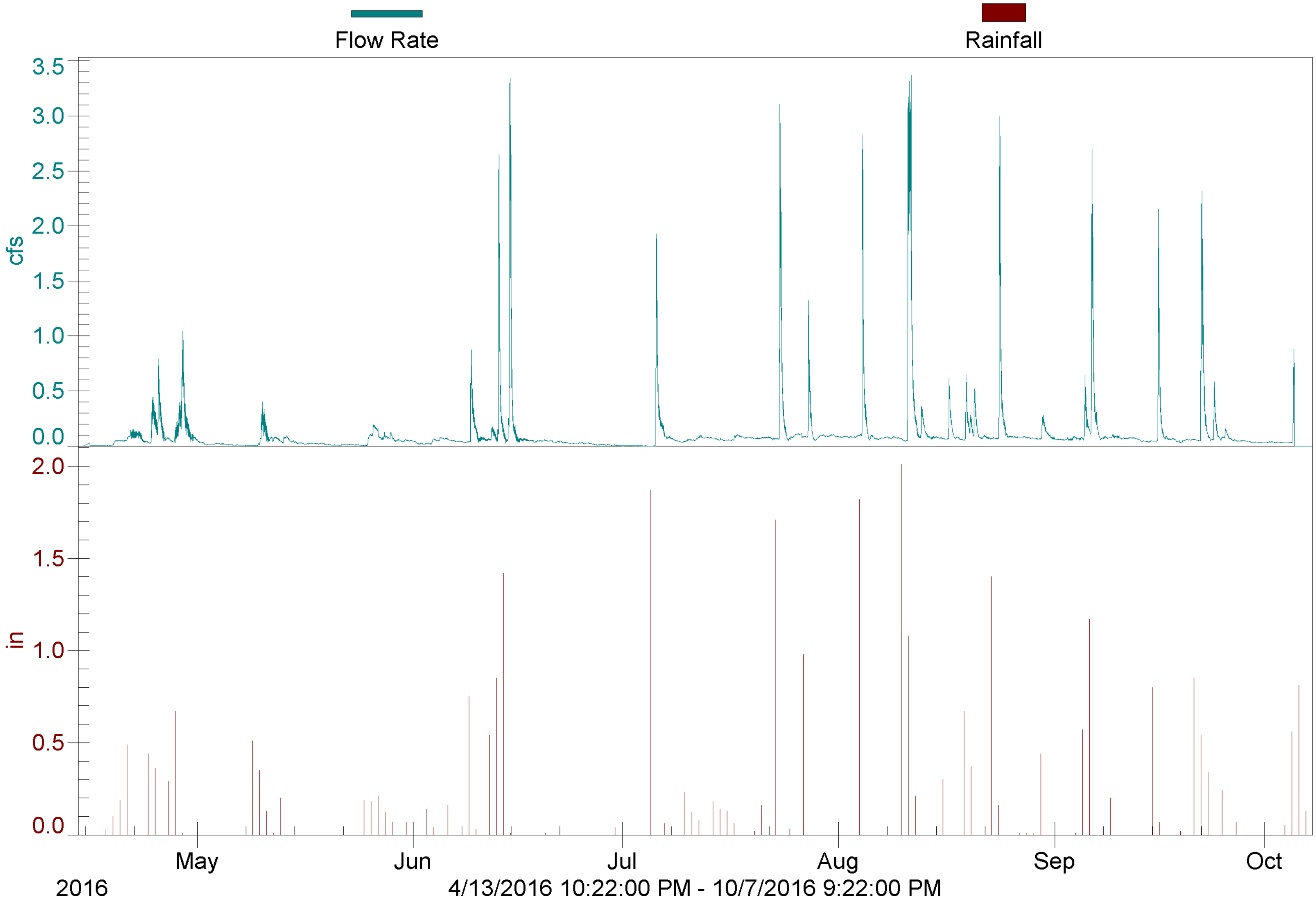


Chart B.8 TBNS - Magnolia Pond

Flow Rates and Rainfall

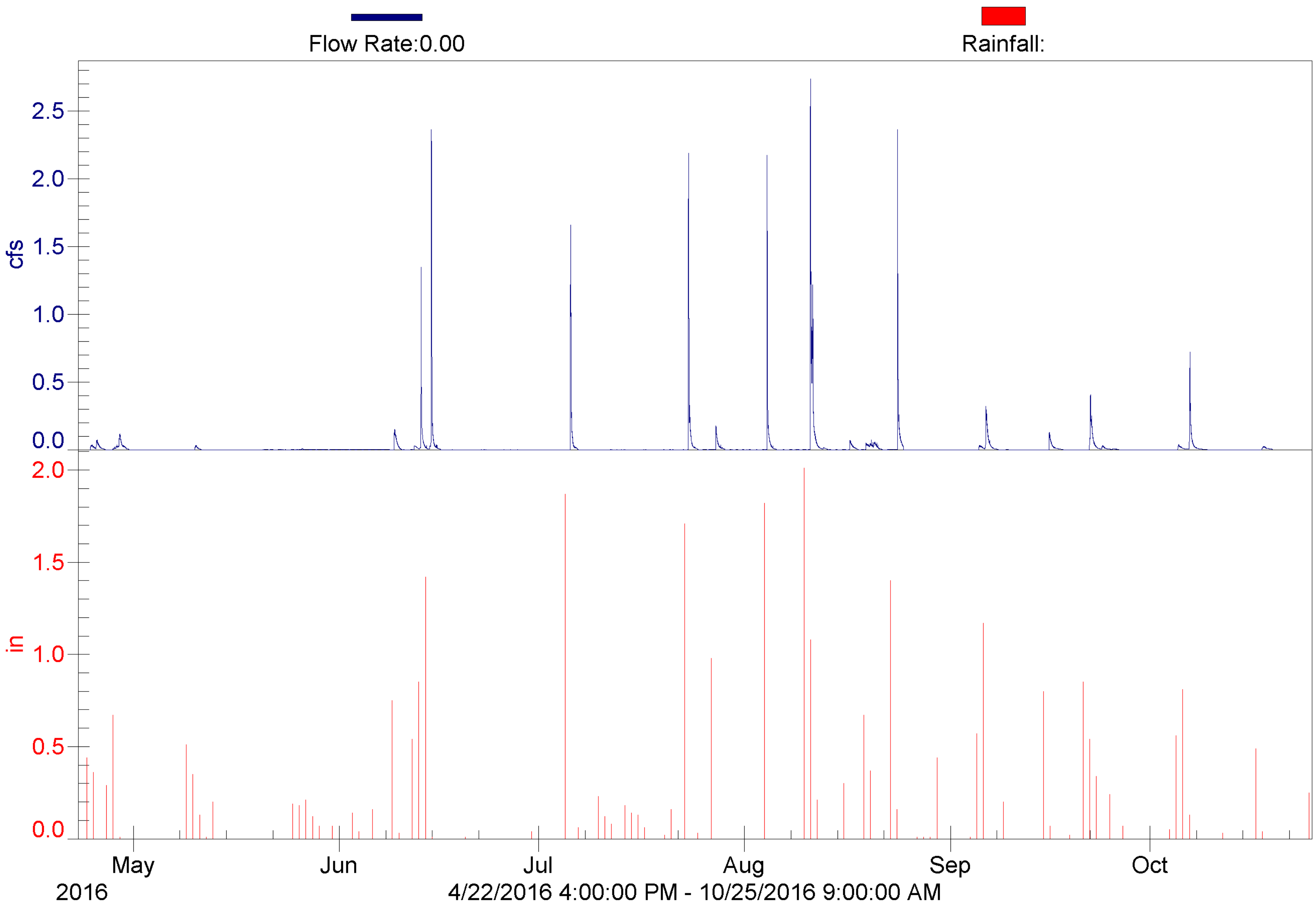
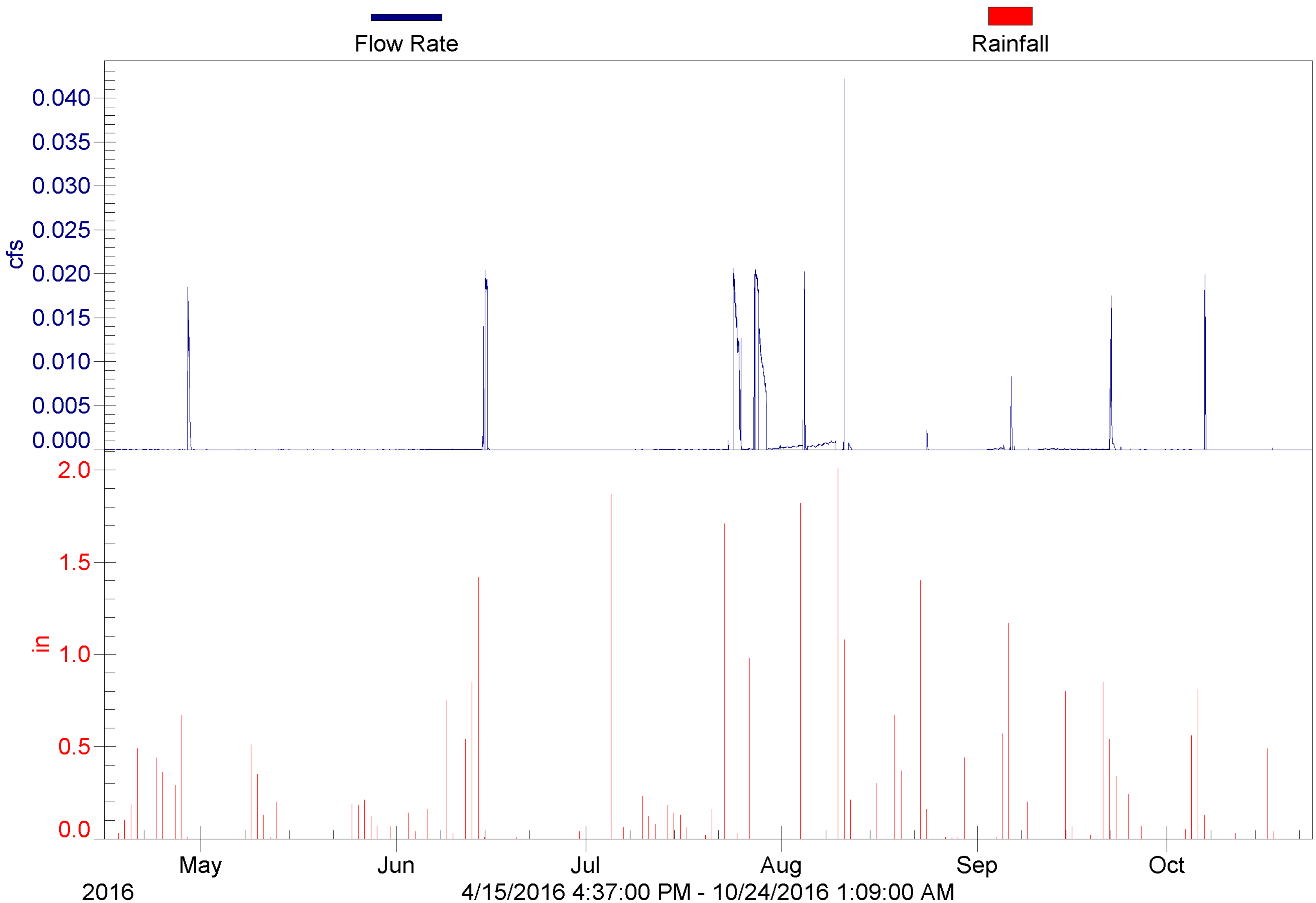


Chart B.9 TBNS - Jenks Pond

Flow Rates and Rainfall



Appendix C – Water Quality Summary and Pollutant Load Calculations

City of Saint Paul
2016 Water Quality and Quantity Report
Table C.1
WSB Project Number: 01610-100

BEACON BLUFF WATER QUALITY SUMMARY

LAB ID	Date Composite Sampling Started	Date Composite Sampling Ended	TSS (mg/L)	TDS (mg/L)	VSS (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Chloride (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite as N (mg/L)	Hardness as CaCO3 (mg/L)	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Sulfate (mg/L)	pH	CBOD (mg/L)	E. Coli (MPN/ 100 mL)
10340660001		3/7/2016 10:00	8.00 J		5.60	0.27		204		1.90	0.44								157
2484151		5/25/2016 11:00																	2420 >
2484472	5/25/2016 11:34	5/26/2016 7:37				0.76	0.206	9.2		3.90	0.27	24	24.8	33.2	146.0				
2485698	5/27/2016 16:18	5/27/2016 16:48				0.25		9.6		1.40	0.08 <								
2485699	5/31/2016 9:03	5/31/2016 11:34				1.27		35.5		5.70	0.08 <								
2486907	6/3/2016 14:33	6/3/2016 18:37				1.60		13.4		9.50	0.08 <								
2486908	6/4/2016 17:48	6/4/2016 20:24				0.79		7.3		4.70	0.08 <								
2489877		6/13/2016 9:30	2.0 J	53.0	2.0 J	0.09	0.053	3.1	0.21	0.80	0.95	20	4.5	1.3	10.8	2.9	6.50	1.8	
2490617	6/14/2016 13:31	6/14/2016 22:02	50.0	31.0	21.0	0.16	0.041	2.6	0.03 J	0.85	0.29	10 <	6.6	11.8	31.1	1.7	6.40	14.0	
2495079	6/30/2016 6:48	6/30/2016 13:31				1.26	0.162	30.6		7.50	0.08 <								
2496457	7/5/2016 18:18	7/5/2016 20:40	60.0	44.0	25.0	0.35	0.137	3.2	0.02 <	1.50	0.28	20	11.0	13.3	50.7	1.7	6.00	9.6	
2497789	7/10/2016 6:06	7/10/2016 7:40	50.0		28.0	0.32		7.3		2.20	0.18								
2497790	7/12/2016 0:03	7/12/2016 2:21	182.00		64.00														
2502639	7/23/2016 11:18	7/23/2016 17:37	30.0		12.0	0.18	0.077	3.0		0.93	0.11								
2503640	7/27/2016 14:18	7/27/2016 16:27	54.0		21.0	0.15	0.580	2.0 <		0.95	0.34								
2505403		8/4/2016 10:20	5.0	50.0	3.0	0.16	0.126	2.0 <	0.20	0.82	0.41	44	6.6	2.4	15.9	1.8	7.50	5.5	2420 >
2507246		8/4/2016 11:00	2.0 J		2.0 J	0.20	0.170	3.4		0.66	0.25								
25172001		9/15/2016 16:30	414.0		210.0	1.11	0.429	13.8		6.90	1.25	60	42.5	52.4	223.0				
5219042	9/21/2016 21:02	9/22/2016 4:34	96.0	28.0	30.0	0.27	0.024	2.0 <	0.02 <	1.60	0.37	24	8.2	26.6	70.9	2.6	6.40		
2519044		9/22/2016 9:00																	2420 >
2523709	10/5/2016 1:47	10/6/2016 3:51	142.0		68.0	0.55		5.2		2.20	0.08 <								
2524571	10/6/2016 20:47	10/7/2016 0:37	37.0	25.0	12.0	0.27		2.8	0.06	1.20	0.09	12							
2526886	10/17/2016 17:33	10/17/2016 18:11				1.25		6.0		5.20	0.08 <								
2529575	10/26/2017 0:02	10/26/2016 15:56	72.0			0.84	0.491	5.3		1.70	0.08 <								
2539649		11/28/2016 11:30	103.0	18.0	10.0 J	0.29	0.156	13.3	0.04 J	0.89	0.10	36					7.50	12.0	1300
MINIMUM			**2.0**	**18.0**	**2.0**	**0.09**	**0.024**	**2.0**	**0.02**	**0.66**	**0.08**	**10**	**4.5**	**1.3**	**10.8**	**1.7**	**6.00**	**1.8**	**1300**
AVERAGE			**86.6**	**35.6**	**36.3**	**0.58**	**0.204**	**8.6**	**0.08**	**2.91**	**0.26**	**28**	**14.9**	**20.1**	**78.3**	**2.1**	**6.72**	**8.6**	**2140**
MEDIAN			**54.0**	**31.0**	**21.0**	**0.32**	**0.156**	**5.3**	**0.04**	**1.60**	**0.11**	**24**	**8.2**	**13.3**	**50.7**	**1.8**	**6.5**	**9.6**	**2420**
MAXIMUM			**414.0**	**53.0**	**210.0**	**1.60**	**0.580**	**35.5**	**0.21**	**9.50**	**1.25**	**60**	**42.5**	**52.4**	**223.0**	**2.9**	**7.50**	**14.0**	**2420** >

Laboratory analysis was completed by Metroplian Council Environmental Services (The sample collected on 3/7/2016 was analyzed by Pace Analytical

Grab Sample

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

J - Result reported as estimated between the MDL and Reporting Limit (RL)

City of Saint Paul
2014 Beacon Bluff Pollutant Loading
Table C.2
WSB Job No.: 01610-100

BEACON BLUFF VOLUME AND POLLUTANT REDUCTION SUMMARY

Event Time Interval		Sampling Data								Event Loading and Volume Data[1]	Diversion Structure on Duchess Street																
		TSS	TDS	VSS	TP	Ortho-P	Chloride	Total Kjeldahl Nitrogen	Nitrate + Nitrite as N	Interval Rain	Runoff Volume Draining to Diversion Structure (Subwatershed A)[2]	Volume Directed from Diversion Structure to Downstream Storm Sewer (Bypassed Volume)	Volume Directed from Diversion Structure into Surface Basin (1)	Inflow Volume from West Pond (Subwatershed B - Discharges to Underground System) (2)	Inflow Volume from Eastern Inlet (Subwatershed C - Discharges to Surface Basin)[3] (3) Calculated Volume 3	Underground System Discharged Volume (4)	Volume Captured by BMP (1+2+3)-4	% of Total Inflow to BMP from Diversion Structure	Overall Volume reduction	Captured TSS	Captured TDS	Captured VSS	Captured TP	Captured Ortho-P	Captured Chloride	Captured Total Kjeldahl Nitrogen	Captured Nitrate + Nitrite as N
Start	End	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	In.	cf	cf	cf	cf	cf	cf	cf			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4/18/2016 23:00	4/19/2016 12:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.13	21217	0	21217	1	1013	0	22232	95.4%	100.0%	105.0	53.5	46.0	0.50	0.23	5.6	2.58	0.48
4/20/2016 20:30	4/22/2016 9:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.68	28589	21976	6613	94	1366	0	8072	81.7%	26.9%	38.1	19.4	16.7	0.18	0.08	2.0	0.94	0.17
4/22/2016 9:30	4/22/2016 13:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.00	450	0	450	0	22	0	472	95.4%	100.0%	2.2	1.1	1.0	0.01	0.00	0.1	0.05	0.01
4/24/2016 7:15	4/25/2016 18:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.80	45965	21572	24393	813	2196	0	27402	88.7%	56.0%	129.4	65.9	56.7	0.61	0.28	6.9	3.18	0.59
4/26/2016 10:15	4/26/2016 13:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.00	711	0	711	0	34	0	745	95.4%	100.0%	3.5	1.8	1.5	0.02	0.01	0.2	0.09	0.02
4/27/2016 13:30	4/29/2016 7:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.97	105971	18190	87781	19646	5062	74717	37772	73.4%	28.9%	178.3	90.9	78.2	0.85	0.39	9.6	4.38	0.81
5/5/2016 22:00	5/6/2016 1:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.00	329	0	329	1	16	0	346	95.1%	100.0%	1.6	0.8	0.7	0.01	0.00	0.1	0.04	0.01
5/9/2016 13:30	5/10/2016 18:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.90	59068	15408	43660	84	2821	0	46566	93.7%	75.1%	219.8	112.1	96.4	1.04	0.48	11.8	5.40	1.00
5/11/2016 13:01	5/12/2016 0:00	76	39	33	0.36	0.17	4.06	1.86	0.34	0.13	8582	45	8537	3	410	0	8950	95.4%	99.5%	42.3	21.5	18.5	0.20	0.09	2.3	1.04	0.19
5/13/2016 7:45	5/13/2016 19:00	76	39	33	0.36	0.17	4.06	1.86	0.34	0.20	4345	2759	1586	3	208	0	1797	88.2%	39.4%	8.5	4.3	3.7	0.04	0.02	0.5	0.21	0.04
5/25/2016 10:15	5/25/2016 18:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.21	8406	1930	6476	2	402	0	6879	94.1%	78.1%	32.5	16.6	14.2	0.15	0.07	1.7	0.80	0.15
5/26/2016 2:45	5/26/2016 10:00	76	39	33	0.36	0.17	4.06	1.86	0.34	0.18	14146	5465	8681	3	676	0	9360	92.7%	63.1%	44.2	22.5	19.4	0.21	0.10	2.4	1.09	0.20
5/27/2016 11:00	5/27/2016 23:15	76	39	33	**0.25**	0.17	**9.60**	**1.40**	**0.08** <	0.21	3631	122	3509	5	173	0	3687	95.2%	96.8%	17.4	8.9	7.6	0.06	0.04	2.2	0.32	0.02
5/28/2016 15:45	5/28/2016 20:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.12	13110	3991	9119	2	626	0	9747	93.6%	70.9%	46.0	23.5	20.2	0.22	0.10	2.5	1.13	0.21
5/29/2016 19:45	5/30/2016 3:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.06	1808	0	1808	3	86	0	1897	95.3%	100.0%	9.0	4.6	3.9	0.04	0.02	0.5	0.22	0.04
5/31/2016 8:00	5/31/2016 11:04	76	39	33	**1.27**	0.17	**35.50**	**5.70**	**0.08** <	0.06	4539	0	4538	1	217	0	4756	95.4%	100.0%	22.5	11.4	9.8	0.38	0.05	10.5	1.69	0.02
6/3/2016 14:15	6/3/2016 20:30	76	39	33	**1.60**	0.17	**13.40**	**9.50**	**0.08** <	0.14	5831	1251	4579	2	279	0	4860	94.2%	79.5%	22.9	11.7	10.1	0.49	0.05	4.1	2.88	0.02
6/4/2016 17:45	6/4/2016 20:45	76	39	33	**0.79**	0.17	**7.30**	**4.70**	**0.08** <	0.04	14473	4741	9732	1	691	0	10424	93.4%	68.7%	49.2	25.1	21.6	0.51	0.11	4.8	3.06	0.05
6/6/2016 6:30	6/6/2016 9:00	76	39	33	0.36	0.17	4.06	1.86	0.34	0.07	2017	2	2016	1	96	0	2113	95.4%	99.9%	10.0	5.1	4.4	0.05	0.02	0.5	0.25	0.05
6/6/2016 14:45	6/6/2016 17:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.07	1665	93	1571	1	80	0	1652	95.1%	94.6%	7.8	4.0	3.4	0.04	0.02	0.4	0.19	0.04
6/9/2016 3:45	6/9/2016 10:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.72	52278	0	52278	475	2497	0	55250	94.6%	100.0%	260.8	133.0	114.3	1.24	0.57	14.0	6.41	1.18
6/12/2016 3:45	6/12/2016 7:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.52	19613	0	19613	5	937	0	20555	95.4%	100.0%	97.0	49.5	42.5	0.46	0.21	5.2	2.38	0.44
6/13/2016 0:30	6/13/2016 11:30	**2**	**53**	**2**	**0.09**	**0.05**	**3.10**	**0.80**	**0.95**	0.84	70638	0	70638	14473	3374	25351	63134	75.9%	71.4%	7.9	208.9	7.9	0.35	0.21	12.2	3.15	3.74
6/14/2016 12:45	6/14/2016 23:45	**50**	**31**	**21**	**0.16**	**0.04**	**2.60**	**0.85**	**0.29**	1.41	133416	0	133416	22170	6373	63885	98074	79.6%	60.6%	306.1	189.8	128.6	0.98	0.25	15.9	5.20	1.78
6/30/2016 6:45	6/30/2016 14:30	76	39	33	**1.26**	**0.16**	**30.60**	**7.50**	**0.08** <	0.04	8517	0	8517	0	407	0	8923	95.4%	100.0%	42.1	21.5	18.5	0.70	0.09	17.0	4.18	0.04
7/5/2016 18:15	7/5/2016 23:30	**60**	**44**	**25**	**0.35**	**0.14**	**3.20**	**1.50**	**0.28**	1.87	124112	90517	33595	1833	5928	0	41357	80.4%	31.4%	154.9	113.6	64.5	0.90	0.35	8.3	3.87	0.72
7/7/2016 5:00	7/7/2016 8:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.05	894	0	894	2	43	0	939	95.3%	100.0%	4.4	2.3	1.9	0.02	0.01	0.2	0.11	0.02
7/10/2016 6:00	7/10/2016 10:30	**50**	39	**28**	**0.32**	0.17	**7.30**	**2.20**	**0.18**	0.23	18208	5985	12223	2	870	0	13095	93.3%	68.6%	40.9	31.5	22.9	0.26	0.14	6.0	1.80	0.15
7/12/2016 0:00	7/12/2016 4:15	**182**	39	**64**	0.36	0.17	4.06	1.86	0.34	0.20	15221	3473	11748	3	727	0	12477	94.2%	78.2%	141.8	30.0	49.9	0.28	0.13	3.2	1.45	0.27
7/14/2016 21:15	7/15/2016 4:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.31	11772	6627	5145	4	562	0	5711	90.1%	46.3%	27.0	13.7	11.8	0.13	0.06	1.4	0.66	0.12
7/16/2016 23:00	7/17/2016 6:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.19	2974	2711	263	19	142	0	424	60.3%	13.5%	2.0	1.0	0.9	0.01	0.00	0.1	0.05	0.01
7/20/2016 9:00	7/20/2016 10:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.02	449	449	0	5	21	0	26	0.0%	5.6%	0.1	0.1	0.1	0.00	0.00	0.0	0.00	0.00
7/21/2016 4:45	7/21/2016 7:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.16	10765	6064	4701	9	514	0	5224	90.0%	46.3%	24.7	12.6	10.8	0.12	0.05	1.3	0.61	0.11
7/23/2016 11:15	7/23/2016 19:15	**30**	39	**12**	**0.18**	**0.08**	**3.00**	**0.93**	**0.11**	1.41	154040	119341	34700	19599	7358	41913	19744	35.9%	10.9%	37.0	47.5	14.8	0.22	0.09	3.7	1.15	0.14
7/27/2016 14:15	7/27/2016 17:45	**54**	39	**21**	**0.15**	**0.58**	**2.00** <	**0.95**	**0.34**	0.97	105971	36980	68991	455	5062	0	74508	92.5%	66.8%	251.2	179.3	97.7	0.70	2.70	9.3	4.42	1.58
8/4/2016 7:30	8/4/2016 11:30	**5**	**50**	**3**	**0.16**	**0.126**	**2.00** <	**0.82**	0.34	1.80	196647	126554	70093	7496	9393	17599	69383	78.8%	32.5%	21.7	216.6	13.0	0.69	0.55	8.7	3.55	1.49
8/10/2016 20:45	8/11/2016 8:30	76	39	33	0.36	0.17	4.06	1.86	0.34	3.08	336485	244402	92083	26679	16073	120807	14028	60.5%	3.7%	66.2	33.8	29.0	0.31	0.14	3.6	1.63	0.30
8/12/2016 17:45	8/12/2016 21:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.20	13142	2185	10957	34	628	0	11619	94.3%	84.2%	54.9	28.0	24.0	0.26	0.12	2.9	1.35	0.25
8/16/2016 17:30	8/16/2016 22:00	76	39	33	0.36	0.17	4.06	1.86	0.34	0.30	37314	16775	20539	17	1782	0	22339	91.9%	57.1%	105.5	53.8	46.2	0.50	0.23	5.7	2.59	0.48
8/19/2016 3:00	8/19/2016 8:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.45	46517	23158	23359	29	2222	0	25610	91.2%	52.5%	120.9	61.6	53.0	0.57	0.26	6.5	2.97	0.55
8/19/2016 19:30	8/20/2016 1:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.22	8263	8082	182	25	395	0	602	27.1%	6.9%	2.8	1.4	1.2	0.01	0.01	0.2	0.07	0.01
8/20/2016 9:15	8/20/2016 15:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.36	39329	11395	27934	587	1879	0	30400	91.7%	72.7%	143.5	73.2	62.9	0.68	0.31	7.7	3.53	0.65
8/23/2016 23:00	8/24/2016 4:30	76	39	33	0.36	0.17	4.06	1.86	0.34	1.54	168243	122817	45426	22283	8036	36592	39153	43.3%	19.7%	184.8	94.2	81.0	0.88	0.40	9.9	4.54	0.84
8/30/2016 0:00	8/30/2016 5:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.45	49162	25493	23669	17	2348	0	26034	90.9%	50.5%	122.9	62.6	53.9	0.58	0.27	6.6	3.02	0.56
9/5/2016 1:45	9/5/2016 8:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.56	61179	13172	48007	9	2922	0	50939	94.2%	79.5%	240.5	122.6	105.4	1.14	0.53	12.9	5.91	1.09
9/6/2016 3:00	9/6/2016 13:15	76	39	33	0.36	0.17	4.06	1.86	0.34	1.11	121266	48543	72723	14433	5792	32024	60924	74.2%	43.1%	287.6	146.6	126.1	1.36	0.63	15.4	7.06	1.31
9/6/2016 21:15	9/7/2016 0:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.05	814	0	814	0	39	0	853	95.4%	100.0%	4.0	2.1	1.8	0.02	0.01	0.2	0.10	0.02
9/9/2016 3:30	9/9/2016 18:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.20	21850	1451	20398	0	1044	0	21442	95.1%	93.7%	101.2	51.6	44.4	0.48	0.22	5.4	2.49	0.46
9/15/2016 16:15	9/15/2016 23:15	**414**	39	**210**	**1.11**	**0.43**	**13.80**	**6.90**	**1.25**	0.79	86306	39257	47050	1349	4123	0	52521	89.3%	57.2%	1357.4	126.4	688.5	3.64	1.41	45.2	22.62	4.10
9/16/2016 20:30	9/16/2016 22:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.07	7647	3544	4103	0	365	0	4469	91.8%	55.8%	21.1	10.8	9.2	0.10	0.05	1.1	0.52	0.10
9/19/2016 11:00	9/19/2016 12:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.02	582	62	519	0	28	0	547	94.9%	89.8%	2.6	1.3	1.1	0.01	0.01	0.1	0.06	0.01
9/21/2016 20:45	9/22/2016 7:45	**96**	**28**	**30**	**0.27**	**0.024**	**2.00** <	**1.60**	**0.37**	1.36	148578	38818	109760	1645	7097	0	118502	92.5%	75.3%	710.2	207.1	221.9	2.00	0.18	14.8	11.84	2.74
9/23/2016 16:00	9/23/2016 22:30	76	39	33	0.36	0.17	4.06	1.86	0.34	0.34	37144	10050	27095	205	1774	0	29074	93.1%	74.3%	137.3	70.0	60.2	0.65	0.30	7.4	3.37	0.62
9/25/2016 7:00	9/25/2016 10:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.23	25127	4408	20719	1	1200	0	21920	94.5%	83.3%	103.5	52.7	45.4	0.49	0.23	5.6	2.54	0.47
9/27/2016 17:45	9/27/2016 21:15	76	39	33	0.36	0.17	4.06	1.86	0.34	0.07	1601	209	1392	1	76	0	1470	94.7%	87.6%	6.9	3.5	3.0	0.03	0.02	0.4	0.17	0.03
10/5/2016 0:00	10/5/2016 8:15	**142**	39	**68**	**0.55**	0.17	**5.20**	**2.20**	**0.08**	0.60	65549	15958	49591	223	3131	0	52946	93.6%	76.8%	469.4	127.4	224.8	1.82	0.55	17.2	7.27	0.26
10/6/2016 19:30	10/7/2016 8:45	**37**	**25**	**12**	**0.27**	0.17	**2.80**	**1.20**	**0.09**	0.93	101601	32495	69106	6619	4853	13270	67308	84.5%	59.5%	155.5	105.0	50.4	1.13	0.69	11.8	5.04	0.38
10/17/2016 17:15	10/18/2016 5:30	76	39	33	**1.25**	0.17	**6.00**	**5.20**	**0.08**	0.52	56809	19400	37410	0	2714	0	40123	93.2%	67.4%	189.4	96.6	83.0	3.13	0.41	15.0	13.03	0.20
10/25/2016 20:30	10/26/2016 14:45	**72**	39	33	**0.84**	**0.49**	**5.30**	**1.70**	**0.08**	0.77	11366	3978	7388	1442	543	0	9372	75.0%	70.2%	42.1	22.6	19.4	0.49	0.29	3.1	0.99	0.05
10/29/2016 15:30	10/29/2016 21:45	76	39	33	0.36	0.17	4.06	1.86	0.34	0.11	1675	455	1220	0	80	0	1300	93.8%	74.1%	6.1	3.1	2.7	0.03	0.01	0.3	0.15	0.03
Sum										30.04	2,769,682	1,182,351	1,535,569	162,814	129,825	426158	1,402,050			**7046.2**	**3313.4**	**3072.8**	**33.01**	**14.85**	**374.3**	**171.37**	**31.41**
Average		92	39	41	0.60	0.19	8.59	3.09	0.26	0.52	1,849	19,706	25,593	2,714	89	7790	23,367			117.4	55.2	51.2	0.52	0.25	3.0	1.6	0.5
Weighted Ave		76	39	33	0.36	0.17	4.06	1.86	0.34																		
STDEV		109	12	57	0.50	0.21	9.65	2.75	0.33											205.5	60.3	96.8	0.7	0.4	7.3	3.7	0.8
Median		54	38	23	0.34	0.13	5.25	1.65	0.09								12048			43.2	29.0	19.8	0.37	0.12	4.4	1.75	0.20
Min		2	25	2	0.09	0.00	2.00	0.80	0.08								26			0	0.06	0.1	0.00	0.00	0.0	0.00	0.00
Max		414	53	210	1.60	0.58	35.50	9.50	1.25								118,502			1357	216.6	688.5	3.64	2.70	45.2	22.62	4.10
Percent Capture of Total Runoff																	45.8%			**50.2%**	**45.7%**	**50.0%**	**49.5%**	**48.3%**	**49.4%**	**48.7%**	**48.6%**

< Sample Was not detected above the method detection limit (MDL) - MDL is reported

J Result reported as estimated between the MDL and the Reporting Limit (RL)

BOLD Sampled Event

GREY Events with no sampling data (weighted average used)

1 See Figure 2 for Locations of Subwatersheds

2 Erroneous flow data was recorded at the diversion upstream, on occasion, as a result of turbulent and high velocity flow. Runoff to the diversion was modeled for those events using a rainfall to runoff ratio developed using historical monitoring data. The events are shaded brown.

3 Volume calculated based on ratio of Subwatershed C area to Subwatershed A area - (4.66 ac)/(136.77 ac)*(Upstream Volume)

City of Saint Paul
2016 Water Quality and Quantity Report
Table C.3
WSB Project Number: 01610-100

HAMPDEN PARK WATER QUALITY SUMMARY

LAB ID	Date Composite Sampling Started	Date Composite Sampling Ended	TSS (mg/L)	VSS (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Chloride (mg/L)	Ammonia as N (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Nitrate + Nitrite as N (mg/L)	Hardness as CaCO3 (mg/L)	Copper (ug/L)	Lead (ug/L)	Zinc (ug/L)	Sulfate (mg/L)	pH	CBOD (mg/L)	E. Coli (MPN/ 100 mL)
2484152		5/25/2016 11:50																488.00
2484474	5/25/2016 10:00	5/26/2016 5:35			0.901	0.007 J	26.9		7.20	1.40	192	67.3	38.6	372.0				
2489879	6/12/2016 3:38	6/12/2016 4:38			0.157		5.2		2.40	0.86								
2489881	6/13/2016 0:43	6/13/2016 2:48	4.0	3.0 J	0.076	0.016	2.5		0.78	0.35								
2489883	6/13/2016 5:23	6/13/2016 5:53	64.0	16.0	0.190	0.037	2.0 <	0.38	1.30	0.26	56	10.9	25.2	74.0	1.45	6.8	4.0	
2490619	6/14/2016 12:38	6/14/2016 21:15	31.0	12.0	0.104	0.006 J	2.6	0.12	0.84	0.37	16	7.9	6.1	49.3	1.77	6.5	4.6	
2495081	6/30/2016 6:33	6/30/2016 7:17	18.0	13.0	0.469	0.257	5.8		1.90	0.20	20	7.3	3.0	35.7				
2496459	7/5/2016 18:18	7/5/2016 22:30	16.0	9.0	0.157	0.080	2.0 <	0.22	0.88	0.36	10.0 <	5.5	2.7	25.6	1.67	7.3	3.2	
2497791	7/10/16 5:48	7/10/16 9:04			0.079		3.1		0.83	0.34								
2502641	7/23/16 11:14	7/23/16 18:21	9.0	5.0	0.114	0.035	2.8		0.80	0.21								
2503642	7/27/16 13:39	7/27/16 17:38	12.0	5.0	0.090	0.040	2.0 <		0.74	0.32								
2505788	8/4/16 7:34	8/4/16 12:29	28.0	9.0	0.110		2.0 <		0.90	0.35								
2507248		8/10/16 21:34	16.0	7.0	0.109	0.052	2.0 <		0.65	0.25								
2509572	8/16/16 17:19	8/17/16 1:30	34.0	9.0	0.085	0.046	2.0 <		0.67	0.18	12.0	5.0 <	5.2	25.7				
2509574	8/19/16 3:14	8/19/16 6:52	14.0	6.0	0.051	0.024	2.0 <		0.58	0.320	16.0	5.0 <	2.3	17.2				
2510453	8/20/16 8:44	8/20/16 20:36	2.00 J	1.0 J	0.028 J	0.015	2.00 <		0.29	0.11								
2510753	8/23/16 21:29	8/24/16 4:53	27.00	7.0	0.085	0.028	2.00 <		0.42	0.14								
2514696	8/29/16 23:59	8/29/16 7:22	18.00	8.0	0.089		2.00 <		0.56									
2514697	9/5/16 4:19	9/5/16 7:22	9.00	4.0	0.091		2.00 <		0.60	0.23								
2514698	9/6/16 4:09	9/6/16 12:33	27.00	9.0	0.096	0.042	2.00 <		0.69	0.22	10.0 <	5.0 <	4.2	21.4				
2517203	9/15/16 16:24	9/15/16 22:50	18.00	9.0	0.143	0.063	2.1		0.69	0.23								
2519045		9/22/16 7:55																2420 >
2519046	9/21/16 16:24	9/22/16 7:55	23.0	9.0	0.116	0.058	2.0 <	0.24	0.77	0.26	12.0	5.0 <	3.0	18.9	1.67	6.90	3.7	
2523710	10/4/16 22:34	10/5/16 7:56	14.0	9.0	0.071		2.0 <		0.52	0.15								
2524573	10/6/16 19:29	10/7/16 4:26	1.0 J	1.0 J	0.066		2.0 <	0.04 J	0.28	0.11	12.0							
2526887	10/17/16 16:44	10/18/16 3:15	47.0	18.0	0.144	0.038	2.0 <		0.98	0.33								
2529578	10/25/16 18:09	10/26/16 13:13	17.0	11.0	0.165	0.064	2.2		0.68	0.21								
2537651		11/28/16 12:00	9.0	4.0 J	0.207	0.148	3.6	0.17	0.75	0.19	10.0 <					7.50	2.8	2420 >
MINIMUM			**1**	**1.0**	**0.028**	**0.006**	**2.0**	**0.04**	**0.28**	**0.01**	**10**	**5.0**	**2.3**	**17.2**	**1.67**	**6.5**	**2.8**	**488**
AVERAGE			**20**	**8.0**	**0.154**	**0.056**	**3.4**	**0.15**	**1.07**	**0.32**	**33**	**13.2**	**10.0**	**71.1**	**1.64**	**7.0**	**3.7**	**1776**
MEDIAN			**17**	**9.0**	**0.107**	**0.040**	**2.0**	**0.20**	**0.75**	**0.25**	**12**	**5.5**	**4.2**	**26**	**1.67**	**6.9**	**3.7**	**2420**
MAXIMUM			**64**	**18.0**	**0.901**	**0.257**	**26.9**	**0.38**	**7.20**	**1.40**	**192**	**67.3**	**38.6**	**372**	**1.77**	**7.5**	**4.6**	**2420**

Laboratory analysis was completed by Metroplian Council Environmental Services (The sample collected on 3/7/2016 was analyzed by Pace Analytical

Grab Sample

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

J - Result reported as estimated between the MDL and Reporting Limit (RL)

City of Saint Paul
2016 Water Quality and Quantity Report
Table C.4
WSB Project No.: 01610-100

HAMPDEN PARK VOLUME AND POLLUTANT REDUCTION SUMMARY

Event Time Interval		Sampling Data							Event Loading and Volume Data													
Start	End	TSS	VSS	TP	Ortho-P	Chloride	Total Kjeldahl Nitrogen	Nitrate + Nitrite as N	Interval Rain	Hampden/Raymond Inflow Volume[1] (1)	Eastern Hampden Modeled Inflow Volume[2] (2)	Bypass Volume[3] (3)	Volume Captured by BMP (1+2-3)	Percent Captured	Captured TSS	Captured VSS	Captured TP	Captured Ortho-P	Captured Chloride	Captured Total Nitrogen[4]	Captured Total Kjeldahl Nitrogen	Captured Nitrate + Nitrite as N
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	In.	cu-ft	cu-ft	cu-ft	cu-ft		lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
4/18/16 21:00	4/19/16 8:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.16	3850.5	635	0	4485.8	100%	6.0	2.3	0.03	0.013	0.59	0.29	0.22	0.08
4/20/16 20:15	4/21/16 5:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.25	5024.1	829	0	5853.1	100%	7.8	3.0	0.04	0.016	0.77	0.38	0.29	0.10
4/21/16 9:30	4/21/16 20:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.2	4333.1	715	0	5048.0	100%	6.7	2.6	0.04	0.014	0.66	0.33	0.25	0.08
4/24/16 6:15	4/24/16 19:30	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.8	10452.1	1725	0	12176.7	100%	16.2	6.2	0.09	0.034	1.60	0.80	0.59	0.20
4/24/16 20:40	4/25/16 7:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.11	1782.3	294	0	2076.3	100%	2.8	1.1	0.01	0.006	0.27	0.14	0.10	0.03
4/25/16 8:30	4/25/16 21:30	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.31	2226.4	367	0	2593.8	100%	3.5	1.3	0.02	0.007	0.34	0.17	0.13	0.04
4/27/16 16:45	4/27/16 20:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.29	2791.1	461	0	3251.6	100%	4.3	1.7	0.02	0.009	0.43	0.21	0.16	0.05
4/27/16 23:15	4/28/16 12:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.27	3670.2	606	0	4275.8	100%	5.7	2.2	0.03	0.012	0.56	0.28	0.21	0.07
4/28/16 15:15	4/29/16 1:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.46	6133.6	1012	0	7145.6	100%	9.5	3.6	0.05	0.020	0.94	0.47	0.35	0.12
5/9/16 13:10	5/10/16 17:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.64	15640.5	2581	0	18221.1	100%	24.3	9.3	0.13	0.051	2.40	1.19	0.89	0.30
5/11/16 12:55	5/12/16 3:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.11	1758.9	290	0	2049.2	100%	2.7	1.0	0.01	0.006	0.27	0.13	0.10	0.03
5/13/16 7:30	5/13/16 15:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.15	1965.9	324	0	2290.3	100%	3.1	1.2	0.02	0.006	0.30	0.15	0.11	0.04
5/25/16 9:55	5/25/16 16:00	21.4	8.2	**0.901**	**0.007**	**26.9**	**7.20**	**1.4**	0.21	2677.9	442	0	3119.7	100%	4.2	1.6	0.18	0.001	5.24	1.67	1.40	0.27
5/26/16 2:45	5/26/16 8:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.27	3098.6	511	0	3609.9	100%	4.8	1.8	0.03	0.010	0.48	0.24	0.18	0.06
6/3/16 12:15	6/3/16 18:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.15	2441.9	403	0	2844.8	100%	3.8	1.5	0.02	0.008	0.37	0.19	0.14	0.05
6/6/16 6:15	6/6/16 11:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.02	188.0	31	0	219.0	100%	0.3	0.1	0.00	0.001	0.03	0.01	0.01	0.00
6/6/16 17:25	6/6/16 22:30	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.04	369.1	61	0	430.0	100%	0.6	0.2	0.00	0.001	0.06	0.03	0.02	0.01
6/9/16 0:00	6/9/16 13:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	1.09	18196.0	3002	0	21198.3	100%	28.3	10.8	0.15	0.060	2.79	1.39	1.03	0.35
6/10/16 15:06	6/10/16 16:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.04	143.4	24	0	167.1	100%	0.2	0.1	0.00	0.000	0.02	0.01	0.01	0.00
6/12/16 3:26	6/12/16 5:45	21.4	8.2	**0.157**	0.045	**5.2**	**2.40**	**0.88**	0.05	594.0	98	0	692.0	100%	0.9	0.4	0.01	0.002	0.22	0.14	0.10	0.04
6/13/16 0:30	6/13/16 4:00	**4.0**	**3.0** J	**0.076**	**0.016**	**2.5**	**0.78**	**0.36**	0.13	1875.0	309	0	2184.3	100%	0.5	0.4	0.01	0.002	0.34	0.16	0.11	0.05
6/13/16 5:11	6/13/16 9:30	**64.0**	**16.0**	**0.190**	0.045	**2.0** <	**1.30**	**0.26**	0.93	8081.5	1333	0	9414.9	100%	37.6	9.4	0.11	0.027	1.18	0.92	0.76	0.15
6/14/16 12:30	6/14/16 14:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.28	2080.9	343	0	2424.3	100%	3.2	1.2	0.02	0.007	0.32	0.16	0.12	0.04
6/14/16 18:37	6/14/16 20:34	**31.0**	**12.0**	**0.104**	**0.006**	**2.6**	**0.84**	**0.37**	1.22	11306.7	1866	0	13172.3	100%	25.5	9.9	0.09	0.005	2.14	1.00	0.69	0.30
6/19/16 23:30	6/20/16 2:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.05	423.1	70	0	492.9	100%	0.7	0.3	0.00	0.001	0.06	0.03	0.02	0.01
6/22/16 20:00	6/22/16 21:30	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.02	196.7	32	0	229.1	100%	0.3	0.1	0.00	0.001	0.03	0.02	0.01	0.00
6/30/16 6:26	6/30/16 8:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.4	4833.0	797	0	5630.4	100%	7.5	2.9	0.04	0.016	0.74	0.37	0.27	0.09
6/30/16 12:15	6/30/16 14:15	**18.0**	**13.0**	**0.469**	**0.257**	**5.8**	**1.90**	**0.20**	0.02	260.1	43	0	303.0	100%	0.3	0.2	0.01	0.005	0.11	0.04	0.04	0.00
7/5/16 18:00	7/6/16 6:30	**16.0**	**9.0**	**0.157**	**0.080**	**2.0**	**0.88**	**0.36**	1.45	8074.4	1332	0	9406.7	100%	9.4	5.3	0.09	0.047	1.17	0.73	0.52	0.21
7/7/16 4:35	7/7/16 6:05	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.04	346.0	57	0	403.1	100%	0.5	0.2	0.00	0.001	0.05	0.03	0.02	0.01
7/10/16 5:25	7/10/16 10:55	21.4	8.2	**0.079**	0.045	**3.1**	**0.83**	**0.34**	0.23	3203.8	529	0	3732.4	100%	5.0	1.9	0.02	0.011	0.72	0.27	0.19	0.08
7/12/16 0:00	7/12/16 3:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.07	1012.3	167	0	1179.4	100%	1.6	0.6	0.01	0.003	0.16	0.08	0.06	0.02
7/13/16 21:45	7/14/16 2:25	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.01	202.1	33	0	235.5	100%	0.3	0.1	0.00	0.001	0.03	0.02	0.01	0.00
7/14/16 20:55	7/15/16 11:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.11	1718.0	283	0	2001.5	100%	2.7	1.0	0.01	0.006	0.26	0.13	0.10	0.03
7/16/16 22:20	7/17/16 8:30	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.16	4647.8	767	0	5414.6	100%	7.2	2.8	0.04	0.015	0.71	0.35	0.26	0.09
7/21/16 4:40	7/21/16 9:10	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.11	1518.1	250	0	1768.6	100%	2.4	0.9	0.01	0.005	0.23	0.12	0.09	0.03
7/23/16 10:50	7/23/16 22:00	**9.0**	**5.0**	**0.114**	**0.035**	**2.8**	**0.80**	**0.21**	1.03	9656.8	1593	0	11250.1	100%	6.3	3.5	0.08	0.025	1.97	0.71	0.56	0.15
7/27/16 13:47	7/27/16 17:35	**12.0**	**5.0**	**0.090**	**0.040**	**2.0** <	**0.74**	**0.32**	0.79	8660.3	1429	0	10089.2	100%	7.6	3.1	0.06	0.025	1.26	0.67	0.47	0.20
8/4/16 7:15	8/4/16 10:30	**28.0**	**9.0**	**0.110**	0.045	**2.0** <	**0.90**	**0.36**	1.3	19663.4	3244	0	22907.9	100%	40.0	12.9	0.16	0.065	2.86	1.80	1.29	0.51
8/10/16 20:15	8/11/16 7:37	**16.0**	**7.0**	**0.109**	**0.052**	**2.0** <	**0.65**	**0.26**	2.76	44453.4	7335	0	51788.2	100%	51.7	22.6	0.35	0.168	6.47	2.94	2.10	0.84
8/12/16 16:50	8/12/16 20:20	21.4	**9.0**	0.114	**0.046**	**2.0** <	0.78	**0.18**	0.22	2784.5	459	0	3243.9	100%	4.3	1.8	0.02	0.009	0.41	0.19	0.16	0.04
8/16/16 17:00	8/16/16 20:47	**34.0**	8.2	**0.085**	0.045	2.1	0.78	0.27	1.26	18576.0	3065	0	21641.0	100%	45.9	11.0	0.11	0.061	2.85	1.42	1.06	0.36
8/19/16 2:55	8/19/16 9:25	**14.0**	**6.0**	**0.051**	**0.024**	**2.0** <	0.78	**0.31**	0.31	4683.2	773	0	5456.0	100%	4.8	2.0	0.02	0.008	0.68	0.37	0.27	0.11
8/19/16 19:00	8/20/16 2:35	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.16	3503.8	578	0	4082.0	100%	5.4	2.1	0.03	0.011	0.54	0.27	0.20	0.07
8/20/16 8:25	8/20/16 22:35	**2.0** J	**1.0** J	**0.028**	**0.014**	**2.0** <	**0.29**	**0.11**	0.3	5844.0	964	0	6808.2	100%	0.9	0.4	0.01	0.006	0.85	0.17	0.12	0.05
8/23/16 22:29	8/24/16 2:46	**27.0**	**7.0**	**0.085**	**0.028**	**2.0** <	**0.42**	**0.14**	0.85	11132.9	1837	0	12969.9	100%	21.9	5.7	0.07	0.023	1.62	0.45	0.34	0.11
8/27/16 10:20	8/27/16 19:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.01	445.3	73	0	518.8	100%	0.7	0.3	0.00	0.001	0.07	0.03	0.03	0.01
8/29/16 23:40	8/30/16 7:10	**18.0**	**8.0**	**0.089**	0.045	**2.0** <	**0.56**	**0.32**	0.37	7160.4	1181	0	8341.8	100%	9.4	4.2	0.05	0.023	1.04	0.46	0.29	0.17
9/5/16 3:55	9/5/16 6:33	**9.0**	**4.0**	**0.091**	0.045	**2.0** <	**0.60**	**0.23**	0.46	6674.6	1101	0	7775.9	100%	4.4	1.9	0.04	0.022	0.97	0.40	0.29	0.11
9/6/16 3:50	9/6/16 17:30	**27.0**	**9.0**	**0.096**	**0.042**	**2.0** <	**0.69**	**0.22**	0.87	15160.3	2501	0	17661.8	100%	29.8	9.9	0.11	0.046	2.21	1.00	0.76	0.24
9/6/16 20:20	9/7/16 3:25	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.11	451.0	74	0	525.5	100%	0.7	0.3	0.00	0.001	0.07	0.03	0.03	0.01
9/9/16 3:15	9/9/16 12:20	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.1	2113.7	349	0	2462.5	100%	3.3	1.3	0.02	0.007	0.32	0.16	0.12	0.04
9/15/16 16:05	9/16/16 1:10	**18.0**	**9.0**	**0.143**	**0.063**	**2.1**	**0.69**	**0.23**	0.7	10064.4	1661	0	11725.0	100%	13.2	6.6	0.10	0.046	1.54	0.67	0.51	0.17
9/19/16 10:30	9/19/16 15:40	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.02	387.5	64	0	451.4	100%	0.6	0.2	0.00	0.001	0.06	0.03	0.02	0.01
9/21/16 0:10	9/21/16 5:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.02	304.9	50	0	355.2	100%	0.5	0.2	0.00	0.001	0.05	0.02	0.02	0.01
9/21/16 16:05	9/22/16 7:15	**23.0**	**9.0**	**0.116**	**0.058**	**2.0** <	**0.77**	**0.26**	1.23	13820.8	2280	0	16101.2	100%	23.1	9.0	0.12	0.058	2.01	1.04	0.77	0.26
9/23/16 15:30	9/24/16 0:45	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.46	5406.4	892	0	6298.5	100%	8.4	3.2	0.04	0.018	0.83	0.41	0.31	0.11
9/25/16 1:45	9/25/16 19:15	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.16	3890.0	642	0	4531.9	100%	6.0	2.3	0.03	0.013	0.60	0.30	0.22	0.08
9/27/16 17:10	9/28/16 0:00	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.07	1257.7	208	0	1465.2	100%	2.0	0.7	0.01	0.004	0.19	0.10	0.07	0.02
10/4/16 8:55	10/5/16 14:05	**14.0**	**9.0**	**0.071**	0.045	**2.0** <	**0.52**	**0.15**	0.66	10488.6	1731	0	12219.2	100%	10.7	6.9	0.05	0.034	1.53	0.51	0.40	0.11
10/6/16 19:10	10/7/16 0:11	**1.0** J	**1.0** J	**0.066**	0.045	**2.0** <	**0.28**	**0.11**	1.07	10962.3	1809	0	12771.1	100%	0.8	0.8	0.05	0.036	1.59	0.31	0.22	0.09
10/17/16 16:25	10/18/16 8:25	**47.0**	**18.0**	**0.144**	**0.038**	**2.0** <	**0.98**	**0.33**	0.6	7332.3	1210	0	8542.2	100%	25.1	9.6	0.08	0.020	1.07	0.70	0.52	0.18
10/25/16 18:05	10/26/16 15:50	**17.0**	**11.0**	**0.165**	**0.064**	**2.2**	**0.68**	**0.21**	0.72	16354.7	2699	0	19053.3	100%	20.2	13.1	0.20	0.076	2.62	1.06	0.81	0.25
10/29/16 14:40	10/29/16 21:55	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.11	2484.1	410	0	2894.0	100%	3.9	1.5	0.02	0.008	0.38	0.19	0.14	0.05
11/18/16 8:40	11/19/16 2:10	21.4	8.2	0.114	0.045	2.1	0.78	0.27	0.77	11523.4	1901	0	13424.7	100%	17.9	6.8	0.10	0.038	1.77	0.88	0.65	0.22
Sum									28.34	393560	64937	0	458498	100%	611.7	233.9	3.3	1.3	65.2	30.0	22.4	7.7
Average		20.4	8.2	0.151	0.051	3.4	1.12	0.32														
Weighted Avg		21.4	8.2	0.114	0.045	2.1	0.78	0.27														
STDEV		14.7	4.3	0.176	0.059	5.0	1.41	0.27														
Min		1.0	1.0	0.028	0.006	2.0	0.28	0.11														
Max		64.0	18.0	0.901	0.257	26.9	7.20	1.40														
Percent Capture															**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

< Sample was not detected above the method detection limit (value reported)
GREY FONT Events with no sampling data (weighted average concentration used)
BOLD Sampling event

1 - Flow in monitored at a system inlet location at the intersection of Raymond Ave and Hampden Ave
2 - Additional stormwater is conveyed to the system from the east via a pipe along Hampden Avenue. This flow is modeled using the monitored flow from the Hampden/Raymond location and the ratio of drainage
3 - Water Levels in the BMP did not exceed the system outlet elevation
4 - Total captured nitrogen is the sum of captured Total Kjeldahn Nitrogen and Nitrate + Nitrite as N.

MARYLAND POND WATER QUALITY SUMMARY

Pre-Treatment[1,3]	Post-Treatment[2]	Date Composite Sampling Start	Date Composite Sampling End/ Grab Sample	Soluble Reactive Phosphorus (mg/L)					Total Phosphorus (mg/L)				Dissolved Phosphorus (mg/L)				
Sample ID	Sample ID			Pre-Treament		Post-Treatment		% Reduction	Pre-Treatment		Post-Treatment	% Reduction	Pre-Treament		Post-Treatment		% Reduction
10348063003	10348063004		5/10/2016 22:27	0.002	<	0.002	<	0	0.130		0.054	58	0.020	J	0.016	J	20
2489256	2489258		6/10/2016 12:50	0.020		0.026		-30	0.097		0.040	59	0.067		0.023	J	66
2490160	2490162	6/13/2016 6:25	6/13/2016 14:47	0.014	J	0.014		0	0.226		0.095	58	0.035	J	0.036	J	-3
2490621	2490623	6/14/2016 9:37	6/15/2016 9:37	0.013	J	0.008		38	0.105		0.081	23	0.020	J	0.023	J	-15
2496460	2496463	7/5/2016 19:07	7/5/2016 23:57	0.013	J	0.051		-292	0.124		0.159	-28	0.041	J	0.020		51
2502643	2502645	7/23/2016 11:52	7/24/2016 9:12	0.038		0.042		-11	0.114		0.184	-61	0.074		0.074		0
2503916	2503918	7/27/2016 15:57	7/28/2016 1:32	0.020	J	0.026		-30	0.115		0.119	-3	0.029	J	0.049	J	-69
2505789	2505792	8/4/2016 8:37	8/5/2016 0:37	0.007	J	0.018	J	-157	0.129		0.300	-133	0.021	J	0.058		-176
2507640	2507642		8/12/2016 12:57	0.018	J	0.014		22	0.068		0.180	-165	0.032	J	0.045	J	-41
2509560	2509560	8/19/2016 5:27	8/19/2016 13:25	0.007	J	0.005	J	29	0.070		0.093	-33	0.020	J	0.026	J	-30
2510449	2510541	8/20/2016 10:22	8/20/2016 18:22	0.005	J	0.005	<	0	0.037	J	0.090	-143	0.020	J	0.020	J	0
2511065	2511067	8/23/2016 23:52	8/24/2016 22:32	0.005	<	0.005	J	0	0.043	J	0.081	-88	0.020	<	0.022	J	-10
2512657	2512659	8/30/2016 4:12	8/30/2016 16:12	0.005	<	0.005	J	0	0.073		0.149	-104	0.020	<	0.020	J	0
2514700	2514702	9/5/2016 6:42	9/5/2016 18:42	0.010	J	0.015		-50	0.071		0.121	-70	0.023	J	0.030	J	-30
2514704	2514706	9/6/2016 5:37	9/7/2016 1:37	0.009	J	0.012	J	-33	0.063		0.093	-48	0.024	J	0.028	J	-17
2517193	2517195	9/15/2016 19:07	9/16/2016 10:35	0.008	J	0.007	J	13	0.080		0.118	-48	0.037	J	0.031	J	16
2519034	2519036	9/21/2016 21:42	9/22/2016 11:03	0.009	<	0.011	J	-22	0.042	J	0.104	-148	0.020	<	0.020	<	0
2519947	2519949	9/23/2016 19:07	9/24/2016 7:42	0.005		0.005	<	0	0.077		0.048	38	0.055		0.020	<	64
2523701	2523703	10/5/2016 4:03	10/6/2016 12:45	0.008	J	0.009	J	-13	0.065		0.118	-82	0.022	J	0.035	J	-59
MINIMUM				0.002		0.002		-292	0.037		0.040	-165	0.020		0.016		-176
AVERAGE				0.011		0.015		-28	0.091		0.117	-48	0.032		0.031		-12
MEDIAN				0.009		0.011		0	0.077		0.104	-48	0.023		0.026		-3
MAXIMUM				0.038		0.051		38	0.226		0.300	59	0.074		0.074		66

Laboratory analysis was completed by Metropolian Council Environmental Services (Samples on 5/10/2016 were analyzed by Pace Analytical)

1 - Pre-treatment samples were collected from the pond near the outlet control structure (OCS) 1 foot below the water surface

2 - Post-treatment samples were collected from the oulet pipe within the OCS

3 - Pre-treatment and post-treatment automated samplers were programmed to collect simultaneously at consistant flow intervals recorded by the flow meter within the OCS

Grab Sample

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

J - Result reported as estimated between the MDL and Reporting Limit (RL)

City of Saint Paul
2016 Water Quality and Quantity Summary
Table C.6
WSB Project Number 01610-100

MARYLAND POND POLLUTANT REDUCTION SUMMARY

Flow Event Start [1]	Start	Stop	Total Rainfall (inches)	TP Pre-Treatment (mg/L)	TP Post-Treatment (mg/L)	TP Pre-Treatment Load (grams)	TP Post-Treatment Load (grams)	TP Load Captured (grams)	SRP Pre-Treatment (mg/L)	SRP Post-Treatment (mg/L)	SRP Pre-Treatment Load (grams)	SRP Post-Treatment Load (grams)	SRP Load Captured (grams)
20-Apr	4/20/2016 22:00	4/21/2016 21:00	0.50	*0.090*	*0.134*	20.0	29.7	-9.7	*0.015*	*0.017*	3.2	3.9	-0.7
24-Apr	4/24/2016 9:00	4/26/2016 4:00	0.80	*0.090*	*0.134*	108.4	160.7	-52.3	*0.015*	*0.017*	17.4	21.0	-3.5
27-Apr	4/27/2016 20:00	4/30/2016 2:00	0.60	*0.090*	*0.134*	132.6	196.6	-64.0	*0.015*	*0.017*	21.3	25.6	-4.3
9-May	5/9/2016 23:30	5/11/2016 3:55	0.86	**0.130**	**0.054**	59.8	24.8	34.9	**0.002**	**0.002**	0.9	0.9	0.0
11-May	5/11/2016 14:30	5/13/2016 0:00	0.13	*0.090*	*0.134*	19.9	29.5	-9.6	*0.015*	*0.017*	3.2	3.8	-0.6
13-May	5/13/2016 8:30	5/14/2016 12:30	0.20	*0.090*	*0.134*	16.9	25.1	-8.2	*0.015*	*0.017*	2.7	3.3	-0.5
25-May	5/25/2016 10:30	5/26/2016 1:00	0.19	*0.090*	*0.134*	11.3	16.7	-5.4	*0.015*	*0.017*	1.8	2.2	-0.4
26-May	5/26/2016 3:00	5/27/2016 2:00	0.18	*0.090*	*0.134*	32.1	47.6	-15.5	*0.015*	*0.017*	5.2	6.2	-1.0
27-May	5/27/2016 18:00	5/28/2016 6:00	0.21	*0.090*	*0.134*	10.2	15.1	-4.9	*0.015*	*0.017*	1.6	2.0	-0.3
28-May	5/28/2016 16:00	5/29/2016 7:00	0.12	*0.090*	*0.134*	11.8	17.4	-5.7	*0.015*	*0.017*	1.9	2.3	-0.4
29-May	5/29/2016 19:00	5/30/2016 5:00	0.07	*0.090*	*0.134*	5.2	7.7	-2.5	*0.015*	*0.017*	0.8	1.0	-0.2
31-May	5/31/2016 10:00	5/31/2016 17:00	0.07	*0.090*	*0.134*	3.2	4.8	-1.6	*0.015*	*0.017*	0.5	0.6	-0.1
3-Jun	6/3/2016 14:00	6/4/2016 7:00	0.14	*0.090*	*0.134*	8.3	12.4	-4.0	*0.015*	*0.017*	1.3	1.6	-0.3
4-Jun	6/4/2016 18:00	6/5/2016 10:00	0.04	*0.090*	*0.134*	10.5	15.6	-5.1	*0.015*	*0.017*	1.7	2.0	-0.3
6-Jun	6/6/2016 6:30	6/7/2016 0:00	0.16	*0.090*	*0.134*	8.0	11.9	-3.9	*0.015*	*0.017*	1.3	1.5	-0.3
9-Jun	6/9/2016 4:00	6/10/2016 7:05	0.75	**0.097**	**0.040**	75	0	74.5	**0.020**	**0.026**	15.4	20.0	-4.6
12-Jun	6/12/2016 5:00	6/12/2016 16:00	0.53	*0.090*	*0.134*	13.6	20.2	-6.6	*0.015*	*0.017*	2.2	2.6	-0.4
13-Jun	6/13/2016 6:00	6/14/2016 4:00	0.86	**0.226**	**0.095**	256	108	148.3	**0.014**	**0.014**	15.9	15.9	0.0
14-Jun	6/14/2016 18:00	6/16/2016 1:00	1.42	**0.105**	**0.081**	213	165	48.8	**0.013**	**0.008**	26.4	16.3	10.2
5-Jul	7/5/2016 18:30	7/7/2016 0:30	1.87	**0.124**	**0.159**	169	217	-47.8	**0.013**	**0.051**	17.7	69.6	-51.9
10-Jul	7/10/2016 7:00	7/10/2016 14:00	0.23	*0.090*	*0.134*	3.8	5.6	-1.8	*0.015*	*0.017*	0.6	0.7	-0.1
12-Jul	7/12/2016 0:00	7/12/2016 15:00	0.2	*0.090*	*0.134*	11.7	17.4	-5.6	*0.015*	*0.017*	1.9	2.3	-0.4
15-Jul	7/15/2016 1:00	7/15/2016 11:00	0.32	*0.090*	*0.134*	5.7	8.5	-2.8	*0.015*	*0.017*	0.9	1.1	-0.2
16-Jul	7/16/2016 23:30	7/17/2016 9:30	0.19	*0.090*	*0.134*	8.2	12.1	-3.9	*0.015*	*0.017*	1.3	1.6	-0.3
21-Jul	7/21/2016 4:30	7/21/2016 7:30	0.16	*0.090*	*0.134*	2.4	3.5	-1.2	*0.015*	*0.017*	0.4	0.5	-0.1
23-Jul	7/23/2016 11:00	7/24/2016 9:00	1.71	**0.114**	**0.184**	224	361	-137.4	**0.038**	**0.042**	74.6	82.4	-7.9
27-Jul	7/27/2016 14:30	7/28/2016 11:00	0.98	**0.115**	**0.119**	76	79	-2.6	**0.020**	**0.026**	13.2	17.2	-4.0
4-Aug	8/4/2016 7:30	8/5/2016 0:00	1.82	**0.129**	**0.3**	183	426	-242.9	**0.007**	**0.018**	9.9	25.6	-15.6
10-Aug	8/10/2016 20:30	8/13/2016 3:40	3.3	**0.068**	**0.18**	326	864	-537.5	**0.018**	**0.014**	86.4	67.2	19.2
16-Aug	8/16/2016 17:30	8/17/2016 3:00	0.3	*0.090*	*0.134*	31.4	46.6	-15.2	*0.015*	*0.017*	5.1	6.1	-1.0
19-Aug	8/19/2016 4:30	8/20/2016 3:00	1.03	**0.070**	**0.093**	42	56	-13.8	**0.007**	**0.005**	4.2	3.0	1.2
20-Aug	8/20/2016 9:00	8/20/2016 18:00	0.36	**0.037**	**0.090**	11	27	-16.2	**0.005**	**0.005**	1.5	1.5	0.0
23-Aug	8/23/2016 22:30	8/24/2016 22:10	1.56	**0.043**	**0.081**	78	146	-68.5	**0.005**	**0.005**	9.0	9.0	0.0
30-Aug	8/30/2016 0:00	8/30/2016 15:50	0.45	**0.073**	**0.149**	21	44	-22.4	**0.005**	**0.005**	1.5	1.5	0.0
5-Sep	9/5/2016 4:00	9/5/2016 18:00	0.57	**0.071**	**0.121**	29	49	-20.2	**0.010**	**0.015**	4.0	6.1	-2.0
6-Sep	9/6/2016 3:30	9/7/2016 1:00	1.17	**0.063**	**0.093**	100	147	-47.4	**0.009**	**0.012**	14.2	19.0	-4.7
9-Sep	9/9/2016 6:00	9/9/2016 21:00	0.2	*0.090*	*0.134*	12.4	18.3	-6.0	*0.015*	*0.017*	2.0	2.4	-0.4
15-Sep	9/15/2016 18:00	9/15/2016 20:15	0.8	**0.080**	**0.118**	19	28	-9.1	**0.008**	**0.007**	1.9	1.7	0.2
21-Sep	9/21/2016 21:00	9/22/2016 18:00	1.39	**0.042**	**0.104**	69	171	-102.1	**0.009**	**0.011**	14.8	18.1	-3.3
23-Sep	9/23/2016 17:00	9/24/2016 8:00	0.34	**0.077**	**0.048**	29	18	11.0	**0.005**	**0.005**	1.9	1.9	0.0
25-Sep	9/25/2016 9:00	9/26/2016 12:00	0.24	**0.065**	**0.118**	16	30	-13.3	**0.008**	**0.009**	2.0	2.3	-0.3
Sum			27.02			2484	3683	-1198.9			394.1	473.3	-79.2
Total Pond Discharge[2]													
Average													

1 - Monitoring for 2016 concluded on 10/5/2016 when the flow sensor was determined to be damaged
2 - In 2016, baseflow was observed at Maryland pond. The event-based volume and the total observed volume are both presented. Pollutant load

GREY FONT - Events with no sampling data, (flow weighted average concentraion used)

Bold - Sampled Event

Negative Load Reduction

TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

TP Summary	
FWA In (mg/L)	0.090
FWA Out (mg/L	0.134
Total Load Captured (g)	-1199
Percent Reduction %	-48

SRP Summary	
FWA In (mg/L)	0.015
FWA Out (mg/L	0.017
Total Load Captured (g)	-79
Percent Reduction %	-20

City of Saint Paul
2016 Water Quality and Quantity Report
Table C.7
WSB Project Number 01610-100

MAGNOLIA POND WATER QUALITY SUMMARY

Pre-treatment[1,3] Sample ID	Post-treatment[2] Sample ID	Date Composite Sampling Start	Date Composite Sampling End/ Grab Sample	Soluble Reactive Phosphorus (mg/L) Pre-Treament	Soluble Reactive Phosphorus (mg/L) Post Treatment	Soluble Reactive Phosphorus (mg/L) % Reduction	Total Phosphorus (mg/L) Pre-Treament	Total Phosphorus (mg/L) Post Treatment	Total Phosphorus (mg/L) % Reduction	Dissolved Phosphorus (mg/L) Pre-Treament	Dissolved Phosphorus (mg/L) Post Treatment	Dissolved Phosphorus (mg/L) % Reduction
10348063001	10348063002		5/11/2016 14:23	0.071	0.083	-17	0.160	0.110	31	0.052	0.086	-65
2489182	2489183	6/9/2016 5:18	6/10/2016 10:50	0.011	0.007 J	36	0.442	0.334	24	0.557	0.067	88
2489260	2489263		6/10/2016 13:00	0.231	0.159	31	0.395	0.182	54	0.297	NA	NA
2490164	2490166	6/13/2016 15:10	6/14/2016 5:22	0.176	0.049	72	0.923	0.194	79	0.222	0.075	66
2490625	2490627		6/15/2016 12:40	0.142	0.070	51	0.198	0.091	54	0.142	0.065	54
2496465	2496467	7/5/2016 18:34	7/5/2016 19:53	0.075	0.073	3	0.239	0.185	23	0.100	0.085	15
2502647	2502649	7/23/2016 11:33	7/24/2016 16:03	0.045	0.039	13	0.181	0.118	35	0.075	0.066	12
2502648	2503922	7/27/2016 15:23	7/28/2016 16:13	0.013	0.005	62	0.100	0.139	-39	0.036 J	0.024 J	33
2505793	2505795	8/4/2016 8:09	8/5/2016 7:54	0.007 J	0.005 <	29	0.235	0.169	28	0.030 J	0.023 J	23
2507644	2507646	8/10/2016 20:57	8/12/2016 9:17	0.036	0.037	-3	0.153	0.113	26	0.052	0.055	-6
2509564	2509566	8/19/2016 18:54	8/19/2016 20:49	0.005 <	0.005 <	0	0.019	0.056	-196	0.023 J	0.020 <	13
2509568	2509570	8/19/2016 5:29	8/19/2016 11:45	0.008 J	0.025	-213	0.250	0.080	68	0.039 J	0.034 J	13
2511069	2511071	8/23/2016 23:29	8/25/2016 11:10	0.041	0.049	-20	0.104	0.103	1	0.050	0.059	-18
2514708	2514712	9/6/2016 4:04	9/6/2016 9:59	0.145	0.031	79	0.563	0.099	82	0.153	0.037 J	76
2517197	2517199	9/15/2016 19:17	9/16/2016 9:45	0.014	0.022	-57	0.155	0.126	19	0.036 J	0.037 J	-3
2519038	2519040	9/21/2016 21:29	9/22/2016 10:43	0.016	0.027	-69	0.142	0.073	49	0.027 J	0.035 J	-30
2523705	2523707	10/5/2016 4:47	10/5/2016 20:47	0.086	0.005 <	94	0.175	0.066	62	0.106	0.020 <	81
2529571	2529573	10/26/2016 4:04	10/26/2016 16:55	0.008 J	0.005 <	38	0.595	0.151	75	0.093	0.025 J	73
MININUM				0.005	0.005	-213	0.019	0.056	-196	0.023	0.020	-65
AVERAGE				0.063	0.039	7	0.279	0.133	26	0.116	0.048	25
MEDIAN				0.039	0.029	21	0.190	0.116	33	0.064	0.037	15
MAXIMUM				0.231	0.159	94	0.923	0.334	82	0.557	0.086	88

Laboratory analysis was completed by Metropolian Council Environmental Services (Samples on 5/11/2016 were analyzed by Pace Analytical)

1 - Pre-treatment samples were collected from the pond near the outlet control structure (OCS) 1 foot below the water surface

2 - Post-treatment samples were collected from the oulet pipe within the OCS

3 - Pre-treatment and post-treatment automated samplers were programmed to collect simultaneously at consistant flow intervals recorded by the flow meter within the OCS

Grab Samples

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

J - Result reported as estimated between the MDL and Reporting Limit (RL)

City of Saint Paul
2016 Water Quality and Quantity Summary
Table C.8
WSB Project Number 01610-100

MAGNOLIA POND POLLUTANT REDUCTION SUMMARY

Treatment Event Start	Start	Stop	Treatment Event Duration (hours)	Flow Volume (cubic feet)	Total Rainfall (inches)	TP Pre-Treatment (mg/L)	TP Post-Treatment (mg/L)	TP Pre-Treatment Load (grams)	TP Post-Treatment Load (grams)	TP Load Captured (grams)	SRP Pre-Treatment (mg/L)	SRP Post-Treatment (mg/L)	SRP Pre-Treatment Load (grams)	SRP Post-Treatment Load (grams)	SRP Load Captured (grams)
24-Apr	4/24/2016 12:25	4/26/2016 18:30	54.1	4178	0.78	*0.250*	*0.128*	29.6	15.2	14.4	*0.061*	*0.039*	7.2	4.6	2.6
27-Apr	4/27/2016 21:30	4/30/2016 8:30	59.0	5598	0.97	*0.250*	*0.128*	39.7	20.4	19.3	*0.061*	*0.039*	9.7	6.2	3.4
10-May	5/10/2016 5:30	5/11/2016 6:00	24.5	1105	0.86	**0.160**	**0.110**	5.0	3.4	1.6	**0.071**	**0.083**	2.2	2.6	-0.4
26-May	5/26/2016 8:30	5/26/2016 14:30	6.0	109	0.37	*0.250*	*0.128*	0.8	0.4	0.4	*0.061*	*0.039*	0.2	0.1	0.1
9-Jun	6/9/2016 5:25	6/10/2016 11:00	29.6	5156	0.75	**0.442**	**0.334**	64.6	48.8	15.8	**0.011**	**0.007**	1.6	1.0	0.6
12-Jun	6/12/2016 5:30	6/14/2016 5:50	48.3	12962	1.39	**0.923**	**0.194**	338.9	71.2	267.7	**0.176**	**0.049**	64.6	18.0	46.6
14-Jun	6/14/2016 18:30	6/16/2016 2:40	32.2	21395	1.42	**0.198**	**0.091**	120.0	55.2	64.9	**0.142**	**0.070**	86.1	42.4	43.6
5-Jul	7/5/2016 18:30	7/6/2016 22:30	28.0	14990	1.87	**0.239**	**0.185**	101.5	78.6	22.9	**0.075**	**0.073**	31.8	31.0	0.8
23-Jul	7/23/2016 11:00	7/24/2016 23:30	36.5	22403	1.71	**0.181**	**0.118**	114.9	74.9	40.0	**0.045**	**0.039**	28.6	24.8	3.8
27-Jul	7/27/2016 13:00	7/29/2016 1:00	36.0	4134	0.98	**0.100**	**0.139**	11.7	16.3	-4.6	**0.013**	**0.005**	1.5	0.6	0.9
4-Aug	8/4/2016 8:15	8/5/2016 18:30	34.3	18979	1.82	**0.235**	**0.169**	126.4	90.9	35.5	**0.007**	**0.005**	3.8	2.7	1.1
10-Aug	8/10/2016 21:00	8/13/2016 14:00	65.0	46888	3.30	**0.153**	**0.113**	203.2	150.1	53.1	**0.036**	**0.037**	47.8	49.1	-1.3
16-Aug	8/16/2016 16:30	8/18/2016 2:00	33.5	2668	0.30	*0.250*	*0.128*	18.9	9.7	9.2	*0.061*	*0.039*	4.6	3.0	1.6
19-Aug	8/19/2016 5:30	8/21/2016 17:30	60.0	5609	1.04	**0.250**	**0.080**	39.7	12.7	27.0	**0.008**	**0.025**	1.3	4.0	-2.7
23-Aug	8/23/2016 23:30	8/24/2016 21:15	21.8	20731	1.56	**0.104**	**0.103**	61.1	60.5	0.6	**0.041**	**0.049**	24.1	28.8	-4.7
5-Sep	9/5/2016 6:20	9/8/2016 4:30	70.2	10835	1.74	**0.563**	**0.099**	172.8	30.4	142.4	**0.145**	**0.031**	44.5	9.5	35.0
15-Sep	9/15/2016 19:20	9/17/2016 22:30	51.2	4307	0.80	**0.155**	**0.126**	18.9	15.4	3.5	**0.014**	**0.022**	1.7	2.7	-1.0
21-Sep	9/21/2016 21:30	9/23/2016 14:00	40.5	10493	1.39	**0.142**	**0.073**	42.2	21.7	20.5	**0.016**	**0.027**	4.8	8.0	-3.3
23-Sep	9/23/2016 18:00	9/26/2016 8:30	62.5	1726	0.58	*0.250*	*0.128*	12.2	6.3	6.0	*0.061*	*0.039*	3.0	1.9	1.1
5-Oct	10/5/2016 4:50	10/6/2016 13:30	32.7	1672	0.61	**0.175**	**0.066**	8.3	3.1	5.2	**0.086**	**0.005**	4.1	0.2	3.8
6-Oct	10/6/2016 21:00	10/9/2016 15:00	66.0	11422	0.94	*0.250*	*0.128*	81.0	41.5	39.4	*0.061*	*0.039*	19.7	12.7	7.0
Totals:			891.7	227359	25.2			1611.4	826.6	**785**			392.8	254.0	**138.8**
Averages:			42.5	10827											

GREY FONT - Events with no sampling data, (flow weighted average concentraion used)
Bold - Sampled Event
Negative Load Reduction
TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

TP Summary	
FWA In (mg/L)	0.250
FWA Out (mg/L)	0.128
Total Load Captured (g)	785
Percent Reduction %	48.7

SRP Summary	
FWA In (mg/L)	0.061
FWA Out (mg/L)	0.039
Total Load Captured (g)	139
Percent Reduction %	35.3

City of Saint Paul
2016 Water Quality and Quantity Report
Table C.9
WSB Project Number 01610-100

JENKS POND WATER QUALITY SUMMARY

Pre-treatment[1,3]	Post-treatment[2]	Date Composite Sampling Start	Date Composite Sampling End/ Grab Sample	Soluble Reactive Phosphorus (mg/L)			Total Phosphorus (mg/L)			Dissolved Phosphorus (mg/L)		
Sample ID	Sample ID			Influent	Effluent	% Reduction	Influent	Effluent	% Reduction	Influent	Effluent	% Reduction
2490629	2490631	6/14/2016 19:32	6/15/2016 2:02	0.026	0.024	8	0.105	0.074	30	0.034 J	0.027 J	21
2502651	2502653	7/24/2016 8:19	7/24/2016 21:25	0.013	0.010	23	0.107	0.135	-26	0.061	0.025 J	59
2503644	2503646	7/27/2016 17:19	7/28/2016 4:15	0.009 J	0.017	-89	0.065	0.134	-106	0.021 J	0.023 J	-10
2507242	2507244	8/11/2016 8:40	8/11/2016 8:40	0.029	0.038	-31	0.130	0.063	52	0.048 J	0.048 J	0
MININUM				0.009	0.010	-89	0.065	0.063	-106	0.021	0.023	-10
AVERAGE				0.019	0.022	-22	0.102	0.102	-13	0.041	0.031	18
MEDIAN				0.020	0.021	-12	0.106	0.104	2	0.041	0.026	10
MAXIMUM				0.029	0.038	23	0.130	0.135	52	0.061	0.048	59

Laboratory analysis was completed by Metropolian Council Environmental Services (Samples on 5/11/2016 were analyzed by Pace Analytical)

1 - Pre-treatment samples were collected from the pond near the outlet control structure (OCS) 1 foot below the water surface

2 - Post-treatment samples were collected from the oulet pipe within the OCS

3 - Pre-treatment and post-treatment automated samplers were programmed to collect simultaneously at consistant flow intervals recorded by the flow meter within the OCS

Grab Samples

< - Analyte not detected above the Method Detection Limit (MDL), MDL value reported

J - Result reported as estimated between the MDL and Reporting Limit (RL)

JENKS POND POLLUTANT REDUCTION SUMMARY

Flow Event Start	Start	Stop	Treatment Event Duration (hours)	Flow Volume (cubic feet)	Total Rainfall (inches)	TP Pre-Treatment (mg/L)	TP Post-Treatment (mg/L)	TP Pre-Treatment Load (grams)	TP Post-Treatment Load (grams)	TP Load Captured (grams)	SRP Pre-Treatment (mg/L)	SRP Post-Treatment (mg/L)	SRP Pre-Treatment Load (grams)	SRP Post-Treatment Load (grams)	SRP Load Captured (grams)
28-Apr	4/28/2016 21:00	4/29/2016 11:30	14.5	455	0.97	*0.062*	*0.062*	0.80	0.80	0.00	*0.013*	*0.016*	0.17	0.21	-0.04
14-Jun	6/14/2016 14:00	6/15/2016 18:00	28.0	667	1.42	**0.105**	**0.074**	1.98	1.40	0.59	**0.026**	**0.024**	0.49	0.45	0.04
24-Jul	7/24/2016 8:00	7/25/2016 15:00	31.0	1376	1.71	**0.107**	**0.135**	2.02	2.55	-0.53	**0.013**	**0.010**	0.51	0.39	0.12
27-Jul	7/27/2016 14:00	7/29/2016 15:30	49.5	2202	0.98	**0.065**	**0.134**	1.23	2.53	-1.30	**0.009**	**0.017**	0.56	1.06	-0.50
4-Aug	8/4/2016 15:00	8/4/2016 23:00	8.0	130	1.82	**0.130**	**0.063**	2.45	1.19	1.27	**0.029**	**0.038**	0.11	0.14	-0.03
10-Aug	8/10/2016 20:30	8/11/2016 17:30	21.0	262	3.09	*0.062*	*0.062*	0.46	0.46	0.00	*0.013*	*0.016*	0.10	0.12	-0.02
24-Aug	8/24/2016 0:00	8/24/2016 5:30	5.5	15	1.56	*0.062*	*0.062*	0.03	0.03	0.00	*0.013*	*0.016*	0.01	0.01	0.00
6-Sep	9/6/2016 3:30	9/6/2016 14:30	11.0	93	1.17	*0.062*	*0.062*	0.16	0.16	0.00	*0.013*	*0.016*	0.04	0.04	-0.01
21-Sep	9/21/2016 21:00	9/22/2016 22:30	25.5	259	1.32	*0.062*	*0.062*	0.46	0.45	0.00	*0.013*	*0.016*	0.10	0.12	-0.02
6-Oct	10/6/2016 20:30	10/7/2016 6:00	9.5	237	0.90	*0.062*	*0.062*	0.42	0.42	0.00	*0.013*	*0.016*	0.09	0.11	-0.02
Sum			203.5	5694.6	14.9			10.01	9.98	0.02			2.17	2.66	-0.49
Average			37.0	569											

GREY FONT - Events with no sampling data, (flow weighted average concentraion used)

Bold - Sampled Event

Negative Load Reduction

TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

TP Summary	
FWA In (mg/L)	0.062
FWA Out (mg/L	0.062
Total Load Captured (g)	0.02
Percent Reduction %	0.2

SRP Summary	
FWA In (mg/L)	0.013
FWA Out (mg/L	0.016
Total Load Captured (g)	-0.49
Percent Reduction %	-22.7

Appendix D – Photolog

Saint Paul Stormwater 2016 Photolog

Arundel BMP Inspections

11/16/2016

4/7/2016

9/20/16

Beacon Bluff 4/6/2016

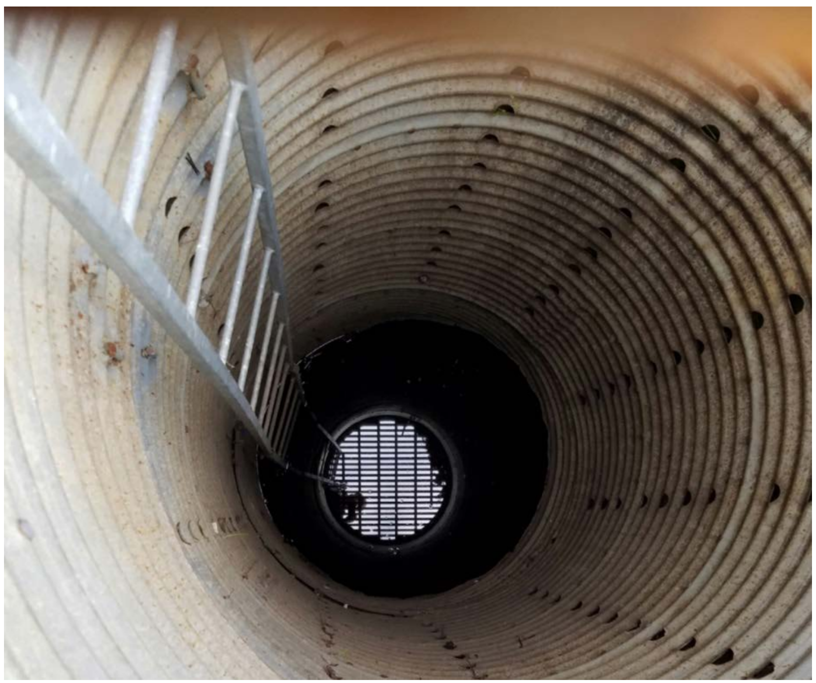


Beacon Bluff Rain Garden 5/6/2016

Beacon Bluff Rain Event
5/9/2016



Beacon Bluff BMP Inspection 5/20/2016



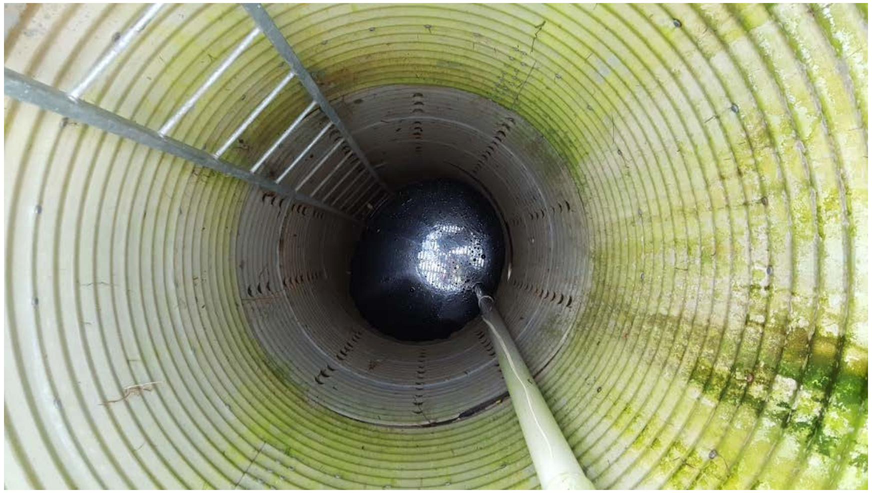
Beacon Bluff
6/9/2016 Rain Event

Beacon Bluff
8/2/2016

Beacon Bluff Post-brush Clearing 10/18/2016

Beacon Bluff BMP Inspection 11/15/2016

(SAFL Baffle – Top L, Rain Garden – Top R, West Pond – BTM L, and Underground Chamber – BTM R)



Sackett Pond
Rain Event 5/9/2016

Sackett Pond Floodplain Logger Install 5/20/6

Sackett Pond
8/2/2016

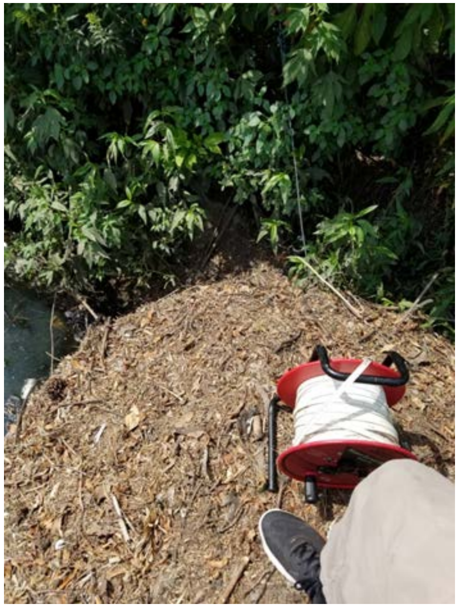
Flandrau-Hoyt Rain Event 5/9/2016

Flandrau-Hoyt
6/16/2016

(Debris on OCS)

Flandrau-Hoyt 8/2/2016

(Debris on OCS)



Hampden Park Rain Event 5/9/2016

Hampden Park BMP
Inspection 5/20/2016

Saint Albans BMP Pipe 4/7/2016

Saint Albans Install 4/12/2016

Saint Albans and University Install 4/12/2016

Saint Albans BMP Inspection 9/20/2016

(BMP Pipe – Top L, Vandalized Equip – Top R, Pre-treatment – BTM)




Saint Albans Pre-Treatment 11/16/2016

Magnolia Pond Install 4/18/2016

TBNS Ponds 5/25/2016 (Magnolia – Top, Jenks – BTM Left, Maryland – BTM Right)

TBNS 6/14/2016 (Magnolia – Top, Jenks – Bottom)

Magnolia Pond 6/20/2016

Magnolia Pond after large rain event, 8/11/2016

Maryland Pond after large rain event, 8/11/2016

Jenks Pond 8/11/2016

Hillcrest Knoll Park 5/20/2016

(Float/Gate Valve – L, Pre-treatment – M, BMP Chamber – R)

Hillcrest Knoll Park 11/15/2016

(Pre-treatment – L, BMP Chamber – R)

Appendix E – 2016 Monitoring Protocols

STORMWATER MONITORING PROTOCOL

2016 WATER QUANTITY AND QUALITY MONITORING PROGRAM

FOR THE CITY OF ST. PAUL, MINNESOTA

WSB PROJECT NO. 01610-100

The Most Livable City in America

& Associates, Inc.

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Attachments:

WSB Confined Space Entry Permit

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (BMP Infiltration Sites)

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (TBNS Infiltration Sites)

I. Objectives

This section provides a summary of objectives for this monitoring effort. These objectives are presented in question form anticipating that the answers will be obtained through analysis of the data collected as part of this monitoring program.

a) How do team members maintain a safe work environment?

b) How much stormwater runoff volume reduction is achieved by each BMP on an event and annual basis?

c) What is the average measured infiltration rate of each BMP?

d) How often does each BMP require maintenance?

e) How many volume reduction credits are available at each BMP? Do they perform in accordance with or exceed watershed district rules?

f) What is the cost per cubic-foot of volume reduction actually being achieved by each BMP?

g) What is the mass of pollutants (TP, TSS, chlorides, etc.) removed from the stormwater system by each BMP on an average annual basis?

II. Safety Overview

The following safety guidelines have been developed to ensure that all WSB team members are providing and maintaining a safe work environment. Proper planning and situational awareness can help team members identify and eliminate potentially dangerous situations. Every team member has stop work authority if they feel endangered by unsafe working conditions. All team members are encouraged to report unsafe acts or unsafe working conditions to their supervisor as soon as possible. The following sections describe potentially hazardous working conditions and hazard mitigation procedures.

II.1 Adverse Weather Conditions:

Field team members will likely encounter a wide range of weather conditions during field duties. Field staff should be aware of the weather conditions and take proper measures to protect themselves from the elements.

- During excessive heat and sun conditions, field staff should stay hydrated, don skin protective clothing, and apply sunscreen .During excessive cold conditions, field staff should dress in layers and avoid perspiration
- During lightning producing conditions, field staff must seek shelter in a work vehicle or other safe location if a lightning strike or thunder is observed. The field staff should wait at least 30 minutes from the last lightning strike before resuming outdoor activities. <u>Lightning safety is especially important due to the likelihood of thunderstorms during stormwater sampling events</u>
- Field staff should be aware of the signs of heat exhaustion, heat stroke, hypothermia, and frostbite, and have an understanding of basic first aid procedures

II.2 Working in the street:

At times, it will be necessary for team members to access manholes in roadways.

- While working in roadways, field staff should be visible to traffic, don reflective vests and hardhats, and utilize vehicle hazard lights
- Field staff should park close to the manhole and encompass work area with safety cones
- Field staff should be aware of any unauthorized entry into the work area by untrained personnel or the public

II.3 Confined Space Entry[1]

Only WSB staff with confined space entry training can complete a confined space entry. When entry to confined spaces is required for monitoring activities, the following checklist must be reviewed and adhered to:

<u>Permits/Notifications:</u>

- Execute a confined space entry permit form and follow appropriate protocols (**Confined Space Entry Permit Attached**). See WSB's safety office, Trent Noeker, for a copy of the form
- Obtain a no fee lane use right-of-way permit if work is to be done in the street:
    - St. Paul ROW: 651-266-6151

[1] Review <u>Entering and Working in Confined Spaces</u>, Confined Space Entry Program for WSB & Associates, Inc. for WSB's confined space entry protocols prior to entering a confined space.

- ☐ Notify City staff
    - St. Paul Sewer Maintenance: 651-266-9836
- ☐ Notify local fire department of planned confined space entry

Required Safety Gear:

- ☐ Hard hat
- ☐ Sturdy boots
- ☐ Reflective safety vest
- ☐ 4-Gas Monitor
- ☐ Tripod
- ☐ 3-way lifeline winch
- ☐ Body harness
- ☐ Air ventilation blower and generator
- ☐ 28” reflective traffic cones and vehicle hazard lighting

Gear Maintenance:

- ☐ **Calibrate 4-gas monitor every 180 days:** The 4-gas monitor will indicate when calibration is needed. Viking Safety Products will calibrate the device free of charge. Call Viking for more information: 651-646-6374.
- ☐ **Inspect the tripod for wear and damage annually:** Viking Safety Products will inspect the equipment and provide a formal certificate of inspection free of charge. Call Viking for more information: 651-646-6374

General Confined Space Entry Procedures:

- ☐ Never complete a confined space entry during a rain event. Check the weather forecast and ensure clear conditions for the duration of the entry.
- ☐ Prior to leaving the office, confirm all equipment is functioning and that monitoring equipment is in compliance with the calibration schedule.
- ☐ Secure the area from untrained personnel and pedestrians.
- ☐ Ensure team members are knowledgeable of the roles and responsibilities of the confined space entrant, attendant, and supervisor.
- ☐ Complete air monitoring prior to, and for the duration of the confined space entry. Ensure team members are knowledgeable of the 4-gas monitor alarms and unsafe gas levels that prompt an evacuation of the confined space.
- ☐ Utilize a rope and bucket to deliver equipment to the entrant.
- ☐ Ensure there is a reliable method of communication between all team members completing the confined space entry.

III. Monitoring Sites

Below is a summary of sites which are included in this monitoring effort. Equipment and methods used and monitoring parameters analyzed for each site are provided for quick reference. (See Figures for site locations and monitoring configuration.)

III.1 Beacon Bluff:

This site consists of an infiltration basin situated over the top of an underground infiltration pipe gallery system. Stormwater flows into the infiltration basin from three storm sewer outfalls and into the underground chambers from a single storm sewer pipe. An outlet pipe connected directly to the underground chambers conveys overflow back to the storm sewer when the system reaches capacity.

Equipment:

3 – ISCO 2150 Area velocity sensors (Upstream, Downstream, WPO)
6 – System Level Loggers
- BMP Pipe
- OCS
- IR-31(Rain Garden - west)
- IR-32 (In-rock east)
- IR-33 (Rain Garden - east)
- BaroTroll (atmospheric logger)

4 – Groundwater Level Loggers (reduced to 2 mid-way of season)
1 – ISCO 6712 Portable water quality sampler

Monitoring Parameters:

- Rainfall
- Flow Rate/Volume
- Water Level/Infiltration rate
- Water Quality **(NPDES Permit Required Parameters)**

III.2 Hillcrest Knoll Park:

Flow is diverted from the main storm sewer into the Hillcrest Knoll Park infiltration BMP. When the system has reached its storage capacity, a float gate valve closes the inlet and water continues through the storm sewer downstream. The system includes a Vortechs pretreatment device to provide skimming and settling of runoff prior to entering the infiltration chamber.

Equipment:

2 – ISCO 2150 Area velocity sensors (Upstream, Downstream)
3 – Level Troll 500
- BMP Pipe
- IR-1
- HK-GW

Monitoring Parameters:
- Rainfall
- Flow Rate/Volume
- Water Level/Infiltration rate

III.3 St. Albans:

The St. Albans Street infiltration system was constructed in 2010 to provide volume reduction along the Central Corridor. The system was constructed in an offline configuration. When the system reaches its storage capacity, water stops flowing into the system and continues through the storm sewer. The system includes a pretreatment structure which consists of box culvert sections and baffled weirs to provide skimming and settling of runoff prior to entering the infiltration chamber.

Equipment:

3 – ISCO 2150 Area velocity sensors (Upstream, Downstream, SA-University)
1 - Level Troll 500
BMP Pipe

Monitoring Parameters:
- Rainfall
- Flow Rate/Volume
- Water Level/Infiltration rate

III.4 Arundel Street:

The Arundel Street infiltration system was constructed in 2011 to provide volume reduction along the Central Corridor. The system was constructed in an offline configuration. When the system reaches its storage capacity, water stops flowing into the system and continues through the storm sewer. The system includes a pretreatment structure which consists of box culvert sections and baffled weirs to provide skimming and settling of runoff prior to entering the infiltration chamber.

Equipment:

1 - Level Troll 500
BMP Pipe

Monitoring Parameters:
- Rainfall
- Water Level/Infiltration rate

III.5 Hampden Park

The Hampden Park infiltration gallery was constructed in 2014. The system consists of eight parallel perforated pipes that are five feet in diameter and range in length from 40 to 100 feet. Runoff is routed to the pretreatment system via a 24" RCP from main storm sewer near Hampden and Raymond Avenues. From that location, stormwater enters a pretreatment structure which consists of a box culvert section and baffled weir to provide skimming and settling of runoff prior to entering the infiltration chamber. The infiltration gallery receives flow from a second inlet location along Raymond Avenue, farther to the north. When the system reaches full capacity, stormwater is routed back to the storm sewer via a 24" pipe from the southeast side of the system.

Equipment:

1 – ISCO 6712 Portable water quality sampler
2 – ISCO 2150 Area velocity sensors (Upstream, Downstream- **No modem, direct connect download**)
1 – Level Troll 500
    P-2
1 – Rugged Troll 100
    BMP

Monitoring Parameters:

- Rainfall
- Water level/Infiltration rate
- Flow Rate
- Water Quality **(NPDES Permint Required Parameters)**

III.6 Trout Brook Nature Sanctuary

The Trout Brook Nature Sanctuary (TBNS) is a 42 acre site located between Norpac Road and Maryland Avenue, west of I-35E. The objective of the construction effort, which was finalized in 2015, was to create a nature preserve in the heart of a heavily urbanized area. The focal points of the plan included expanding the Trout Brook Regional Trail and daylighting the Trout Brook creek, which had previously been filled in and routed through underground sewer. The development of the sanctuary also included a series of stormwater management features including wetlands and ponds constructed with iron enhanced sand for additional water treatment.

Stormwater is conveyed to the iron-enhanced ponds from individual diversion structures along the 42” main stormsewer line. Prior to the pond, the flow is routed through a Vortech’s pre-treatment structure for particle settling. As the level in the pond rises, the water gravity flows through a sand filtration bench that has additional iron content. The iron-enhanced sand provides a mechanism to remove soluble reactive phosphorus, a dissolved bio-available form of phosphorus, which is not effectively removed by settling pre-treatment devices. Beneath the sand bench is 8" drain tile to convey the treated water to the outlet control structure of the pond.

The City completed performance monitoring at three iron enhanced ponds at the Site: Maryland Pond, Magnolia Pond, and Jenks Pond. Removal efficiency of the iron enhanced material was determined by collecting samples simultaneously from the within the pond and the pond outlet control structure. A flow sensor was installed in the outlet control structure to provide treatment volume for load reductions.

Equipment (Complete set at each of the three ponds) :

1 – ISCO 2150 Area velocity sensors (outlet control structure)
2 – ISCO 6712 portable water quality sampler (pond, outlet control structure)
1 – Van Essen Mini-Diver
Pond

Monitoring Parameters:

- Rainfall
- Water Level
- Flow Rate
- Water Quality **(Total Phosphorus, Dissolved Phosphorus, and Soluble Reactive Phospohrus only)**

III.7 Level Logger Only Sites

The following Sites are evaluated for level/infiltration only. The sites include:

Level Only sites:

- Montreal Trench
- Wordsworth Trench
- Sackett Park Pond
- Flandrau-Hoyt Pond
- East Phalen (groundwater)

Each site consists of 1 – In-Situ electronic level logger.

IV. Preparation and Logistics

Preparedness is crucial to successful implementation of this monitoring program. Anticipation of target storm events, readiness with field equipment, and understanding of confined space entry procedures play a role in this process. This section provides essential information related to these items.

IV.1 Storm Selection Criteria for Water Quality Sampling

The activities below should be completed at least weekly to determine the potential need to prepare sampling equipment and mobilize crews to undertake water quality samplings:

- Track storms using local ALERT systems and by accessing National Weather Service forecasts: www.nws.noaa.gov
- Determine Quantity of Precipitation Forecast (QPF) for an impending storm
- If QPF is greater than 0.1-inches initiate sample collection preparation procedures (see **Section 6**)

IV.2 Portable Sampler (ISCO 6712) Preparation

This is to be done after all sampling events and or when receive a low battery alarm.

- Change out samples bottles in automated sampler with clean bottles
- Reset automated sampler for a new event. Update the sample flow volume interval if more or less samples need to be collected based on lab requirements, storm event size, or modification to protocols
- Ensure that batteries are adequately charged and positioned
- Make sure clean grab sample bottles are on hand

V. Visual Inspection and Manual Data Collection

Routine BMP inspections conducted on a visual basis will provide information related to specific maintenance needs and provide information that may be pertinent to any anomalies in the water quality sampling results. Additionally, the pervious pavement infiltration studies will consist of manual data collection in accordance with ASTM method C1701. The following section provides field guidance for those tasks.

Infiltration SystemsFrequency:

- Once per month

Visual Inspection:

- Identify significant obstructions present in the source pipes
- Indicate whether there is standing water in the infiltration system
- Indicate whether there is evidence of illicit discharges
- Identify any structural issues in the system
- Describe other observations
- Sketch inspection observations as appropriate

Manual Data Collection:

- Take digital photos of all visual inspection parameters
- Quantify the amount of sediment present in the system's:
  - Sump manhole
  - Pretreatment device
  - Stormwater storage area
- Quantify the amount of floatables present in the system's:
  - Sump manhole
  - Pretreatment device
  - Stormwater storage area

Required Equipment:

- Measuring rod
- Digital camera

Required Forms:

- Infiltration BMP Inspection and Maintenance Form

V.1 Pervious Pavement Infiltration Tests

Frequency:

- Once per year

Visual Inspection:

- Identify number and location of missing pavers (if present)
- Identify significant cracking, chips, or other damage
- Identify location and approximate depth of deflection

Manual Data Collection:

- Take digital photos of all visual inspection parameters
- Record depth of aggregate at six (6) locations (if pavers)
- Measure infiltration rate in six (6) locations
    - Follow the modified ASTM method C1701
    - Locations should be marked by a drill hole or a nail so that the same locations can be tested each time
    - 3 locations should be within 1 foot of the concrete strip separating the permeable surface from the roadway

Equipment:

- Infiltration measurement apparatus
- Water tank and feeder hose
- Digital camera
- Scale
- 12” PVC Pipe
- Plumbers putty

Required Forms:

- Permeable paver inspection form

Monitoring Parameters:

- Infiltration rate
- BMP visual inspection

VI. Sample Collection, Preservation, and Laboratory Analysis

The following procedures must be followed to maintain a consistent approach for obtaining composite water quality samples and to reduce the risk of cross contamination when retrieving and transporting samples to the laboratories:

VI.1 Composite Sampling Using Automated Sampler:

Estimating pollutant loads as part of this monitoring program will include determination of the event mean concentration (EMC) for the target storm events using composite samples. To obtain composite samples that are representative of the storm events analyzed, the following minimum number of aliquots and percent capture values should be met:

Total Event Precipitation (in.)	Minimum Acceptable Number of Aliquots	Percent Capture Requirement[2]
0 – 0.25	6	85
0.25 – 0.50	8	80
0.50 – 1.0	10	80
> 1.0	12	75

To meet these requirements the automatic samplers should be programmed to collect samples at flow-paced intervals. Determination of the flow volume between sampling events should be based on the following information:

Total Event Precipitation (in.)	Hampden Park	Beacon Bluff
	Runoff Volume (cu-ft)	Runoff Volume (cu-ft)
0.10-0.15”	2,430	4,500
0.25”	3,869	20,986
0.5”	5,516	63,000
1.0”	10,539	156,756
2.0”	48,834	373,550
3.0”	138,105	657,879

Program Automated Sampling Parameters:

Based on the information above and other considerations, the following provides the parameters that should be used for programming the automated samplers:

- **Start Time:** Begin sampling at specific water level depths
  - Hampden Park 1.0-inches
  - Beacon Bluff: 1.0-inches

[2] $$Percent\ storm\ capture = \frac{flow\ volume\ that\ passed\ during\ sample\ collection}{total\ flow\ that\ passed\ during\ the\ entire\ monitoring\ event}$$

- **Pacing:** Set sampler to collect samples at constant flow volume intervals
  - Beacon Bluff: minimum 1,750 cu-ft (0.034 Mgal)
  - Hampden Park: 405 cu-ft (0.010 Mgal)
- **Distribution:** Multiple samples per bottle - sample aliquot volume should be no less than 200 mL

Multiple bottles will be collected for each event. The testing laboratory should be directed to develop a composite sample with the collection of bottles by either batch mixing or by combining equal fractions of each bottle into a single bottle or container.

VI.2 Grab Sample Collection

Grab samples will be collected for E coli analysis from the Beacon Bluff and Hampden Park. Samples will be collected from the influent stormwater stream prior to entering the systems. The purpose of E. coli analysis is to ensure that human effluent is not contaminating the water. The following provides the process for obtaining the grab samples:

Sampling Locations:

- Man holes up stream of the automatic samplers at Hampden Park and Beacon Bluff

Procedures:

- Collect 3 samples (one every 10 minutes for composite testing) while it is raining.
- Use sterile sample bottles with an unbroken seal when testing for e-coli
- Place sample bottle directly below or in outfall water stream to collect the sample

Required Equipment:

- Personal rain gear
- Powder-free nitrile gloves
- 1-Liter plastic sample bottles and lids
- Sterile bacteria sample bottles and lids from laboratory
- Bottle labels and water proof pen
- Chain of custody forms for laboratory
- Manhole pick
- Cooler with ice
- Grab sample collection rod

VI.3 Analytical Parameters:

The following table provides a list of parameters and the sampling frequency as established by Permit No. MN0061263. Samples collected from the automated samplers will be analyzed for the water quality parameters in Table 1 of the City of St. Paul's MS4 permit (when volumes allow). These parameters do not apply to the TBNS Sites.

Monitoring Parameters		
Parameters	**Sample Type**	**Frequency**
BOD, Carbonaceous 5-Day (20 Deg C)	Composite or Grab	Quarterly

Chloride, Total	Composite or Grab	As noted for loading calculations (Par V.C7.f)
Copper, Total (asCu)	Composite or Grab	Monthly
E. coli	Grab	Quarterly
Flow	Measurement	
Hardness, Carbonate (as CaCo3)	Composite or Grab	Monthly
Lead, Total (as Pb)	Composite or Grab	Monthly
Nitrite Plus Nitrate, Total (asN)	Composite	As noted for loading calculations (Par V.C7.f)
Nitrogen, Ammonia, Un-ionized (as N)	Composite	Quarterly
Nitrogen, Kjeldahl, Total	Composite	As noted for loading calculations (Par V.C7.f)
pH	Composite or Grab	Quarterly
Phosphorus, total Dissolved or Ortho	Composite	Quarterly
Phosphorus, Total as P	Composite	As noted for loading calculations (Par V.C7.f)
Precipitation	Measurement	1 x Day
Solids, Total Dissolved (TDS)	Composite	Quarterly
Solids, Total Suspended (TSS)	Composite	As noted for loading calculations (Par V.C7.f)
Sulfate	Composite or Grab	2 x Year
Volatile Suspended Solids (VSS)	Composite	As noted for loading calculations (Par V.C7.f)
Zinc, Total (as Zn)	Composite or Grab	Monthly

Samples Collected at the TBNS shall be analyzed for Total Phosphorus, Dissolved Phosphorus and Soluble Reactive Phosphorus.

VI.4 Sample Preservation

- Collect samples from automated sampler within 24 hours
- Composite individual sample containers from the autosampler into one, clean, 4-liter jug, provided by MCES Lab
    - If the storm event produced volume in exceess of 4 liters, the sample volume shall be composited in the churn sampler splitter.
    - Fill the churn will all samples collected from the event. One staff shall provide constant mixing using the paddle, while the other staff shall open the spickot, gradually filling the lab container with the mixed sample
    - The churn sampler splitter shall be cleaned between uses
- The sample containers shall be labeled with the relevant Site and sample information which shall include:
    - Site Name [**See attached Chain of Custody (CoC)** examples for Site IDs].
    - The composite start and end time, as indicated on the autosampler
    - Name of staff collecting the sample
- The sampler shall complete a CoC form to submit with the sampler or communicate sample information to the Project Manager to complete the form electronically, and submit to the lab
- Place all samples to be analyzed in a cooler with ice
    - Target holding temperature for samples is 4˚C
- Deliver samples to lab

VI.5 Cleaning of Sample Equipment and Bottles

- **Clean sample bottles and churn splitter after every use:** wash them with a brush and soapy water or use a dishwasher
- **Clean the suction line, strainer, and pump tubes twice per year:** Place the end of the suction line in a cleaning solution and pump it through the system. Rinse with clean water

VI.6 Quality Assurance/Quality Control:

- Before samples are collected, make sure that all sampling equipment and bottles are cleaned using the appropriate cleaning procedures
- Wear powder-free nitrile gloves when handling bottles, lids, tubing, or strainers.
- Never touch the inside surface or exposed end of a sample bottle or lid, even with a gloved hand
- Never let any material other than sample water touch the inside surface or exposed end of sample bottle
- Avoid allowing rain water to drip from rain gear or other surfaces into sample bottles

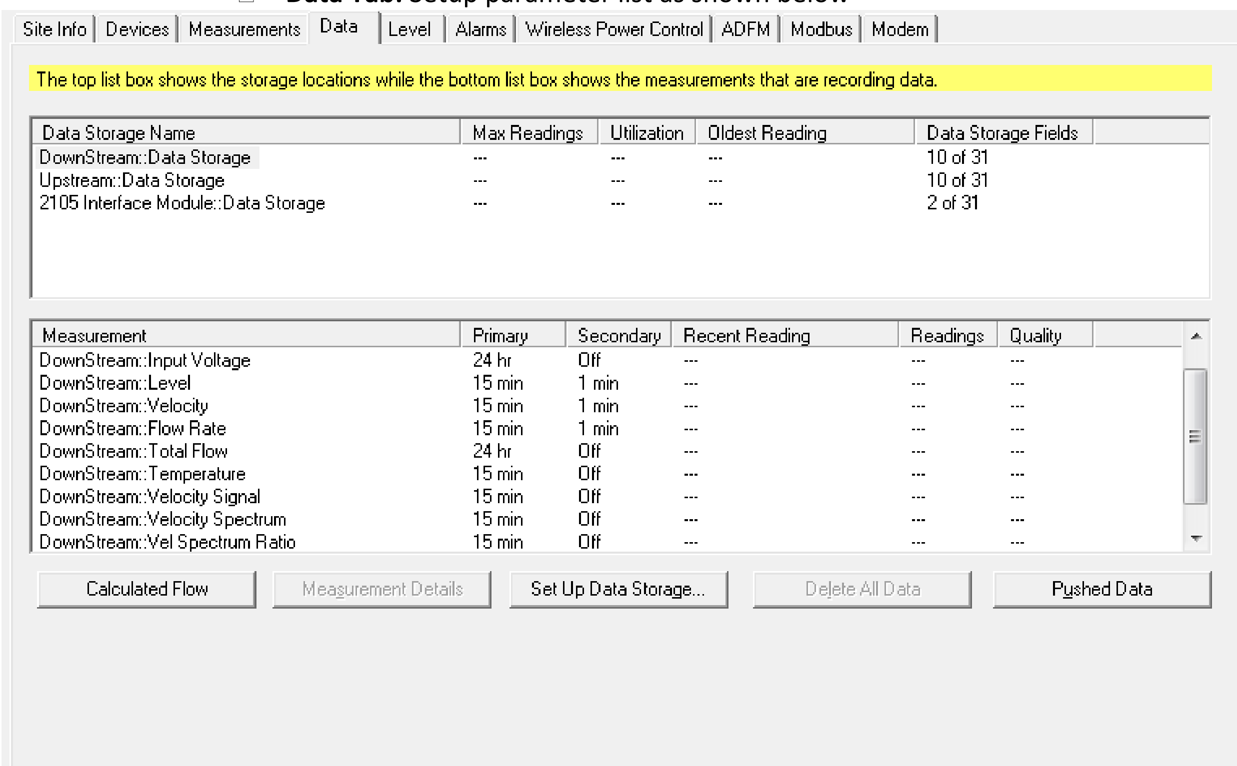
VII. Operation and Maintenance of Monitoring Equipment

The following provides a summary of procedures to follow for operating and maintaining monitoring equipment for collection of flow, rainfall, water level, and sampling data. These procedures should be followed when the devices are initially setup and during routine data dumps and maintenance activities.

VII.1 Flow Meters (ISCO 2150)[3] and Interface Modules (ISCO 2105/2103)[4]:

Setup/Initialization:

- **Software Required:** Flowlink
- **Quick Connect:** Connect the device to a laptop using the communication cable. Start Flowlink and select Quick Connect Icon in the tool bar. Use "Direct" Type Connection and check "Create New Site" for new instillation. Click on the large *2100 Instruments* button to connect
- **Site Info Tab:** Add applicable information and "Synchronize Site's Time to Computer's"
- **Devices Tab:** Change Module Names for Area Velocity Meters to reflect location
- **Data Tab:** Setup parameter list as shown below



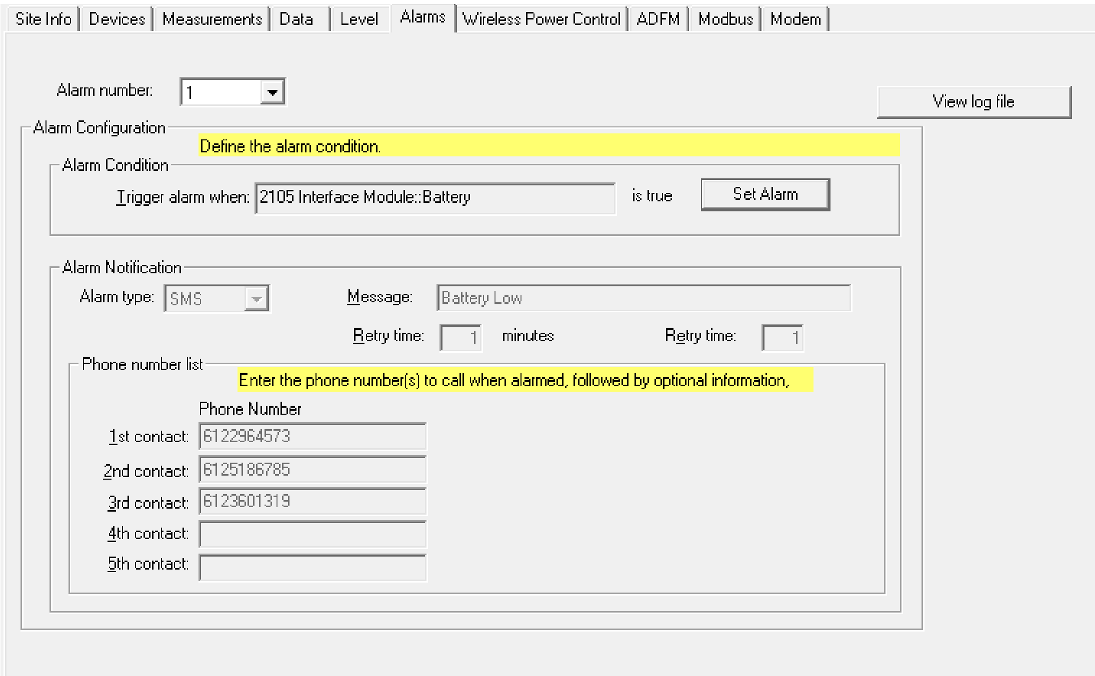
- **Measurement Details:** Set units for all measurements (in, cfs, or cf)
  - **Level:** If flow is present, measure the water depth from the water surface to the channel bottom. Enter the value on the *Level*

[3] See 2150 Area Velocity Flow Module and Sensor – Installation and Operation Guide, Teledyne ISCO, Rev. March 9, 2011.

[4] See 2105 Interface Module – Installation and Operation Guide, Teledyne ISCO, Rev. July 8, 2010.

measurement tab in FLowlink. If no flow is present, enter a value of zero. (Level measurements may drift over time, so it is important to do this routinely.)

  - **Velocity Measure Tab:**
    - **No Velocity Data:** Uncheck the *"Set flow rate to zero if no velocity data"* checkbox on the *Velocity* measurement tab in Flowlink. Data can be post processed to remove low level velocity noise
    - **Synchronize Velocity Measurements:** Check the Prevent *interference box* on the *Velocity* measurement tab in Flowlink to prevent velocity signal interference at sites with multiple modules
  - **Flow Rate Tab:** Input pipe shape and diameter.
- **Data Storage Rates:** Click on *Set Up Data Storage…* button on a measurement tab in Flowlink to set storage rate.
  - <u>Level</u>, <u>Velocity</u>, <u>Flow Rate</u>, <u>Total flow</u>,: Primary = *15 min*, Secondary = *1 min* (Flow Depth > 1in)
  - <u>Temperature</u>, <u>Velocity Signal</u>, <u>Velocity Spectrum</u>, <u>Velocity Spectrum Ratio</u>: Primary = 15 min
  - <u>Input Voltage</u>, <u>Wireless Signal</u>: Primary = *24 hours*
    Note: In "Condition Builder" set Hysteresis to 0.5" and Duration to 5 min for all Sampler Level Triggers.
- **Pushed Data Capability:** Click the Pushed Data button to set up a schedule for the data to be pushed
  - **Set IP address:** 207.173.231.99, Port 1700
  - Use Primary Data Transmission interval of *4 hours*
- **Alarms Tab:**
  - **Alarm Condition:** Define alarm condition using Equation Builder
    - Low Battery: When Modem Input voltage drops below 10V



- **Sampler Interface:**
  - **Set Up Data Storage:** Select "Enable Logging"
  - **Sampler enable:** Enable on Trigger - using equation builder to specify level threshold to enable sampler

    Note: In "Condition Builder" set Hysteresis to 0.5" and Duration to 5 min for all Sampler Level Triggers
  - **Sampler Pacing:** input desired flow pulsing interval in cubic feet

<u>Routine Data Retrieval and Re-initialization:</u>

- **Frequency:** Once per month
- **Quick Connect:** Connect the device to a laptop using the communication cable Start Flowlink and click on the large *2100 Instruments* button to connect
- Download data and transfer to WSB server folder K:\01610-100\WR\Flow Data
- Set water level to zero. (Make sure to annotate date and time of level reset)

<u>Routine Maintenance:</u>

The following maintenance activities must be completed routinely and during every field visit:

- **Check desiccant cartridges:** When entire length of the cartridge turns pink or green, the desiccant needs to be replaced
- **Check battery voltage:** Replace both batteries when voltage is below 10
- **Check hydrophobic filter:** Rinse and dry if the filter is plugged
- **Check connector O-rings:** Replace or lubricate as needed
- **Check flow sensor:** Remove debris and clean sensor as needed
- **Check sensor cable for damage:** Replace if needed. Loose cable should be fastened to the structure

VII.2 Portable Sampler (ISCO 6712)[5]:

Setup/Initialization:

- **Software Required:** Flowlink
- **Measure length of suction hose:** Length will be a required input during Program setup. Cut hose to whole ft. Increments if required. Hose should generally slope downward toward the sampling probe
- **Use Standard Program:** Follow Steps in Table 4-2 of the operation guide for flow pacing. Make the corresponding deviations listed below. Standard Programing Flow Charts can also be found in Appendix A in the operation guide (Figures A-2 & A-3)
  - (3)Set appropriate Site Description (i.e. Hampden Park, Beacon Bluff)
  - (8) Select 1 pulse between sample events
  - (9) Samples/Bottle
  - (11) 5 Samples/Bottle (200 mL each)
  - (12) No Delay to Start
- **Automatically index to next bottle when sampler is enabled:** This will allow each storm event to be composited separately, but may decrease the overall available sampling volume during multiple events
  - From home screen, enter 6712.9 and hit enter
  - Enter Code: 1199 and hit enter (Sampler should report Code Accepted)
- **Calibration:** The Sampler delivers accurate sample volumes without calibration. If you find that sample volumes vary significantly from the programmed values, first check the suction line for proper installation. Be sure it slopes continuously downhill to the liquid source and drains completely after each sampling cycle. Refer to Section 4.12 of the operation guide for additional calibration notes
  - Note: If sampler does not disable when the program is set to run, check all cable connections and then make sure the 2105 is configured correctly. If the water level is below the trigger threshold, the 2105 should be indicating that the Sampler is disabled. If the sampler is still not disabling, the cable or the sampler may be malfunctioning. The cable can be diagnosed by removing the sampler cable and using a paper clip to short pins “B” and “F” on the back of the sampler control head

Routine Data Retrieval and Re-initialization:

- **Frequency:** Once per month
- **Interrupt Program:** Press the Stop button once to pause the program. Scroll down to “VIEW DATA” and check for errors with sampling. See page 4-19 in the operators guide for more information. When complete, select “RESUME PROGRAM”

Routine Maintenance:

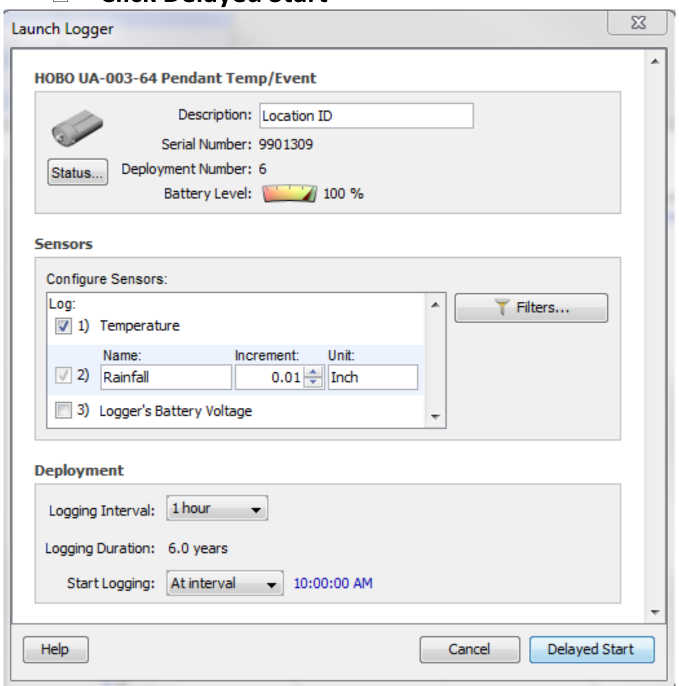
[5] See 6712 Portable Samplers – Installation and Operation Guide, Teledyne ISCO, Rev. April 11, 2011.

- ☐ **Check the pump tube for wear:** Replace if necessary
- ☐ **Check the pump tubing housing:** Clean if necessary
- ☐ **Check the suction line:** Change if necessary
- ☐ **Check the humidity indicator:** Desiccant should be replaced when all indicator areas turn light pink or white
- ☐ **Check the controller's internal battery status:** Replace the battery every five years
- ☐ **Check the keypad label:** If it has bubbles under it, the air inside the controller has expanded, and pressure can be released by unscrewing the flow meter cable or connector cap on the back of the controller

VII.3 Data Logging Rain Gauge:

Setup/Initialization:

- **Software Required:** Onset HOBOware.
- **Connect Rain Gauge:** Open HOBOware and select Launch Device.
- **Configure Sensors:**
  - Log 1) Temperature
  - Log 2) Rainfall
    - Name: Rainfall
    - Increment: 0 .01
    - Unit: Inch
- **Deployment**
  - Logging Interval: 1 hour
  - Start Logging: At Interval
- **Click Delayed Start**



Routine Data Retrieval and Re-initialization:

- **Frequency:** Once per month
- **Connect to device using HOBOware:**
- Download data using readout device and transfer to WSB server folder K:\01610-100\WR\Exported Data. (Do not stop logging before reading out the logger until the end of the season)

Routine Maintenance:

- **Check the filter screen, funnel, and tipping mechanism for debris** (dirt, bugs, bird droppings, etc.): Clean with mild soap and water
- **Check the needle bearings and apply light oil annually**

VII.4 Water Level Logger (Level Troll 500)[6]:

Setup/Initialization:

- **Software Required:** Win-Situ 5
- **Piezometer Specifications:** 3" PVC Pipe should be used as a Piezometer for underground stormwater structures. Drill ½" holes on four sides of the pipe so that there are approximately 20 holes per foot of length in the pipe. Holes do not need to be drilled above top of BMP structure. Wrap section expected to be submerged in highly permeable geotextile fabric, and secure with zip ties. Secure the pipe to the floor, the manhole, and the overhead casting wall
- Hang the Logger from the eye bolt installed inside of PVC pipe piezometer. This will allow a more accurate set up of the reference elevation
- **Stabilization Time:** Allow the Level TROLL to stabilize to the water conditions for *about an hour* before logging data. A generous stabilization time is always desirable, especially in long-term deployments. Even though the cable is shielded, temperature stabilization, stretching, and unkinking can cause apparent changes in the probe reading. If you expect to monitor water levels to the accuracy of the probe, it's worth allowing the extra time for the probe to stabilize to its environment
- **Connection:** With the Troll Com plugged into a USB port, launch Win-Situ Software
- **Win-Situ Launches:** the screen shows the "My Data Tab".
  - On first connection, be sure to select the correct COM port for a USB connection
  - Then connect to the device
- When Connected, the focus shifts to the Home tab. Readings are shown in "meter" view. Values in gray are not being updated in real time
- **Set up a site**: Click the Site Button, select the Default Site or Click the New button to set up a custom site. The site name can have up to 32 characters. Location coordinates are optional
- **Set up a data log:** follow the steps in the logging setup wizard.
  - **Log Name:** Site_2015_ Monitoring Season
  - **Log Parameters:** Pressure (PSI), Temperature (F), Elevation (ft.)
  - **Choose Logging Method:** Long-Term Monitoring – Event
  - **Choose Event Parameter:**
    - Check event parameter every 1 min
    - Log all parameters when the event is greater than 0.25 ft. above BMP invert, or normal water level elevation
    - Default record data every 60 measurements
  - **Schedule Start time:** on Next Hour
  - **Output:** Ground Water Elevation
  - **Set Level Reference to Depth of Water:** Select new reference

[6] See Level TROLL – Operator's Manual, In-Situ Inc., March 2010.

        - Calculate the reference elevation as either the casting invert (known elevation) minus the distance to the water surface, or to the bottom of the sensor probe if the Piezometer is dry.
        - Be sure to note the casting invert reference elevation used, and the calculated elevation of the bottom of the sensor probe in the Notes option in the Site Data Folder for future reference
    - **Specific Gravity Value**: Custom 0.999
- **Finished Programing:** Disconnect the Troll Com and reattach the desiccant

Routine Data Retrieval and Re-initialization:

- **Frequency:** Once per month
- **Connect to device using Win-Situ 5:**
- Download data and transfer to WSB server folder K:\01610-100\WR\Exported Data. (Do not stop logging until the end of the season)
- Re-reference water level elevation
    - Select "Sensor Tab" then click on calibrate sensor.
    - **Adjust Level Reference:** input the New Reference if required

Routine Maintenance:

- **Check desiccant cartridge:** When entire length of the cartridge changes color, the desiccant needs to be replaced
- **Check minimum cable bend radius:** Half the cable diameter = Approx. 0.54".
- **Check the holes in the nose cone:** If they are plugged, swish the Level TROLL in a bucket of water, rinse under a tap, or soak in a mild acidic solution such as vinegar overnight
    - DON'T dig or scrape in the pressure sensor openings!
    - DON'T touch the pressure sensor diaphragm when the nose cone is removed!
- **Check twist-lock connectors**: Keep pins on all connectors free of dirt and moisture
- **Field Recalibration:** Sensor should be factory recalibrated every 12-18 months. The following procedure may be used, **with caution,** to "zero" the offset of a vented pressure sensor to correct for electronic drift. The drifted offset is visible when the sensor is in air and reading other than zero. It is recommended you **do not** zero the offset if it is outside the specified accuracy of your pressure sensor (30 PSI Sensor: ±0.03 PSI). If the reading in air deviates from zero by more than this amount, you may want to consider a factory recalibration

Attachments

WSB Confined Space Entry Permit

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (BMP Infiltration Sites)

Metropolitan Council Environmental Services Laboratory Chain-of-Custody (TBNS Infiltration Sites)

WSB & Associates, Inc.
Safety and Health Program

Confined Space Entry Permit	SAF-002-01	Revision 1

Reference WSB & Associates, Inc. Confined Space Entry Program when completing this permit.

Section 1: General Entry Information

Space Description		Entry Date(s)	
Work Being Performed		Authorized Duration	

Section 2: Hazard Analysis

Space Related Hazards Anticipated

YES☐ NO☐ **O_2 Enrichment / Deficiency**	YES☐ NO☐ **Pressurized System**	YES☐ NO☐ **Engulfment/ Entrapment**
YES☐ NO☐ **Flammables**	YES☐ NO☐ **Electrical**	YES☐ NO☐ **Fall Potential**
YES☐ NO☐ **Toxic Atmosphere**	YES☐ NO☐ **Mechanical**	YES☐ NO☐ **Temperature Extremes**
YES☐ NO☐ **Other** (Describe)		

Work Related Hazards

YES☐ NO☐ **Weld / Cut / Grind**	YES☐ NO☐ **Solvents / Coatings**	YES☐ NO☐ **Compressed Gasses**
YES☐ NO☐ **Other** (Describe)		

Section 3: Initial Air Sampling

Substance	Acceptable	Reading	Initial Sample By	
Oxygen Content	19.5-23.5%	%		Date/Time: __________/_________
Flammability/LEL	<10%	%		
Carbon Monoxide	< 35 PPM	PPM	Sample Monitor Number	List other Sampling
Hydrogen Sulfide	< 10ppm	PPM		
Other:				

Note - Gases and Vapors can be heavier than air. Unless the space has ventilation paths that circulate all air in the space, sampling must be performed that tests various levels within the space. If entry into this space is required for testing, entry will be made under this permit and attendant SHALL be posted.

Section 4: Control / Elimination of Hazards

Hazard	**Is the Hazard Controlled or Eliminated? (Circle One)**	**Document how the hazards in the space are being controlled or how the hazards have been eliminated.**
	Controlled Eliminated	
	Controlled Eliminated	
	Controlled Eliminated	
	Controlled Eliminated	
	Controlled Eliminated	
	Controlled Eliminated	

Is isolation needed for this work? YES☐ NO☐ If YES, Describe: ______________________________

WSB & Associates, Inc.
Safety and Health Program

Confined Space Entry Permit	SAF-002-01	Revision 1

I certify that all hazards of the space are either controlled or eliminated.

Entry Supervisor (print): ____________________________ (signature):___________________________ Date: ____/____/____

Section 5: Classification of the Space (Determined by Entry Supervisor)

This Space Classified As:

☐ **Permit Required**	Complete Sections 1 – 10 of permit
☐ **Alternate Procedure** (No physical hazards, all atmospheric hazards are controlled with forced air ventilation)	Complete sections 1 – 5, 8 (10 optional) of permit
☐ **Non-Permit Required** (Reclassified from Permit Required) NO HAZARDS EXIST – All Hazards identified in Section 2 have been Eliminated and certified under Section 4	Complete sections 1 – 5, 8 (10 optional) of permit

If it is necessary to reclassify this space, this permit must be removed and a new permit with the correct classification be issued.

Air Sampling Required: ☐ Periodically: (how often) ___________ ☐ Continuously (Mandatory for Permit-Required)
Log Follow-up Air Sampling Results in Section 10, Log continuous sample every 15-20 minutes

Section 6: Rescue Service Requirements (Mandatory for Permit-required Entries)

Rescue Service Identified: _____________________________________ (Not Required for Non-Permit Spaces)

Method to summon Rescue Service: ☐ Radio ☐ Paging System ☐ Phone (Location) __________ ☐ Other __________

Section 7: Task Related Hazard Protective Measures (Check any required)

☐ Mechanical Ventilation	☐ Protective Clothing	☐ Non-Entry Rescue Equipment / Lifeline
☐ Attendant	☐ Explosion Proof Lights	☐ Other (List)
☐ Respiratory Protection	☐ Flash Lights	
☐ Fall Protection	☐ Life Vests	
☐ Fire Extinguisher	☐ Explosion Proof Lighting / Tools	
Attendant / Entrant Communications: ☐ Visual ☐ Audible ☐ Phone ☐ Radio ☐ Page System ☐ Other:____________		
Additional Permits in Effect: (example hot work)		
Additional Information Necessary to Ensure Employee Safety:		

Section 8: Authorization by Entry Supervisor (each occupied space)

I certify that all precautions have been taken and necessary equipment provided for safe entry and work in this confined space.

Initial Entry Supervisor:

Authorized By (print) ______________________________ (initials)____________ Date:____/____/____Time _________

Entry Supervisor Assuming Role:

Authorized By (print) ______________________________ (initials)____________ Date:____/____/____Time _________

Authorized By (print) ______________________________ (initials)____________ Date:____/____/____Time _________

Authorized By (print) ______________________________ (initials)____________ Date:____/____/____Time _________

Authorized By (print) ______________________________ (initials)____________ Date:____/____/____Time _________

Authorized By (print) ______________________________ (initials)____________ Date:____/____/____Time _________

Authorized By (print) ______________________________ (initials)____________ Date:____/____/____Time _________

Section 9: Entrant / Attendant Log

Entrant (print)	Time In	Time Out	Attendant (print)	Date

Section 10: Additional Air Sampling

Oxygen Content	Flammability / LEL	Carbon Monoxide	Hydrogen Sulfide	Other	Monitor S/N	Sampled By (Initial) Date/Time
Acceptable 19.5-23.5%	Acceptable <10%	Acceptable < 35 PPM	Acceptable < 10 PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			
%	%	PPM	PPM			

Section 11: Permit Cancelled or Terminated

Entry Supervisor (print): __________________________ (sign):_______________________ Date: ____/____/____ Time: _______

City of Saint Paul/ WSB and Associates

WSB Contact: Linnea Henkels 612-704-0727
lhenkels@wsbeng.com
MCES Sample Receiving: 651-602-8293

Date Submitted: ______________________________

Client ID: 140

Sampler: ______________________________

Project #: 5543-16-01

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Location ID:	**BEACON_BL**	**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:	**MH7N**	[**X**] CL-AV	[**X**] CU-MSV	[ ] BOD5C_IS
Sample Name:	[ ] Grab [**X**] Comp	[**X**] N-N-AV	[**X**] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[**X**] NUT-AV [**X**] TSSVSS-GF	[**X**] PB-MSV [**X**] ZN-MSV	[ ] pH [ ]TDS-180
End Date/Time:			**FILT (Monthly)** [**X**] ORTHO_P	[ ] ECOLI-MPNT **FILT (2x/yr)** [ ] SO4-ICV
Location ID:		**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:		[ ] CL-AV	[ ] CU-MSV	[ ] BOD5C_IS
Sample Name:	[ ] Grab [ ] Comp	[ ] N-N-AV	[ ] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[ ] NUT-AV [ ] TSSVSS-GF	[ ] PB-MSV [ ] ZN-MSV	[ ] pH [ ]TDS-180
End Date/Time:			**FILT (Monthly)** [ ] ORTHO_P	[ ] ECOLI-MPNT **FILT (2x/yr)** [ ] SO4-ICV
Location ID:	**HAMP_PRK**	**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:	**MH810793**	[**X**] CL-AV	[**X**] CU-MSV	[ ] BOD5C_IS
Sample Name:	[ ] Grab [**X**] Comp	[**X**] N-N-AV	[**X**] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[**X**] NUT-AV [**X**] TSSVSS-GF	[**X**] PB-MSV [**X**] ZN-MSV	[ ] pH [ ]TDS-180
End Date/Time:			**FILT (Monthly)** [**X**] ORTHO_P	[ ] ECOLI-MPNT **FILT (2x/yr)** [ ] SO4-ICV
Location ID:		**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:		[ ] CL-AV	[ ] CU-MSV	[ ] BOD5C_IS
Sample Name:	[ ] Grab [ ] Comp	[ ] N-N-AV	[ ] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[ ] NUT-AV [ ] TSSVSS-GF	[ ] PB-MSV [ ] ZN-MSV	[ ] pH [ ]TDS-180
End Date/Time:			**FILT (Monthly)** [ ] ORTHO_P	[ ] ECOLI-MPNT **FILT (2x/yr)** [ ] SO4-ICV
Location ID:		**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:		[ ] CL-AV	[ ] CU-MSV	[ ] BOD5C_IS
Sample Name:	[ ] Grab [ ] Comp	[ ] N-N-AV	[ ] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[ ] NUT-AV [ ] TSSVSS-GF	[ ] PB-MSV [ ] ZN-MSV	[ ] pH [ ]TDS-180
End Date/Time:			**FILT (Monthly)** [ ] ORTHO_P	[ ] ECOLI-MPNT **FILT (2x/yr)** [ ] SO4-ICV

City of Saint Paul/ WSB and Associates

WSB Contact: Linnea Henkels 612-704-0727
Email: lhenkels@wsbeng.com
MCES Sample Receiving: 651-602-8293

Date Submitted: ______________________________

Client ID: 140
Project #: 5543-16-01

Sampler: ______________________________

PAGE of

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MRLPON**	[**X**] P-AV	[**X**] P-AV
Sample Name:	[ ] Grab [**X**] Comp		[**X**] ORTHO_P
Start Date/Time:	06/09/2016 05:12		
End Date/Time:	06/10/2016 10:50		

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MRLOCS**	[**X**] P-AV	[**X**] P-AV
Sample Name:	[ ] Grab [**X**] Comp		[**X**] ORTHO_P
Start Date/Time:	06/09/2016 05:12		
End Date/Time:	06/10/2016 10:50		

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MAGPON**	[**X**] P-AV	[**X**] P-AV
Sample Name:	[ ] Grab [**X**] Comp		[**X**] ORTHO_P
Start Date/Time:	06/09/2016 05:18		
End Date/Time:	06/10/2016 10:50		

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MAGOCS**	[**X**] P-AV	[**X**] P-AV
Sample Name:	[ ] Grab [**X**] Comp		[**X**] ORTHO_P
Start Date/Time:	06/09/2016 05:18		
End Date/Time:	06/10/2016 10:50		

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**JENPON**	[ ] P-AV	[ ] P-AV
Sample Name:	[ ] Grab [ ] Comp		[ ] ORTHO_P
Start Date/Time:			
End Date/Time:			

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**JENOCS**	[ ] P-AV	[ ] P-AV
Sample Name:	[ ] Grab [ ] Comp		[ ] ORTHO_P
Start Date/Time:			
End Date/Time:			

Appendix F – ASTM C1701 Procedures

Standard Test Method for Infiltration Rate of In Place Pervious Concrete[1]

This standard is issued under the fixed designation C1701/C1701M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the field water infiltration rate of in place pervious concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C920 Specification for Elastomeric Joint Sealants

2.2 *Other Standards*

Federal Specification A-A-3110 (TT-P-1536A) Plumbing Fixture Setting Compound[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this test method are defined in Terminology C125.

4. Summary of Test Method

4.1 An infiltration ring is temporarily sealed to the surface of a pervious pavement. After prewetting the test location, a given mass of water is introduced into the ring and the time for the water to infiltrate the pavement is recorded. The infiltration rate is calculated in accordance with 9.1.

5. Significance and Use

5.1 Tests performed at the same location across a span of years may be used to detect a reduction of infiltration rate of the pervious concrete, thereby identifying the need for remediation.

5.2 The infiltration rate obtained by this method is valid only for the localized area of the pavement where the test is conducted. To determine the infiltration rate of the entire pervious pavement multiple locations must be tested and the results averaged.

5.3 The field infiltration rate is typically established by the design engineer of record and is a function of the design precipitation event.

5.4 This test method does not measure the influence on in-place infiltration rate due to sealing of voids near the bottom of the pervious concrete slab. Visual inspection of concrete cores is the best approach for determining sealing of voids near the bottom of the pervious concrete slab.

6. Apparatus

6.1 *Infiltration Ring*—A cylindrical ring, open at both ends (See Fig. 1). The ring shall be watertight, sufficiently rigid to retain its form when filled with water, and shall have a diameter of 300 ± 10 mm [12.0 ± 0.5 in.] with a minimum height of 50 mm [2.0 in.]. The bottom edge of the ring shall be even. The inner surface of the ring shall be marked or scored with two lines at a distance of 10 and 15 mm [0.40 and 0.60 in.] from the bottom of the ring. Measure and record the inner diameter of the ring to the nearest 1 mm [0.05 in.].

NOTE 1—Ring materials that have been found to be suitable include steel, aluminum, rigid plastic, and PVC.

6.2 *Balance*—A balance or scale accurate to 10 g [0.02 lb].

6.3 *Container*—A cylindrical container typically made of plastic having a volume of at least 20 L [5 gal], and from which water may be easily poured at a controlled rate into the infiltration ring.

6.4 *Stop Watch*—Accurate to 0.1 s.

6.5 *Plumbers Putty (Non-Hardening)*—Meeting Specification C920 or Federal Specification A-A-3110.

6.6 *Water*—Potable water.

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.49 on Pervious Concrete.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] http://www.everyspec.com

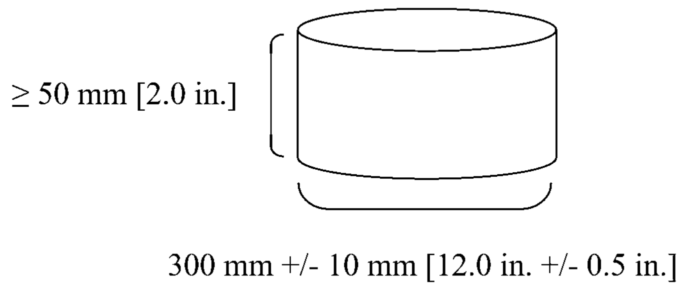

FIG. 1 Dimensions of Infiltration Ring

7. Test Locations

7.1 Perform tests at multiple locations at a site as requested by the purchaser of testing services. Unless otherwise specified, use the following to determine the number of tests to perform:

7.1.1 Three test locations for areas up to 2,500 m^2 [25,000 ft^2].

7.1.2 Add one test location for each additional 1,000 m^2 [10,000 ft^2] or fraction thereof.

7.2 Provide at least 1 m [3 ft] clear distance between test locations, unless at least 24 h have elapsed between tests.

7.3 Do not test if there is standing water on top of the pervious concrete. Do not test within 24 h of the last precipitation.

8. Procedure

8.1 *Infiltration Ring Installation*—Clean the pavement surface by only brooming off trash, debris, and other non-seated material. Apply plumbers putty around the bottom edge of the ring and place the ring onto the pervious concrete surface being tested. Press the putty into the surface and around the bottom edge of the ring to create a watertight seal. Place additional putty as needed

NOTE 2—In a hot environment where the surface temperature is over 38 °C [100 °F] plumbers putty may not adhere to the concrete surface easily. Therefore it is advisable to perform this test during cooler temperature.

8.2 *Prewetting*—Pour water into the ring at a rate sufficient to maintain a head between the two marked lines. Use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the amount of elapsed time to the nearest 0.1 s.

8.3 *Test*—The test shall be started within 2 min after the completion of the prewetting. If the elapsed time in the prewetting stage is less than 30 s, then use a total of 18.00 ± 0.05 kg [40.00 ± 0.1 lb] of water. If the elapsed time in the prewetting stage is greater than or equal to 30 s, then use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Record the weight of water to the nearest 10 g [0.02 lb] (M). Pour the water into the ring at a rate sufficient to maintain a head between the two marked lines and until the measured amount of water has been used. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the testing duration (t) to the nearest 0.1 s.

NOTE 3—If a sloped pavement is being measured, maintain head between the two marked lines at the lowest point of the slope.

8.4 If a test is repeated at the same location, the repeat test does not require pre-wetting if conducted within 5 min after completion of the first test. If more than one test is conducted at a location on a given day, the infiltration rate at that location on that day shall be calculated as the average of the two tests. Do not repeat this test more than twice at the same location on a given day.

9. Calculation

9.1 Calculate the infiltration rate (I) using consistent units as follows:

$$I = \frac{KM}{(D^2 * t)}$$

where:

I = Infiltration rate, mm/h [in./h],
M = Mass of infiltrated water, kg [lb],
D = Inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the concrete, s, and
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units.

NOTE 4—The factor K has units of (mm^3s)/(kgh) [($in.^3$s)/(lbh)] and is needed to convert the recorded data (W, D, and t) to the infiltration rate I in mm/h [in./h].

10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Location,

10.1.3 Date of test,

10.1.4 Age and thickness of concrete (label Unknown if not known),

10.1.5 Time elapsed during prewetting, s,

10.1.6 Amount of rain during last event, if known, mm [in.],

10.1.7 Weight of infiltrated water, kg [lb],

10.1.8 Inside diameter of infiltration ring, mm [in.],

10.1.9 Time elapsed during infiltration test, s,

10.1.10 Infiltration rate, mm/h [in./h], and

10.1.11 Number of tests performed at each location, if applicable.

11. Precision and Bias

11.1 Repeatability testing was performed by a single laboratory by making 2 replicate measurements at three locations on a newly placed pervious concrete pavement. The replicate measurements were repeated daily from day 1 to day 10. The single-operator coefficient of variation of the infiltration rate at one test location was found to be 4.7 %.

11.2 The multi-operator variability data has not been developed. The reproducibility of this test method is being determined and will be available on or before October 1, 2014.

11.3 This test method has no bias because the infiltration rate of in-place pervious concrete is defined only in terms of this test method.

12. Keywords

12.1 concrete; infiltration; pervious; water