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2018 STORMWATER QUALITY AND QUANTITY MONITORING PROGRAM

CITY OF ST. PAUL

MAY 10, 2019

Prepared for:
City of St. Paul
15 Kellogg Blvd West
St. Paul, MN 55102

WSB PROJECT NO. R-001610-100

wsb

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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) 2018 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. That information is provided in the annual MS4 Report submitted to the MPCA and is not further evaluated in this report.

Twelve BMPs and one outfall were monitored in 2018 to quantify progress toward meeting the City's stormwater management goals and to refine current design and maintenance practices. Rainfall was also measured at four locations in the City. The 2018 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 capture
- BMP maintenance

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

Two 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: 2018 City of Saint Paul Monitoring Site Summary

BMP/Site Name	BMP/Site 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, GW
Arundel Street	Underground Infiltration Gallery	WL
Wordsworth	Infiltration Trench	WL
Montreal	Infiltration Trench	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
Jackson Street Pervious Bike Path	Pervious Asphalt	Infiltration
Robie Street	Outfall	Q, WQ
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

. 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 2018 Stormwater Monitoring Protocols document located in **Appendix F**.

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. 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, Hampden Park, 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 and Hillcrest Knoll 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:

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

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 Avenue, and Wordsworth Avenue BMPs, however, since no monitored inflow data was available, inflow volume was not accounted for.

Monitored Infiltration rates were evaluated against design infiltration rates as described in the Minnesota Stormwater Manual (MPCA, 2008) and infiltration rates observed during pre-construction field testing.

2.2. Flow & Volume Reduction

Stormwater runoff volume was measured at Beacon Bluff, Hillcrest Knoll, St. Albans Street, Hampden Park, and Robie Street using continuous flow monitoring equipment. At BMP Sites, the data was utilized 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 flow 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 2-3** and **2-4** 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 2-3: Flow monitoring module

Photo 2-4: Flow sensor in upstream pipe in Beacon Bluff diversion structure

Water treated by the IESF ponds at the TBNS is conveyed to the outlet control structure by eight-inch drain tile beneath the sand benches. Flow sensors at the TBNS IESF Pond sites were installed within the drain tile discharge point to the outlet control structure of the ponds (**Photos 2-5** and **2-6**). Additional details regarding the TBNS IESF pond monitoring configurations are described in **Section 2.3** and **Section 10.**

Photo 2-5: Jenks Pond 8" drain tile and outl pipe within the outlet control structure

Photo 2-6: Sensor and sampler intake location in 8" drain tile in Magnolia Pond outlet control structure

Data Analysis

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 were 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.

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 BMP, Robie Street Outfall, and the 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 structure at Beacon Bluff and the outfall monitoring location at Robie Street (**Photos 2-7** and **2-8**).

Photo 2-7: ISCO 6712 Sampler at Beacon Bluff

Photo 2-8: 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. Tubing was routed from the first sampler through a buried conduit to a float within the pond basin (**Photo 2-9**). 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 eight-inch drain tile outlet into the outlet control structure. This location was established as the post-treatment sample. The samplers (**Photo 2-10**) 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 2-9: Magnolia Pond pretreatment sample float

Photo 2-10: Maryland Pond sampler configuration

Samples from sufficiently sized rainfall events were submitted to the Metropolitan Council Environmental Services (MCES) Laboratory for analysis. The samples were composited using a batch mixing technique to create one sample for the event. Beacon Bluff and Robie Street composite samples were analyzed for the parameters listed in the **Table 2-1** 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), ortho-phosphate [soluble reactive phosphorus (SRP)], total iron, hardness, and total suspended solids (TSS).

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	MPN	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, at applicable sites.

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 inspected from the level monitoring location for accumulation of sediment, debris, and standing water. The TBNS IESF Ponds were inspected for muck accumulation and iron clumping within the sand filtration benches. Inspection photos are included in the photo log (**Appendix E**).

2.5. Pervious Surface Infiltration Rate

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

Data Collection

Infiltration tests were conducted according to the modified ASTM C1701 methods for measuring infiltration rates (**Photo 2-11**). Five locations at Victoria Street and 18 locations at Jackson Street were evaluated to develop an average infiltration rate measurement for the Site. 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 15 minutes of monitoring during a pre-wet test no infiltration was observed, the test was concluded, and no subsequent tests were completed.

Photo 2-11: Permeable Pavement Infiltration Test

3. PRECIPITATION SUMMARY

As part of the City's stormwater monitoring program, seasonal precipitation monitoring is conducted at the following locations: Hampden Park Co-op, Saint Paul Fire House 18, Wilder Recreation Center, and Frost Lake Elementary School (**Figure 1-1**). The precipitation data collected at these locations provides localized rainfall totals which are utilized for calculating rainfall intensity and runoff yield at monitored BMP sites. Each station is equipped with an automated tipping bucket that records continuously throughout the season.

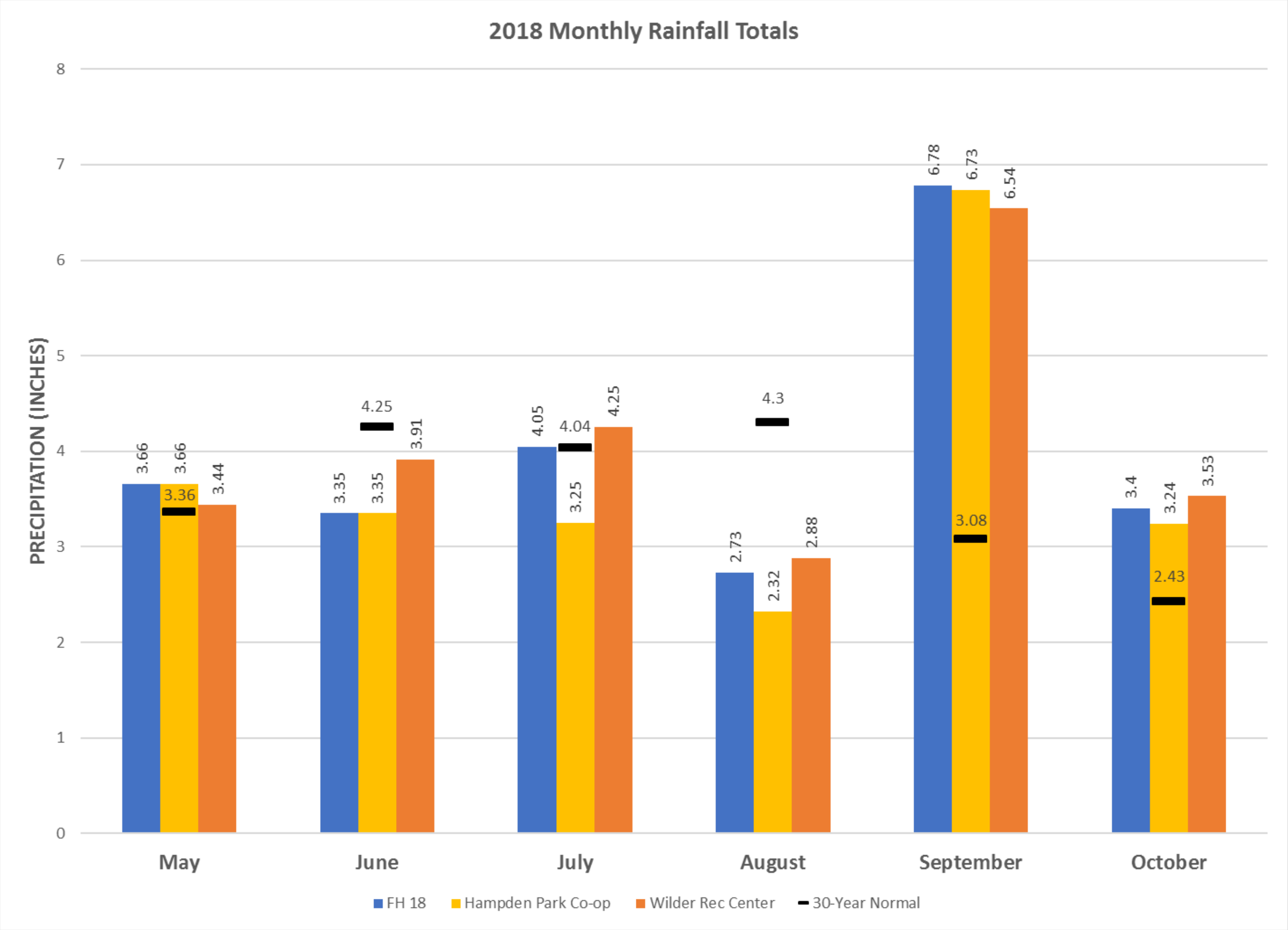
Precipitation data collected by MCES, Minnesota Climatology Working Group (MCWG), and the National Weather Service (NWS) is used to supplement the City's data as needed. This includes any data gaps in seasonally monitored stations as well as parameters, such as snowfall and snow pack depth, which exceed the limitations of the City's monitoring equipment. These stations also provide a longer period of record which is valuable for analyzing rainfall trends. Data collected by MCWG and NWS is accessible through the Midwest Regional Climate Center online database (MCWG, 2018).

Table 3-1 and **Chart 3-1** show 2018 monthly precipitation totals for seasonally monitored sites compared to the 30-year normal. The 30-year normal reflect data collected from 1981-2010 and are updated every ten years, with the most recent update being in 2010. Limited data was collected from the Frost Lake Elementary rain gauge in 2018, as a result of insect nesting within the monitoring device.

May through October rainfall ranged from 22.55 inches at Hampden Park Co-op to 24.55 inches at Wilder Recreation Center. The city-wide average for those months was 23.84 inches which is 0.28 inches less than the 30-year normal. The greatest variability between stations was observed during the month of July with 1.0 inches more rainfall recorded at the Wilder Recreation Center than FH 18. The month of September saw the greatest departure from the 30-year normal (+3.75 inches).

Table 3-1: 2018 Seasonal Precipitation Summary

Month	FH 18	Hampden Park Co-op	Wilder Rec. Center	City-Wide Average	30-yr Normal[1]	Departure from 30-yr Normal
May	3.66	3.66	3.44	3.59	3.36	0.23
June	3.35	3.35	3.91	3.54	4.25	-0.71
July	4.05	3.25	4.25	3.85	4.04	-0.19
August	2.73	2.32	2.88	2.64	4.30	-1.66
September	6.78	6.73	6.54	6.68	3.08	3.75
October	3.40	3.24	3.53	3.39	2.43	0.96
Seasonal Total	**23.96**	**22.55**	**24.55**	**23.84**	**24.12**	**-0.28**


2018 Monthly Rainfall Totals
PRECIPITATION (INCHES)
8
7
6
5
4
3
2
1
0
May
3.66
3.66
3.44
3.36
June
3.35
3.35
3.91
4.25
July
4.05
3.25
4.25
4.04
August
2.73
2.32
2.88
4.3
September
6.78
6.73
6.54
3.08
October
3.4
3.24
3.53
2.43
FH 18
Hampden Park Co-op
Wilder Rec Center
30-Year Normal

Major rainfall events in 2018 are provided in **Table 3-2** below:

Table 3-2: 2018 Significant Rainfall Events

Date	Rainfall Total (in)[1]	Duration (hr)	Intensity (in/hr)
May 29-30, 2018	1.34	9.98	0.13
July 1, 2018	1.09	6.88	0.16
July 12, 2018	1.31	1.23	1.07
August 24, 2018	1.01	9.25	0.11
September 4, 2018	1.10	15.33	0.07
September 20, 2018	3.41	16.75	0.20
October 9-10, 2018	1.13	14.75	0.77

1 - Rainfall event totals may not reflect total daily rainfall

Table 3-3 below provides a five-year monthly precipitation summary as recorded at the University of Minnesota Saint Paul Campus. Annual precipitation has exceeded the 30-year normal every year since 2014. Total precipitation in 2018 was 34.52 inches, 3.91 inches above normal. The month of September 2018 saw 7.19 inches, which is 2.3 times greater than the 30-year normal for that month (3.08 inches).

Table 3-3: 5-year Precipitation Summary (UMN – Saint Paul Campus)

Month	2014	2015	2016	2017	2018	30-yr Normal
January	1.51	0.26	0.28	0.93	1.07	0.90
February	1.19	0.22	0.79	0.70	1.24	0.77
March	0.78	0.71	2.15	0.58	1.38	1.89
April	6.94	2.07	3.66	3.68	2.37	2.66
May	3.54	4.94	2.05	6.54	3.52	3.36
June	9.20	3.31	3.65	3.16	4.64	4.25
July	2.73	6.19	5.97	2.45	4.07	4.04
August	3.12	2.79	9.90	8.89	2.91	4.30
September	2.19	3.82	5.19	1.25	7.19	3.08
October	1.44	2.87	3.32	4.84	3.4	2.43
November	0.95	4.58	2.70	0.42	1.41	1.77
December	0.99	2.13	2.01	0.62	1.32	1.16
Total	**34.58**	**33.89**	**41.67**	**34.06**	**34.52**	**30.61**
Departure from 30-yr Normal	**+3.97**	**+3.28**	**+11.06**	**+3.45**	**+3.91**	**N/A**

4. BEACON BLUFF

This system, shown in **Figure 4-1**, 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 4-1**.

The system is comprised of three connected stormwater treatment structures, which include a stormwater pond west of the Duchess Street cul-de-sac (west pond), an infiltration basin east of the cul-de-sac (rain garden) (**Photo 4-1**), and an underground infiltration chamber (**Photo 4-2**) 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. 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.

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 storm sewer line.

Table 4-1: 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 4-1: Underground infiltration chamber (Facing west)

Photo 4-2: Rain garden located above infiltration chambers (Facing east)

4.1. Water Level and Infiltration Rate Monitoring

Water level in the rain garden (IR-31) and the underground system (IR-32) were measured using continuous water level loggers installed within piezometers. An additional logger was installed within the outlet control structure of the system to confirm when flow was being conveyed back to the storm sewer 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 4-3: IR-31 (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 0.6 feet (ft) to 3.6 ft of depth in 2018. Overflow from the rain garden to the underground system, through open grate structures (**Photo 4-3**), occurred during most treatment events. The 2018 rain garden infiltration rate and infiltration rate trends are provided on **Charts A.3** and **A.5** of **Appendix A**, respectively. The 2018 average infiltration rate for the rain garden was 0.40 inches per hour (in/hr), which is less than the Minnesota Stormwater Manual (MSWM) recommended infiltration rate for SP (poorly graded sand) soils of 0.80 in/hr. This is slightly less than the rates observed in 2017 (0.50 in/hr) and 2017 (0.43 in/hr) (**Table 4-2**). Sediment accumulation has been 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. Dredge maintenance was completed on the rain garden over the winter of 2018-2019.

Table 4-2: Beacon Bluff Infiltration Rates

Location	Average Infiltration Rate (in/hr)						
	2012	2013	2014	2015	2016	2017	2018
Beacon Bluff Rain Garden (IR-31)	2.9	0.85	0.70	0.29	0.43	0.50	0.40
Beacon Bluff Underground System (IR-32)	2.6	0.57	0.64	0.30	0.15	0.11	0.12

Water level in the underground system ranged from 6.1 ft to 17.4 ft deep. Depths greater than 10 feet indicate the water is rising into the substrate above the 10-ft diameter corrugated metal infiltration pipes. The data indicates that the system did not drain to empty during the 2018 monitoring period, including over the winter months. The underground system discharged back to the storm sewer (system outflow) during 14 storm events in 2018. This is an increase from discharge events occurring in 2012-2014 (zero), 2015 (five), 2016 (nine), and 2017 (ten). 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 12 ft below the bottom of the underground chamber, which suggests that groundwater mounding is not the cause of standing water in the system.

The 2018 underground chamber infiltration rate and infiltration rate trends are provided on **Charts A.4** and **A.6** of **Appendix A**, respectively. The 2018 average infiltration rate for underground chamber was 0.12 in/hr, which is less than MSWM recommended infiltration rate for SP soils of 0.8 in/hr. From 2012 to 2017, the infiltration rate has decreased from 2.6 in/hr to 0.11 in/hr, with the largest decline following the first year of monitoring in 2012. As mentioned above, standing water in the underground system has resulted in a decrease in infiltration rates each year.

4.2. 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 control structure was used to identify when the underground system was at capacity, and estimate the volume being conveyed back to the storm sewer system from the BMP. 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 2018 Beacon Bluff Volume Reduction is included in **Table 4-3** below.

In 2018, total runoff to the Beacon Bluff system was 2,590,204 cubic feet (cu-ft). Of that volume, 1,737,142 cu-ft was captured by the system, resulting in a 60% volume reduction. The total flow conveyed back to the storm sewer from the underground system was 392,546 cu-ft, which is 15% 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 18,934 cu-ft/acre which is equivalent to 5.21 inches of runoff as a result of 24.38 inches of rain (21%). The greatest volume captured by the BMP was 173,727 cu-ft on October 9th, 2018. This volume represents 109% of the total storage capacity of the system.

Table 4-3: Beacon Bluff Volume Reduction

Monitoring Period	5/2/2018 - 11/5/2018		
Total Rainfall		24.38	in.
Diversion Structure Water Balance			
Runoff Volume:		2,590,204	cu-ft
Runoff Yield		5.21	in/acre
Bypassed Volume:		624,659	cu-ft
Volume Diverted into BMP:		1,806,346	cu-ft
Beacon Bluff Rain Garden and Infiltration Gallery Inputs			
Inflow Volume from Diversion Structure:	SubWSHD A	1,806,346	cu-ft
Inflow Volume from West Pond:	SubWSHD B	207,221	cu-ft
Inflow Volume from Eastern Inlets	SubWSHD C	116,120	cu-ft
System Discharge (conveyed back to storm sewer from OCS)		392,546	cu-ft
Beacon Bluff System Performance			
Total Runoff Volume:		2,590,204	cu-ft
Total Runoff Volume Captured:		1,737,142	cu-ft
Percent of Total Runoff Volume Captured:		60	%
Maximum Percentage of Storage Volume Utilized [1]		109	%

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.

4.3. 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 4-4 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, 11,406 pounds of TSS and 42.5 pounds of TP were captured by the system. Over the past six years of monitoring, 96,422 pounds of TSS and 363 pounds of TP have been captured at the Beacon Bluff Site.

Table 4-4: Beacon Bluff Load/Capture Summary

Monitoring Period		4/23/2018 – 11/7/2018		
Total Rain		24.38		
Water Quality Parameter	**Flow Weighted Average (mg/L)**	**Total Pollutant Load (lbs)**	**Load Captured (lbs)**	**Percent Reduction %**
Total Suspended Solids	112	19,267	11,406	59.2
Volatile Suspended Solids	33	5,636	3,404	60.4
Total Phosphorus	0.41	67.2	42.5	61.8
Ortho-phosphate	0.10	15.7	10.8	63.2
Chloride	5.08	873.1	599.8	68.7
Total Kjeldahl Nitrogen	1.95	366.3	214.9	63.9
Nitrate + Nitrite as N	0.38	65.2	45.4	69.6

4.4. 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 4-5**, sediment depths in the pretreatment device were approximately 1.0 ft to 2.1 ft throughout the 2018 season. Floatables were observed in the pretreatment structure all 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 2018.

Standing water was observed in the underground system on all visits, as discussed in **Section 4.1**. 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. See **Appendix E** for photos of the BMP inspections.

Table 4-5: Beacon Bluff Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)[1]	Standing Water in Infiltration Gallery?	Observations
May 9, 2018	1.0	NM	Y	Some trash in pre-treatment and rain garden. Pre-treatment in need of cleaning. Sediment felt with water level meter but could not quantify amount.
June 27, 2018	1.4	NM	Y	Some trash in pre-treatment and rain garden. No trash in infiltration gallery.
July 31, 2018	2.0	NM	Y	Large amounts of trash in pre-treatment and rain garden. No trash observed in infiltration gallery.
September 28, 2018	2.0	NM	Y	Bolt head on OSC grate broke off, needs replacement. Trash in pre-treatment.
November 7, 2018	1.7	NM	Y	Trash in pre-treatment, slightly less sediment on downstream side of SAFL Baffle.

1-Not Measured – Sediment levels could not be evaluated in the infiltration galley due to the depth of standing water and the total depth of the system.

5. HILLCREST KNOLL

This system, shown in **Figure 5-1**, is owned and operated by the City. It was constructed in 2012 to help address local flooding issues near Hillcrest Knoll Park (**Photo 5-1**) 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 5-2**). 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 5-1**.

Table 5-1: 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 5-1: Hillcrest Knoll Park Entrance

Photo 5-2: 60" Perforated HDPE pipes during system construction

5.1. Water Level and Infiltration Rate Monitoring

Water elevation was monitored in the system at two locations and groundwater at one location, using continuous water level loggers placed in piezometers and PVC within the BMP pipe gallery. Water level within the BMP pipe and groundwater and daily rainfall totals are presented on **Charts A.7** and **A.8** of **Appendix A**. Water level in the infiltration gallery ranged from 2.9 ft to 7.9 ft, during the 2018 monitoring season. The system drained to empty over the 2017-2018 winter, a change from the winter of 2016-2017. Groundwater was observed at elevations within the infiltration system beginning on March 10, 2018, which persisted throughout the entire 2018 monitoring season. Groundwater interference has been observed during every year monitored to-date.

2018 infiltration rates and infiltration rate trends are presented on **Charts A.9** and **A.10** of **Appendix A,** respectively**.** In 2018, the average infiltration rate within the BMP pipe was 0.39 in/hr (**Table 5-2**). 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 2018 infiltration rates are not adjusted with incremental inflow volumes due to damaged flow sensors at the diversion structure. In all previous years of monitoring, the unadjusted infiltration rates have been slightly less than infiltration rates that have been adjusted with incremental inflow volumes. Overall, the limiting factor for infiltration within the system is groundwater intrusion.

Table 5-2: Hillcrest Knoll Infiltration Rate

Location	**Average Infiltration Rate (in/hr)**					
	2013[1]	**2014[1]**	**2015**	**2016**	**2017**	**2018**
Knoll BMP Pipe	0.40	0.36	0.92	0.58	0.52	0.39

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. 2018 infiltration rate is unadjusted

5.2. 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. In 2018, sensor damage to both the upstream and downstream sensors resulted in unusable flow data for the Hillcrest Knoll Monitoring Site. The total runoff to the diversion structure was modeled using the P8 Urban Catchment model and event-based rainfall totals for 2018. The predicted runoff volumes were then calibrated utilizing observed rainfall to runoff data collected during previous years of monitoring.

In 2018, total runoff to the Hillcrest Knoll System was modeled to be 1,219,834 cu-ft (**Table 5-3**). The total water yield for the 37.1-acre drainage area is 32,880 cu-ft/acre which is equivalent to 9.1 inches of runoff resulting from 25.6 inches of rain (36%). The greatest volume to the diversion structure was 162,405 cu-ft from a 3.17-inch rain event on September 20, 2018. Using the average 2017 volume reduction of 46%, the estimated volume captured in 2018 was 561,123 cu-ft. Storm-specific rainfall and runoff data is provided on **Chart B.2** of **Appendix B**.

Table 5-3: Hillcrest Knoll Volume Reduction

Monitoring Period	5/14/2018 – 11/5/2018	
Total Rainfall	25.6	in.
Diversion Structure Water Balance		
Runoff Volume:	1,219,834	cu-ft
Runoff Yield	9.1	in/acre

5.3. 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 5-4**. 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 2018.

The float mechanism for the system gate valve was inspected regularly in 2018 (**Photo 5-3**). The float was exercised during multiple maintenance visits in 2018 to ensure that it was not stuck in the closed position, which would prevent flow from entering the infiltration system. Photos from the inspection visits are included in the photo log (**Appendix E**).

Photo 5-3: System gate valve and float

Table 5-4: 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
April 10, 2018	2.3	0.5	Y	Float was not stuck but the BMP was full. Very soft muck in the pre-treatment. No sediment in furthest downstream pre-treatment manhole.
June 29, 2018	1.0	0.9	Y	Float was stuck in closed position, exercised. No backed-up water observed. Soft sediment in pre-treatment.
July 31, 2018	1.0	0.7	Y	Float was stuck in closed position, exercised. No backed-up water observed. Soft sediment in pre-treatment.
September 28, 2018	1.0	0.8	Y	Float was exercised, but BMP was full.
November 8, 2018	2.5	0.9	Y	Soft sediment in pre-treat. Survey rod released bubbles.

6. ST. ALBANS STREET

This system, shown in **Figure 6-1**, 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 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 6-1**) via a 30-inch elliptical pipe. The system is also connected to the University Avenue storm sewer system. Any runoff that does not get treated by infiltration trenches and tree planters along University Avenue is directed to this system (**Photo 6-2**). 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 6-1.**

Table 6-1: 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 6-1: St. Albans 48" perforated HDPE installation

6.1. Water Level and Infiltration Rate Monitoring

BMP water level was monitored in the access manhole at the northwest corner of the system. The 2018 water elevations and daily rainfall is provided on **Chart A.11** of **Appendix A**. Water level monitoring indicated that the infiltration gallery reached 100% capacity two times in 2018. Every treatment event monitored in 2018 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 2018, the average infiltration rate of the BMP pipe was 21.3 in/hr (**Table 6-2**), which is above the MSWM recommended infiltration rate for SP soils of 0.8 in/hr, but below 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**.

Table 6-2: St. Albans Infiltration Rate

Location	Average Infiltration Rate (in/hr)						
	2012	2013	2014	2015	2016	2017	2018
St. Albans Street BMP Pipe	38.5	35.7	64.8	55.3	36.2	20.6	21.3

6.2. 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 pipe at the corner of St. Albans Street and University Avenue to capture flows into the system from along University Avenue. Flow rates and daily rainfall are depicted on **Chart B.3** of **Appendix B**.

In 2018, total runoff for the St. Albans Street system was 513,246 cu-ft. Of that volume, 429,504 cu-ft was captured and infiltrated by the system, resulting in a volume reduction of 84% (**Table 6-3**). On average, 44% of the total volume of flow diverted into the BMP was from the University Avenue inlet pipe. The total water yield for the 22.2-acre drainage area is 23,119 cu-ft/acre which is equivalent to 5.2 inches of runoff resulting from 24.8 inches of rain (21%). The greatest volume infiltrated by the BMP was 33,944 cu-ft, which represents 109% of the total storage capacity of the system. Storm-specific rainfall and volume reduction data is provided on **Chart B.4** of **Appendix B**.

Table 6-3: St. Albans Street Volume Reduction

Monitoring Period	04/10/18 – 11/6/18	
Total Rainfall	24.81	in
System Water Balance		
Aurora Runoff Volume:	307,333	cu-ft
Aurora Bypassed Volume:	83,742	cu-ft
St. Albans and University Volume	205,913	cu-ft
St. Albans System Performance		
Total Runoff Volume	513,246	cu-ft
Runoff Yield	5.2	in/acre
Total Runoff Volume Captured	429,504	cu-ft
Percent of Runoff Volume Captured:	84	%
Maximum Volume Discharge to BMP	33,944	cu-ft
Maximum Percentage of Storage Volume Utilized[1]	109	%

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

6.3. 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 6-4**, 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 E** for the **Photolog**.

Table 6-4: St. Albans Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)	Standing Water in Infiltration Gallery?	Observations
April 10, 2018	1.5	0.1	N	Some sediment in pre-treatment, none is second pre-treatment manhole.
June 29, 2018	0.2	0	N	Trash and minimal sediment in pre-treatment. Trash in BMP.
July 31, 2018	0.7	0.1	N	Trash and sediment in pre-treatment. Trace amounts of sediment in BMP.
September 28, 2018	0.4	0	N	Trash and sediment in pre-treatment. Trace amounts of sediment in BMP.
November 8, 2018	0.0	0	N	Slight amount of sediment in pre-treatment manhole.

7. HAMPDEN PARK

The Hampden Park infiltration gallery, shown in **Figure 7-1,** was constructed in 2014. The system consists of eight parallel perforated pipes that are 5 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 Vortechs 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 7-1** below.

Photo 6-1: Hampden Park BMP Construction

Table 7-1 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

7.1. Water Level and Infiltration Rate Monitoring

Water levels were monitored within the underground infiltration system and groundwater (P2), using electronic water level loggers. Water levels and daily rainfall for 2018 are provided on **Chart A.14** and **A.15** of **Appendix A**. Water level within the BMP, ranged from 0 to 3.9 ft. The BMP water level must exceed 6.5 ft for the system to reach capacity and for water to be conveyed back to the sewer system. Based on the 2018 level data, no flow discharged back to the sewer system. Groundwater monitoring data showed that groundwater elevation fluctuated by 0.96 ft in 2018 with a minimum separation of 17.1 ft from the bottom of the BMP.

The 2018 infiltration rates are presented on **Chart A.16** of **Appendix A** and are not adjusted for incremental volume flow due to an inoperable flow meter. The unadjusted average infiltration rate for the BMP was 11.19 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 a Double Ring Infiltrometer (DRI). Infiltration rate trends are depicted on **Chart A17**. Water level data shows that all 2018 events were infiltrated within 48 hours of a treatment event.

Table 7-2: Hampden Park Infiltration Rate

Location	Average Infiltration Rate (in/hr)		
	2016	2017	2018
Hampden Park BMP	14.38	8.30	11.19

7.2. Volume Reduction

One flow meter was installed within the 24-inch RCP diverting flow from the storm sewer to the BMP from the intersection of Hampden and Raymond Avenues. The metered drainage area consisted of 6.7 acres of the total 7.8-acre drainage area to the BMP. In 2018, erroneous sensor readings resulted in unusable flow data for the Hampden Park flow metering site. The total runoff to the diversion structure was modeled using the P8 Urban Catchment model and event-based rainfall totals for 2018. The predicted runoff volumes were then calibrated utilizing observed rainfall to runoff data collected during previous years of monitoring. No discharge was observed at the system outlet therefore that data is not plotted.

In 2018, the modeled total runoff was 328,442 cu-ft. Since monitored level within the BMP did not reach the discharge outlet, 100% of the runoff was infiltrated by the system (**Table 7-3**). The total water yield for the 7.8-acre drainage area is 42,107 cu-ft/acre which is equivalent to 11.6 inches of runoff as a result of 25.6 inches of rain (45%). The greatest volume received by the BMP was 56,628 cu-ft as a result of a 3.43-inch rain event on September 20, 2018. This volume represents 178% 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 7-3: Hampden Park Volume Reduction

Monitoring Period	5/2/2018 – 11/5/2018	
Total Rainfall	25.6	in
Hampden Park Water Balance		
Raymond/Hampden Runoff Volume:	328,442	cu-ft
System Bypass Volume	0	cu-ft
Hampden Park System Performance		
Total Runoff Volume	328,442	cu-ft
Runoff Yield	11.6	in/acre
Total Runoff Volume Captured	328,442	cu-ft
Percent of Runoff Volume Captured:	100	%
Maximum Event Volume Captured by BMP	56,628	cu-ft
Maximum Percentage of Storage Volume Utilized[2]	178	%

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

7.3. 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 7-5**, minimal sediment was observed in both the pretreatment device and infiltration gallery.

Table 7-5: 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
4/10/2018	0.3	0.1	N	Some sediment obs. in pipe groves, no standing water.
6/29/2018	0.3	0.1	N	Some sediment obs. in pipe groves, no standing water.
7/31/2018	0.3	0.1	N	No standing water.
9/28/2018	0.3	0.1	N	1-4" sediment in BMP, depending on area.
11/7/2018	0.4	0.1	N	No standing water.

8. ARUNDEL STREET

This system, shown in **Figure 8-1**, 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 8-1: 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 8-1: Arundel infiltration system access manhole and BMP level monitoring location

8.1. 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.18 of Appendix A**. Water Levels in the infiltration gallery ranged from 0.8 ft to 6.7 ft. Level data shows that the system did not drain to empty during the 2018 season. The system exceeded 100% capacity during 26 runoff events in 2018.

The BMP pipe infiltration rates are presented on **Chart A.19 of Appendix A**. In 2018, the average infiltration rate of the BMP pipe was 0.11 in/hr (**Table 8-2)**, which is slightly greater than the 2017 infiltration rate of 0.09 in/hr. The 2018 infiltration rate 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.20**.

Table 8-2: Arundel Infiltration Rate

Location	Average Infiltration Rate (in/hr)						
	2012	2013	2014	2015	2016	2017	2018
Arundel BMP Pipe	8.0	2.43	1.64	0.42	0.16	0.09	0.11

8.2. 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 8-3**, sediment depths in the infiltration gallery ranged from 0.0 to 0.1 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 E** for the **Photolog.**

Table 8-3: Arundel Maintenance Inspections

Date	Sediment Depth in Pre-treatment (ft)	Sediment Depth in Infiltration Gallery (ft)	Standing water in Infiltration Gallery?	Observations
April 26, 2018	0.5	0.1	Y	Sediment depositing directly around pipe entering pre-treatment structure, very little sediment on downstream side of weir structure in MH .
June 29, 2018	0.0	0.0	Y	Trash accumulation but no sediment accumulation observed in BMP or pre-treatment.
July 31, 2018	0.2	0.0	Y	Trash accumulation.
September 28, 2018	0.4	0.0	Y	Trash accumulation increased significantly between visits.
November 8, 2018	0.4	0.0	Y	No sediment found on downstream side of weir structure in pre-treatment.

9. ROBIE STREET OUTFALL

The Robie Street Outfall is located on Saint Paul's West Side neighborhood within the Lower Mississippi River Watershed. The outfall consists of a 54-inch RCP pipe that receives that runoff from a 118-acre drainage area, which then outfalls to the Mississippi River. The drainage area consists of predominately residential land use and 42% imperious surface. The first year of monitoring at Robie Street was completed in 2018, which consisted of continuous flow measurements and water quality sampling.

Photo 9-1: Robie Street Flow Meter Installation

9.1. Flow Monitoring

2018 monitoring at the Robie Street Outfall produced mostly erroneous flow measurements as a result of the steep pipe upstream from the monitoring location. This produced high water velocities, which presented a challenging monitoring environment. The total runoff was modeled using the P8 Urban Catchment model and event-based rainfall totals for 2018. The modeled data is shown below in **Table 9-1**. Total flow for the outfall was modeled to be 5,189,731 cu-ft, which results in a water yield of 12.1 inches from 25.2 inches of rain (48%). The maximum event volume was 910,838 cu-ft as a result of a 3.18-inch rain event on September 20, 2018.

Table 9-1: Robie Street Outfall Flow Modeling

Monitoring Period	5/2/2018 – 11/5/2018	
Total Rainfall	25.2	in
Robie Street Outfall Flow		
Total Runoff Volume	5,189,731	cu-ft
Runoff Yield	12.1	in/acre
Maximum Event Volume	910,838	cu-ft

9.2. Pollutant Load Monitoring

An automated water quality sampler was installed at the Robie Street Outfall monitoring location to collect flow-paced samples during runoff events. Due to erroneous flow data, the flow-pacing programming did not engage, therefor field staff proceeded with grab water sampling over the course of the monitoring season. The results of the water quality sampling are presented on **Charts C.3** and **C.4** of **Appendix C**.

Table 9-1 below provides a loading summary for the loading parameters defined in NPDES Permit issued to the City in addition to ortho-phosphate. During the monitoring period, an estimated 21,183 pounds of TSS and 64.9 pounds of TP were conveyed through the outfall location.

Table 9-1: Robie Outfall Pollutant Load Summary

Monitoring Period	**5/1/2018 – 11/5/2018**	
Total Rainfall	**25.3**	
Water Quality Parameter	**Flow Weighted Average (mg/L)**	**Total Pollutant Load (lbs)**
Total Suspended Solids	65	21,183
Volatile Suspended Solids	21	6,777
Total Phosphorus	0.20	64.9
Ortho-phosphate	0.105	33.9
Chloride	10.8	3,493
Total Kjeldahl nitrogen	0.99	322
Nitrate + Nitrite as N	0.32	105

10. TROUT BROOK 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 plan featured 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

Photo 10-2: Jenks Pond

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

The IESF technology was produced by the University of Minneapolis Saint Anthony Falls Laboratory in 2005 (Erickson et al. 2012). The research findings indicated that sand media mixed with iron filings (recommended mixture of 5% by weight) can provide a mechanism to remove SRP, a dissolved bio-available form of phosphorus, which is not effectively removed by traditional stormwater BMPs, such as stormwater ponds. As stormwater passes through IESF media, the oxidized iron filings remove SRP through surface sorption.

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 approximately five percent by weight. 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 treated stormwater flows through a wetland, then connects with the constructed creek.

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**). 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 sensor/intake inspection

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.21**, **A.22**, and **A.23** 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)	Observed Treatment Elevation (ft SPCD)	Weir Overflow Elevation (ft SPCD)
Maryland	116.8	116.4	119.3	116.8	119.0
Magnolia	123.1	123.8	126.2	124.1	126.0
Jenks	94.8	95.5	97.4	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 116.9 ft SPCD.
    - The minimum water level was 0.4 ft greater than the normal water level (recorded on August 19, 2018). The periods from July 18, 2018 to August 3, 2018 and August 8, 2018 through August 20, 2018 were the only time that flow through the IESF system was not occurring.
    - Water levels exceeded the weir overflow elevation one time on September 20, 2018.

- Magnolia Pond
    - Flow through the IESF benches was observed when water levels exceeded 124.6 ft SPCD.
    - The minimum water level was 0.7 ft less than the normal water level (recorded on May 1, 2018).
    - Water levels exceeded the weir overflow elevation two times on July 4, 2018 and September 20, 2018.

- Jenks Pond
    - Flow through the IESF benches was observed when water levels exceeded 95.5 ft SPCD.
    - The minimum water level was 0.7 ft less than the normal water level (recorded on August 18, 2018).
    - The maximum water level was 1.9 ft above the normal water level (recorded on September 20, 2018), which did not exceed the OCS weir elevation.
    - A modification was made to the diversion structure to Jenks Pond, resulting in greater flow conveyed to the basin and an increase in pond level and treatment volume in 2017 and 2018 compared to previous years.

10.2. Treatment Volume Monitoring

The treatment volume was monitored at each of the sites using a 2150 flow meter installed within the 8-inch drain tile discharge point to the outlet control structure. This is a modification from 2016 equipment configuration which had the flow meter placed within the outlet pipe of the outlet control structure. Flow over the drain tile metering location was less turbulent and produced better quality data compared to flows observed in prior years at the outlet control pipe monitoring location. Flow rates and daily rainfall for the three sites are provided on **Charts B.6** through **B.8** 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	Monitoring Period	Total Treated Flow (cu-ft)	Average Event Flow (cu-ft)
Maryland	4/25 – 11/6	491,706	23,030
Magnolia	4/25 – 11/6	128,446	7,350
Jenks	4/25 – 8/24*	78,708	7,616

*The Jenks flow sensor was damaged by rodents on 8/24/18, therefor the total 2018 flow is not reflected in the table above.

Maryland Pond treated the greatest volume of water of the three sites, recording 491,706 cu-ft in 2018, which is slightly less than the total volume observed in 2017 (533,000 cu-ft). The 2018 average event flow of 23,030 cu-ft was greater than the 2017 average (18,697 cu-ft).

Magnolia and Jenks Ponds treated 128,446 cu-ft and 78,708 cu-ft of stormwater, respectively. Similar to Maryland, the total 2018 volume at Magnolia was slightly less than 2017 (144,832 cu-ft), although the average event volume (7,350 cu-ft) was greater than 2017 (5,773 cu-ft). Less volume was recorded at Jenks in 2018 due to a sensor that was damaged by an animal on August 24, 2018. The average event volume at Jenks was similar in 2017 (7,535 cu-ft) and 2018 (7,616 cu-ft).

10.3. Pollutant Reduction Monitoring

Water Quality was monitored by collecting flow-paced samples from within the pond (pre-treatment) and the drain tile outlet (post-treatment). Samples were collected simultaneously using automated samplers programmed to collect samples based on the outlet flow pacing. The sample collected from the stormwater pond was collected approximately one foot below the water surface. All samples in 2018 at the Jenks Pond location were collected as grab samples, due to programing related issues with the water quality samplers. At the other two ponds, grab samples were collected periodically for comparison to flow paced sample concentrations. Water quality samples were analyzed for total phosphorus, dissolved phosphorus, and soluble reactive phosphorus (ortho-phosphate), TSS, hardness, and total iron.

TP and SRP

In 2018, 12 treatment events were sampled at Maryland Pond. The analytical data and individual event treatment summary are provided on **Tables C.5** and **C.6** of **Appendix C**.

The median removal efficiencies for TP and SRP from 2015 to 2018 are presented in **Table 10-4** below. The median reduction in TP and SRP was 4% and -35% respectively. The median effluent concentrations of TP and SRP were the greatest that has been observed in monitoring completed to-date. Continuous flow through the IESF media has been observed every year at Maryland Pond and may be affecting the performance of the media. For proper sorption of phosphate to iron oxides, the IESF media must dry out between treatment events to ensure continued rusting of the iron particles (Erickson et al. 2012). The results of iron sampling conducted at Maryland is discussed later in this section. The percent of mass TP and SRP retained during the monitored events was 1% and -51%, respectively.

Table 10-4: TBNS Maryland Median TP, SRP, and Removal Efficiencies

Year	TP Pre (mg/L)	TP Post (mg/L)	% Reduction[1]	SRP Pre (mg/L)	SRP Post (mg/L)	% Reduction[1]
2015	0.180	0.058	62	0.036	0.009	55
2016	0.075	0.100	-48	0.009	0.010	0
2017	0.183	0.114	34	0.017	0.019	5
2018	0.128	0.135	4	0.017	0.035	-35

1 – The % reduction reflects the median reduction of monitored treatment events.

At Magnolia Pond, 12 treatment events were sampled in 2018. The analytical data and treatment event summary are provided on **Tables C.7** and **C.8** of **Appendix C**.

The median TP concentrations, SRP concentrations, and removal efficiencies from 2015 to 2018 are presented in **Table 10-5** below. In 2018, the median reduction in TP and SRP was 16% and -4%, respectively. The median pre-treatment and post-treatment SRP concentrations were greater in 2018 than previous monitoring years. Additionally, 2018 was also the first year that there was a negative median reduction in SRP at Magnolia. Of the three IESF ponds, Magnolia Pond consistently sees the greatest pre-treatment and post-treatment concentrations of TP and SRP. The percent mass of TP and SRP retained in 2018 was 0% and -3%, respectively.

Table 10-5: TBNS Magnolia Median TP, SRP, and Removal Efficiencies

Year[1]	TP Pre (mg/L)	TP Post (mg/L)	% Reduction[2]	SRP Pre (mg/L)	SRP Post (mg/L)	% Reduction[2]
2015	0.380	0.170	56	0.046	0.030	27
2016	0.190	0.116	33	0.039	0.029	21
2017	0.284	0.173	33	0.038	0.050	5
2018	0.241	0.204	16	0.087	0.093	-4

1 – The % reduction reflects the median reduction of monitored treatment events.

At Jenks Pond, 10 treatment events were sampled in 2018. Five of the water quality sampling events did not have paired flow data due to the damaged sensor part way through the year. Due to programming issues with the Jenks Pond samplers, all samples were collected as grab samples. The analytical data and treatment event summary are provided on **Tables C.9** and **C.10** of **Appendix C**.

The median TP, SRP, and removal efficiencies from 2015 to 2018 are presented in **Table 10-6** below. In 2015 and 2016, data sets were limited due to minimal flow being diverted to the basin, resulting in few treatment events. In 2018, the median reduction in TP and SRP was 36% and 17%, respectively. TP and SRP concentrations at Jenks Pond were the lowest of the three sites. Off the three sites, Jenks Pond has the greatest removal efficiencies for both TP and SRP. The percent mass of TP and SRP retained in 2018 was 43% and 41%, respectively. A majority of the SRP load reduction occurred as a result of the second largest treatment event on June 16, 2018, which had an SRP reduction of 69%.

Table 10-6: TBNS Jenks Median TP, SRP, and Removal Efficiencies

Year[1]	TP Pre (mg/L)	TP Post (mg/L)	% Reduction[2]	SRP Pre (mg/L)	SRP Post (mg/L)	% Reduction[2]
2015	0.890	0.054	94	0.320	0.002	99
2016	0.106	0.104	2	0.020	0.021	-12
2017	0.144	0.083	38	0.009	0.013	13
2018	0.235	0.119	36	0.023	0.019	17

1 – Only one event was monitoring in 2015

2 – The % reduction reflects the median reduction of monitored treatment events.

TSS, Total Iron, and Hardness

Additional parameters collected in 2018 included TSS, hardness, and total iron. The median reduction in concentrations for those parameters for all three IESF ponds is provided in **Table 10-7** below. All three ponds exhibited a decrease in TSS as a result of the IESF treatment. The primary means of TSS treatment is particle settling provided by a Vortechs pre-treatment system and settling that occurs within the pond prior to the IESF benches. Overall, median post-treatment effluent TSS concentration were 11 mg/L at Maryland, 9 mg/L at Magnolia Pond, and 6 mg/L at Jenks Pond.

Table 10-7: 2018 Median Reduction in TSS and Total Iron

Site	% Reduction TSS	% Reduction Total Iron	% Reduction Hardness
Maryland	29	-57	-55
Magnolia	33	-1	-70
Jenks	40	39	-113

An export of iron from the IESF media was observed during select sampling events at all three basins. At Maryland Pond, sampled events from April through July showed a negative reduction (increase) in iron from the pond to effluent sample location. Continuous flow through the IES occurred during that time. As mentioned in the water level summary, flow through the IESF bench occurred the entire year, with the exception of two periods in August. All samples collected after the period of no treatment, when the media beds were allowed to dry, showed a reduction in iron from the pond to the effluent. This did not correlate with an increase in removal efficiency for TP or SRP during the same period of time.

In September and October, five events at Magnolia and three events at Jenks showed an export in iron, which had not occurred previously in the year. The select events at Jenks also coincided with negative reductions in TP and SRP. The five events at Magnolia also exhibited a negative reduction in TP, during that time, which was not observed previously during the monitoring season.

The increase in iron is suspected to be related to continuous flow through the IESF media. Additionally, iron precipitate was also observed accumulating at the drain tile outlet at Maryland (**Photo 10-5**). Based on the analytical and flow data, and observed precipitate, it is suspected that continuous flow may be creating anaerobic conditions, which have contributed to the export of iron from the media beds. Total rainfall in September was 2.2 times greater than the 30-year normal and October rainfall also exceeded the 30-year normal. The above normal rainfall may have contributed to higher water levels within the basins which allowed for continued saturation of the media beds at Magnolia and Jenks. Continuous flow at Maryland has been observed every monitoring year to date.

Photo 10-5: Iron Precipitate at drain tile outlet to OCS

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**.

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.24** of **Appendix A**. Water Levels in the trench ranged from 279.4 ft SPCD to 281.8 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 2018. The trench infiltration rates are presented on **Chart A.25** of **Appendix A**. In 2018, the average infiltration rate was 6.5 in/hr **(Table 11-2)**, which is greater than the design infiltration rate of 0.6 in/hr. Infiltration rate trends are depicted on **Chart A.26**.

Table 11-2: Montreal Infiltration Rate

Location	Average Infiltration Rate (in/hr)		
	2016	2017	2018
Montreal Trench	7.5	11.7	6.5

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 (**Photos 12-1** and **12-2**) 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 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 120.8 ft SPCD to 127.6 ft SPCD. Level data shows that the trench drained to empty within 48 hours for every event until October 2018. From October 9, 2018 through November 1, 2018, approximately 0.8 feet of standing water was observed within the trench. This increase in level coincides with 5.1 inches of rain from September 16, 2018, through September 25, 2018.

The trench infiltration rate and infiltration rate trends are presented on **Charts A.28** and **A.29** of **Appendix A**. In 2018, the average infiltration rate was 10.9 in/hr **(Table 12-2)**, which is greater than the design infiltration rate of 0.6 in/hr, and significantly greater than the 2017 infiltration rate of 5.8 in/hr.

Table 12-2: Wordsworth Infiltration Rate

Location	Average Infiltration Rate (in/hr)		
	2016	2017	2018
Wordsworth Trench	4.4	5.8	10.9

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 constructed with substantial void space to allow for infiltration or filtration of stormwater through the pavement surface as a means of stormwater management. Pervious pavement BMPs monitored in the city include porous asphalt and permeable interlocking concrete pavers. The purpose of the infiltration testing is to monitor the change in site conditions and infiltration capability of the BMPs overtime. Pavement maintenance is also monitored to study the effect of routine and rehabilitative maintenance on these BMPs.

Infiltration testing was completed at the Jackson Street Pervious Bike Path BMP in July and November 2018 Testing was also completed at the Victoria Street pervious pavement BMP in November. This section presents the results of the 2018 infiltration testing. The Infiltration testing methodologies are described in **Section 2.5.** A photolog of infiltration testing is provided in **Appendix E.**

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

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 and 2017). Those locations are depicted on **Figure 13-1** and the results of the testing are presented in **Table 13-1** and **Chart D.1** in **Appendix D**.

Table 13-1: Victoria Street Infiltration Rate Summary

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)		2017 Infiltration Rate (in/hr)		2018 Infiltration Rate (in/hr)	
IR-1	168.6	18.1	0	E	3.7	E	4.4	E	0.9	E	1.6
IR-2	266.6	75.7	13.0	A	0	A	4.8	A	0.9	A	1.3
IR-3	271.1	92.2	18.6	B	0.9	B	5.7	B	2.5	B	1.9
IR-4	69.1	24.0	9.7	C	0	C	1.6	C	1.6	C	0.7
IR-5	149.8	49.2	30.8	D	0	D	0	D	0	D	0
Average	**185.04**	**51.84**	**14.42**	**0.92**		**3.33**		**1.19**		**1.11**	

A summary of the 2018 infiltration test results is provided below:

- The overall site infiltration rate was similar in 2018 (1.11 in/hr) compared to 2017 (1.19 in/hr).
- The 2018 infiltration rates were, on average, less than one percent of 2012 infiltration rates.
- No infiltration was observed at Location D, which is consistent with testing completed from 2015 through 2017 (**Photo 13-3 and 13-4**).
- Infiltration rates at Locations E and A were greater in 2018, compared to 2017, while infiltration rates at Locations B and C were less in 2018 than 2017.

Photo 13-3: Location D Pre-test

Photo 13-4: Location D Infiltration Test

13.2. Jackson Street

The Jackson Street BMP (**Photo 13-5** and **13-6**) is a designated bike path constructed of pervious asphalt. It is a section of the Capital City Bikeway (CCB), a system of off-street bicycle trails in downtown Saint Paul. The BMP is eight blocks long, stretching from Kellogg Street to 11th Street, and consists of 2,750 square yards of pervious asphalt. Stormwater runoff filters through the asphalt and underlying media and is then conveyed to the storm sewer system via drain tile.

Monitoring locations JS-1 through JS-11 were established In November 2016 upon completion of the four-block stretch from Kellogg Boulevard to 7th Place East. Monitoring locations JS-12 through JS-18 were established in November 2017 upon completion of the four-block stretch from 7th Place East to 11th street. The monitoring locations were carefully selected to evaluate sediment loading and asphalt compaction from varying levels of pedestrian and vehicular traffic. Each site was characterized into one of three groups, identified in **Table 13-2**, based on their location and surroundings. The site and infiltration test locations are depicted on **Figure 13-2**. Site photos are provided in **Appendix E**.

Table 13-2: Monitoring Site Traffic Characterization

Site Traffic Characterization
Low: No driving and minimal foot traffic area. Adjacent to planter or minimal impervious surface.
Medium: Pedestrian cross walks or adjacent to large areas of impervious surface.
High: Driveways for parking or businesses, heavy vehicular traffic.

Photo 13-5: Capital City Bikeway (CCB) – Jackson Street/Kellogg Avenue

Photo 13-6: Jackson Street Infiltration Test

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

The site was tested for infiltration in July 2018 and October 2018. The infiltration test results from the 18 locations are summarized in **Table 13-3** and **Chart D.2** in **Appendix D**, which includes all infiltration test results completed to-date. **Table 13-3** is color coded to identify the site traffic characterizations described above. The infiltration tests results are also summarized in **Table 13-4**, which presents an average infiltration rate based on the monitoring location traffic characterization. The infiltration test locations are depicted on **Figure 13-2**.

Table 13-3: Jackson Street Infiltration Rate Summary (in/hr)

Infiltration Ring Location	Test Location Description	Nov 2016 Infiltration Rate	Jun 2017 Infiltration Rate	Nov 2017 Infiltration Rate	Jul 2018 Infiltration Rate	Oct 2018 Infiltration Rate
JS-1	Northern half of Securian ramp entrance. Non-painted surface east of path center line.	143.2	2.3	0.7	0.0	0.0
JS-2	Midline of Securian ramp entrance. Non-painted surface east of path center line.	187.6	1.6	0	0.0	0.0
JS-3	Jackson Street pedestrian cross south of 6th Street. Near midline of bike path.	320.5	267.3	90.0	72.8	28.0
JS-4	Midblock between 6th & 5th Street. North of skyway. Near midline of bike path.	530.6	380.0	155.6	116.4	83.2
JS-5	345 parking ramp entrance. Non-painted surface just north of the midline of the entrance. Midline of bike path.	96.5	1.1	0.0	0.0	0.0
JS-6	345 parking ramp entrance. Green painted stripe farthest south. West side of bike path.	29.7	3.0	0.0	0.0	0.0
JS-7	Jackson Street pedestrian cross north of 4th Street. Near midline of bike path.	133.4	88.5	20.6	8.4	3.3
JS-8	Midblock between 4th & Kellogg. Western edge of bike path (adjacent to concrete).	44.4	68.8	10.3	0.0	0.0
JS-9	Midblock between 4th & Kellogg. Eastern side of bike path.	69.5	14.0	0.3	0.0	0.0
JS-10	In line with the southern wall of the US Courthouse (facing Kellogg). Western edge of bike path adjacent to concrete.	139.5	31.4	0.2	0.0	0.0
JS-11	In line with the southern wall of the US Courthouse (facing Kellogg). Eastern side of the bike path.	117.9	31.4	4.0	0.0	0.0
JS-12	N of Credit Union Driveway between 11th St. and 10th St Midline of bike path, next to a planter.	NM	NM	95.6	93.8	99.5
JS-13	In front of Child Care Center between 11th St. and 10th St. Western edge of bike path, next to a planter.	NM	NM	141.8	192.4	133.7
JS-14	S of 10th St. Adjacent to planter (2nd weir). Between Western edge and bike path midline.	NM	NM	52.7	65.2	50.7
JS-15	Firestone driveway, N of 2nd stripe from the S.	NM	NM	11.3	0.0	0.0
JS-16	Pedestrian cross, SW intersection of Jackson and 9th	NM	NM	125.2	21.6	1.0
JS-17	Mid-block of 9th St. and 7th St. Adjacent to planter (southern-most tree). Just W of bike path midline.	NM	NM	189.4	182.0	155.3
JS-18	Pedestrian cross, NW intersection of Jackson and 7th Pl. Adjacent to large concrete area.	NM	NM	75.4	74.3	59.1
Site Average:		164.8	80.9	54.1	45.9	34.1
Average of Sites JS-1 through JS-11 (established Nov 2016):				25.6	18.0	10.4
Average of Sites JS-12 through JS-18 (established Nov 2017):				98.8	89.9	71.3

NM – Not Measured

Table 13-4: Jackson Street Infiltration Summary by Site Traffic Characterization

Site Traffic Characterization	Nov 2016 Infiltration Rate (in/hr)	Jun 2017 Infiltration Rate (in/hr)	Nov 2017 Infiltration Rate (in/hr)1	Jul 2018 Infiltration Rate (in/hr)	Nov 2018 Infiltration Rate (in/hr)
Low: No driving and minimal foot traffic area. Adjacent to planter or minimal impervious surface.	530.6	380.0	127.0	130.0	104.5
Medium: Pedestrian cross walks or adjacent to large areas of impervious surface.	137.5	83.6	40.8	22.1	11.4
High: Driveways for parking or businesses, heavy vehicular traffic.	114.2	2.0	6.0[2]	0.0	0.0

1 – Includes new monitoring locations established in November 2017

2 - The increase in the site average for high traffic areas from June 2017 to November 2017 is a result of a new location added in November 2017

A summary of the 2018 infiltration testing completed at the Jackson Street Pervious Pavement Site is provided below:

- The overall site infiltration rate was 45.9 inches per hour (in/hr) in July 2018 and 34.1 in/hr in October 2018.
  - Nine of 18 locations showed no infiltration during both July and October testing events.
  - Of the remaining nine locations where infiltration occurred, October 2018 infiltrations rates ranged from 1.0 in/hr to 155.3 in/hr.
- Low traffic areas had an average infiltration rate of 130.0 in/hr in July 2018 and 104.5 in/hr in October 2018.
  - All five monitoring locations exhibited infiltration ranging from 50.7 in/hr to 155.3 in/hr in October 2018.
  - Four of the five low traffic testing locations were established in November 2017. The average infiltration rate in October 2018 was 94% of the infiltration rate observed in November 2017 at those locations.
- Medium traffic areas had an average infiltration rate of 22.1 in/hr in July 2018 and 11.4 in/hr in October.
  - Four of eight monitoring locations showed no infiltration during both July and October 2018 testing events.
  - Of the remaining four locations were infiltration occurred, October 2018 infiltration rates ranged from 1.0 in/hr to 59.0 in/hr.
  - Locations JS-8 through JS-11 are within the first constructed section of the pervious pavement near the Jackson Street and Kellogg Boulevard intersection. These sites exhibited no infiltration as of the July 2018 monitoring event.
- High traffic areas had an average infiltration rate of 0.0 in/hr in July 2018 October 2018.
  - No infiltration was observed at all five high traffic monitoring locations in July and October 2018.
  - Four of the five high traffic areas were reduced to no infiltration after one year of monitoring. The remaining location was reduced to no infiltration after 1.5 years of monitoring.

Photo 13-11: Test Locations JS-1 and JS-2 (high traffic)

14. 2018 SUMMARY

Twelve stormwater BMPs and one outfall were evaluated for performance in 2018 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 evaluate 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/Outfall

Four underground infiltration BMPs (Beacon Bluff, Hillcrest Knoll Park, St. Albans, and Hampden Park) and one outfall (Robie Street) were monitored for flow to evaluate runoff and volume reduction at BMP Sites. The runoff data for each site was normalized over the individual drainage areas to evaluate drainage characteristics that contribute to each Site. A summary of runoff and volume reduction data is presented in **Table 14-1** below.

Table 14-1: Runoff Summary

BMP Site	Drainage Area (acres)[1]	Total Monitored Runoff (cf)	% Runoff Captured	Water Yield (in/acre)[1]	Water Yield (cu-ft/acre)[1]	Runoff Coefficient
Beacon Bluff	136.8	2,590,204	60	5.2	18,934	0.21
Hillcrest Knoll Park	37.1	1,219,834	NM	9.1	32,880	0.36
St. Albans	22.2	541,341	84	6.7	24,835	0.21
Hampden Park	7.8	328,442	100	11.6	42,107	0.45
Robie Street Outfall	118	5,189,771	NA	12.1	43,980	0.48

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/modeled runoff volume and the corresponding drainage area

NA – Not Applicable

Of the five sites, the Robie Street Outfall received the greatest amount of runoff per drainage acre, resulting in a rainfall to runoff coefficient of 0.48. Beacon Bluff and St. Alban’s drainage areas showed the least amount of runoff, each having a coefficient of 0.21.

TSS and TP loads captured by the monitored BMPs are summarized in **Table 14-2**. TSS and TP loads for Hillcrest Knoll Park, St. Albans, and Hampden Park were calculated using 2018 flow data and flow-weighted averages from the last year of water quality monitoring at each site, which was 2014 and 2015, and 2017, respectively. The total TSS load and TP load captured by the four systems was 35,880 pounds and 114.5 pounds, respectively.

Table 14-2: Underground Infiltration System Pollutant Capture Summary

BMP Site	TSS Captured (pounds)	TP Captured (pounds)
Beacon Bluff	26,747	80.9
Hillcrest Knoll Park	6,143	25.9
St. Albans	2,453	5.3
Hampden Park	537	2.3
Total	**35,880**	**114.5**

A summary of the 2018 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 0.12 in/hr, which is 4% of the post-construction infiltration rate. The underground system no longer drains to empty, and groundwater mounding does not appear to be the cause of standing water, based on groundwater elevation data. Even with standing water observed in the BMP and an increase in system discharge events, the BMP infiltrated 60% of the total volume monitored.
- Groundwater intrusion into the Hillcrest Knoll BMP has been observed every year since 2013. The mounding that occurs at the site is a limiting factor for infiltration. Infiltration rates have fluctuated between 0.36 in/hr and 0.92 in/hr since 2014, with a rate of 0.39 in/hr observed in 2018.
- The 2018 St. Albans infiltration rate of 21.3 in/hr is greater than the MSWM infiltration rate, but slightly less than design rate of 26.0 in/hr. The St. Albans BMP system regularly drains to empty within 48 hours of a runoff event.
- The infiltration rate for the Hampden Park BMP was 11.2 in/hr, which exceeded the design rate of 1.8 in/hr and is greater than the 2017 infiltration rate. No overflow bypass was observed, therefor 100% of the volume received by the BMP was infiltrated.
- The infiltration rate for the Arundel BMP was 0.11 in/hr, which is less than 1% of the post-construction infiltration rate. The system never fully drained to empty in 2018.
- The Montreal Trench had a monitored infiltration rate of 6.5 in/hr in 2018, which exceeds the design rate of 0.6 in/hr, but was less than the 2017 infiltration rate of 11.7 in/hr
- The Wordsworth Trench had a monitored infiltration rate of 10.85 in/hr in 2018, which exceeds the design rate of 0.6 in/hr and the 2017 infiltration rate of 5.76 in/hr.

14.2. Rain Garden

In 2018, the Beacon Bluff rain garden was monitored for water level. Infiltration within the Beacon Bluff rain garden has decreased from 2.9 in/hr to 0.40 in/hr since 2012, primarily due to sediment accumulation within the basin. Water that does not infiltrate within the rain garden will spill into the underground infiltration gallery through open grates on the surface. Dredge maintenance of the rain garden was completed over the winter of 2018-2019.

14.3. Iron-Enhanced Sand Filtration Ponds

Overall, the median SRP reductions at Maryland Pond (-35%), Magnolia Pond (-4%), and Jenks Pond (17%) were less than reduction rates observed during similar studies which have identified removal efficiencies from 26% SRP (Erickson et al. 2015) to 75% SRP (Erickson 2012).

Continuous flow through the Maryland IESF Pond media may be creating anaerobic conditions, which has contributed to the export of iron from the media beds. Additionally, anaerobic conditions can mobilize SRP by breaking the bonds created during the sorption of SRP to iron oxide. This was observed to a lesser extent at Magnolia Pond and Jenks Pond during heavy rainfall in September and October.

14.4. Pervious Pavement

Infiltration testing was conducted at the Victoria Street permeable pavers and Jackson Street pervious asphalt sites in 2018. The Victoria Street 2018 infiltration rate of 1.1 in/hr is 1% of post-construction monitored infiltration, although infiltration has been observed consistently at 4 of the 5 monitoring locations.

The November 2018 infiltration rate at the Jackson Street Site was 34.1 in/hr, which is 29% of the infiltration rate observed during the first year of monitoring (2016). Low traffic areas were observed to have a significantly greater infiltration rates on average (104.5 in/hr) than medium traffic (11.4 in/hr) and high traffic (0.0 in/hr) areas. Maintenance of both pervious pavement BMPs consists of street sweeping two times annually.

14.5. 2019 Recommendations

The recommendations for the 2019 Monitoring Program include:

- Continue to perform inspections and regular maintenance on BMP pre-treatment systems and infiltration galleries.
- Continue to notify of potential illicit discharges observed at flow monitoring locations.
- Evaluate the change in infiltration rate within the Beacon Bluff as a result of dredge maintenance that was completed.
- Complete additional infiltration testing at Jackson Street Pervious Bike Path to further evaluate changes in pervious surface performance with respect to pavement traffic.

15. REFERENCES

City of Saint Paul, 2018. 2017 Water Quality and Quantity Monitoring Report. Saint Paul, MN.

Erickson, Andrew J., John S. Gulliver, and Peter T. Weiss. "Capturing phosphates with iron enhanced sand filtration." *Water Research* 46.9 (2012): 3032-3042.

Erickson, Andrew J., John S. Gulliver, and Peter T. Weiss. “Monitoring an Iron-Enhanced Sand Filter Trench for the Capture of Phosphate from Stormwater Runoff.” Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/175078, 2015.

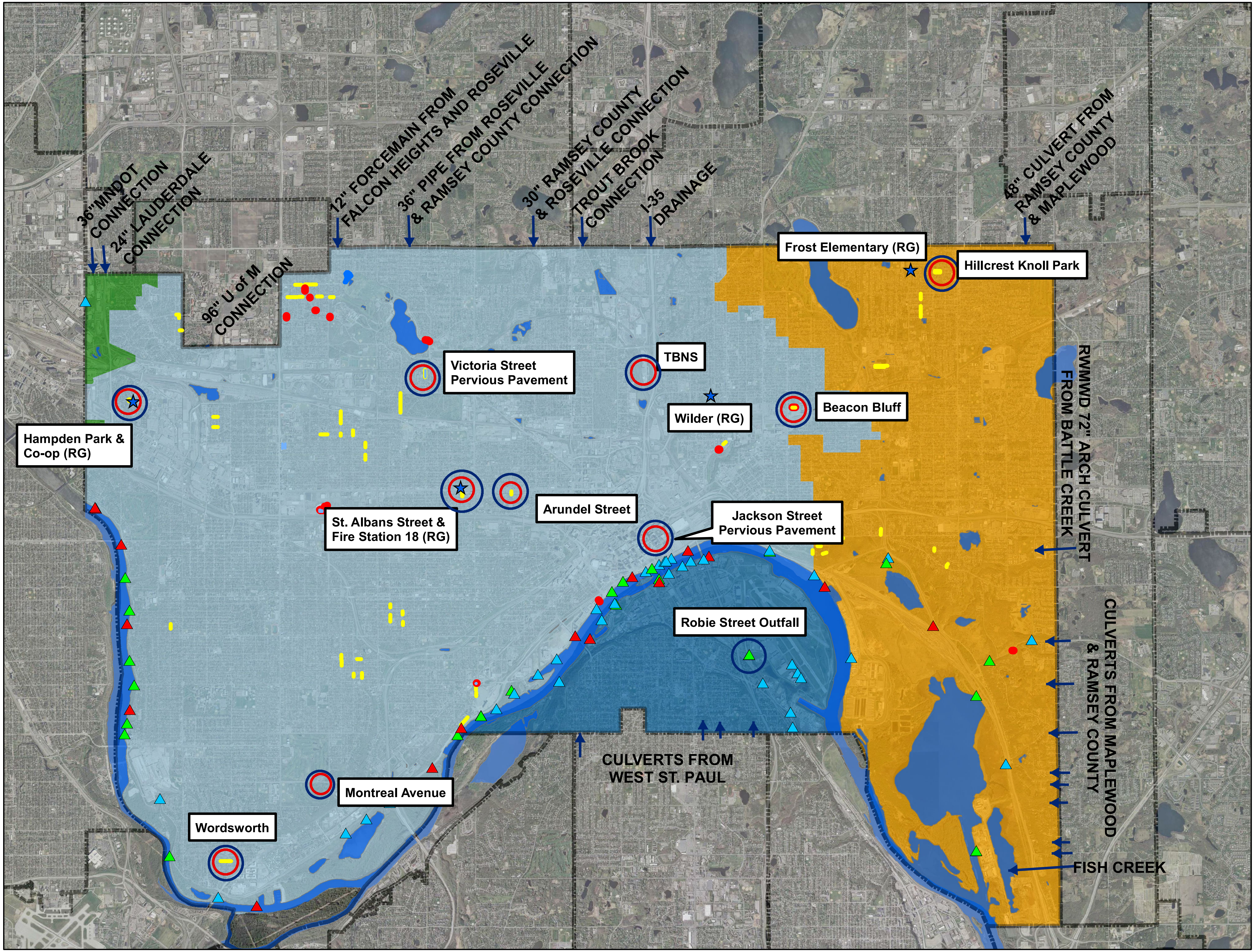
Erickson, Andrew J. “Removing Dissolved Pollutants from Stormwater Runoff.” St. Anthony Falls Laboratory, University of Minnesota. Presentation, October 3, 2012.

Minnesota Climatology Working Group. St. Paul Campus Climatological Observatory: precipitation data. Saint Paul, MN. Accessed 2017. http://mrcc.isws.illinois.edu.

Minnesota Pollution Control Agency 2008. Minnesota Stormwater Manual. Version 2. Accessed 2017. https://stormwater.pca.state.mn.us/index.php?title=Main_Page.

Minnesota Department of Transportation, 2015. Study: “Permeable Pavements in Cold Climates: State of the Art and Cold Climate Case Studies”. Accessed 2017. https://lrrb.org/pdf/201530.pdf.

Figures



City of St. Paul
2018 Water Quantity & Quality Monitoring Program

Figure 1-1

2018 Monitoring Site Locations

N W E S

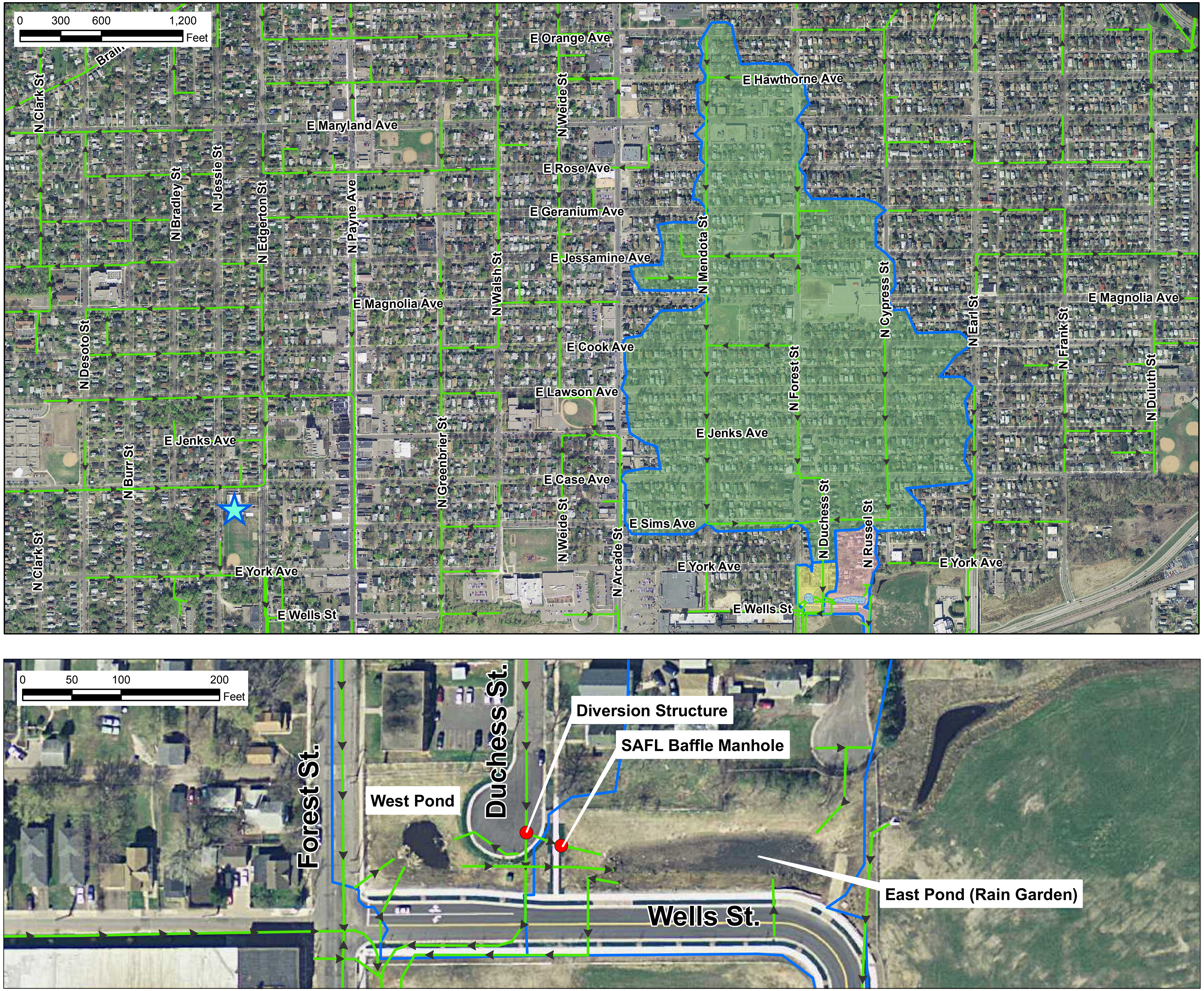
0 2,500 5,000 10,000 Feet

Legend

- ▬ Raingarden/Infiltration Basin
- ▬ Infiltration Trench
- ▬ Pervious Pavement
- ▨ Capitol Region Watershed District
- ▨ Lower Mississippi River WMO
- 🟩 Mississippi WMO
- 🟧 Ramsey/Washington/Metro WD
- ○ 2017 Monitoring Locations
- ○ 2018 Monitoring Locations
- ★ Rain Gauge Locations

Outfalls

- ▲ 30" - 48"
- ▲ 50" - 72"
- ▲ > 72"



City of St. Paul

2018 Water Quantity and Quality Monitoring Program

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FIGURE 4-1

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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2018 Water Quantity and Quality Monitoring Program

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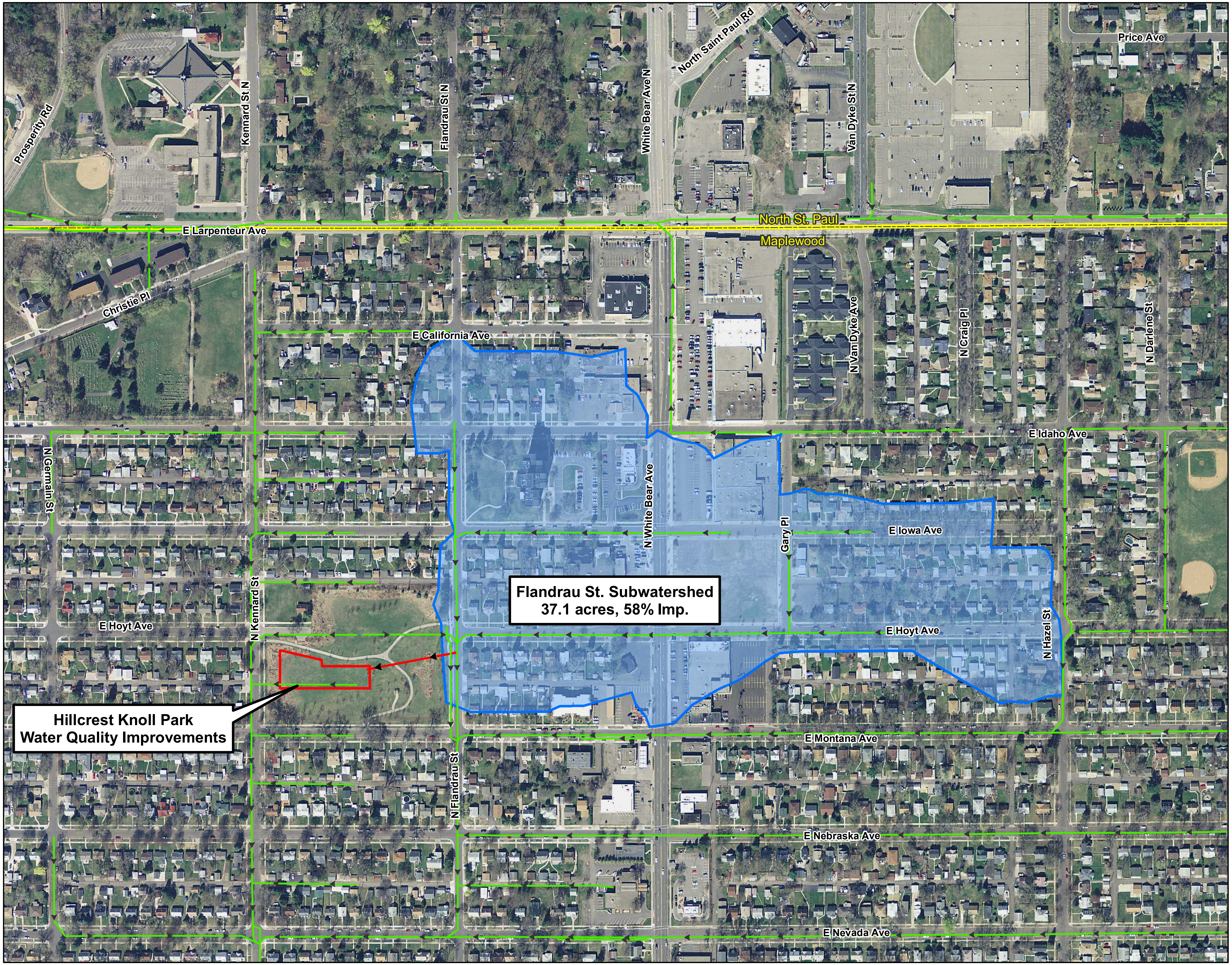
FIGURE 5 - 1

Hillcrest Knoll Park Infiltration BMP Drainage Area

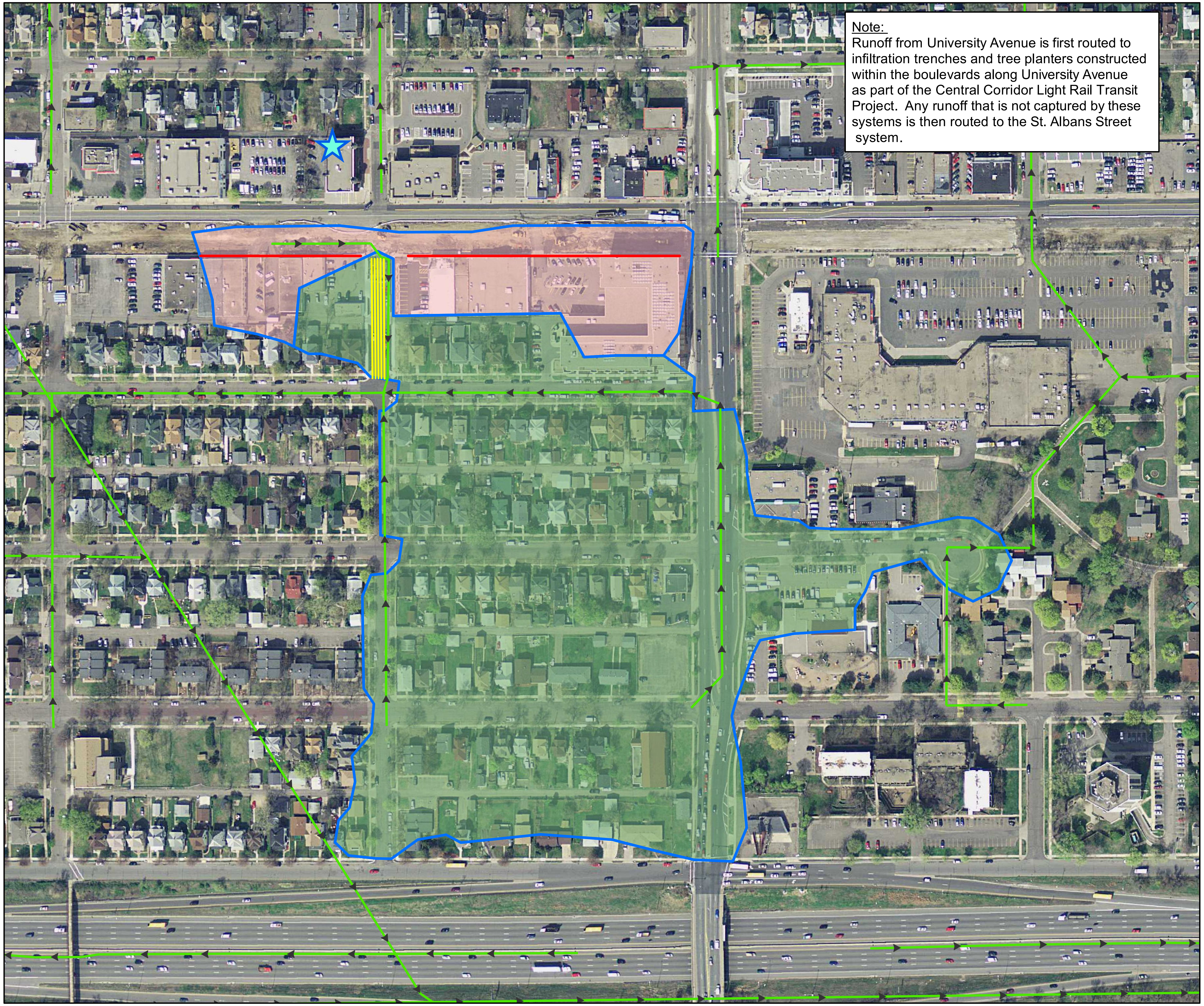


Legend

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

wsb

File: K:\01610-03\GIS\Maps\Volume Reduction\4.2 Storm Sewer.mxd, Feb 10, 2011 5:38:46 PM



Note:
Runoff from University Avenue is first routed to infiltration trenches and tree planters constructed within the boulevards along University Avenue as part of the Central Corridor Light Rail Transit Project. Any runoff that is not captured by these systems is then routed to the St. Albans Street system.

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2018 Water Quantity and Quality Monitoring Program

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FIGURE 6-1

St. Albans Street Infiltration BMP Drainage Areas

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)

wsb

K:\01610-100\GIS\Maps\Figures\2018\Figure 7-1 - Hampden Park NEW.mxd

City of St. Paul

2018 Water Quantity and Quality Monitoring Program

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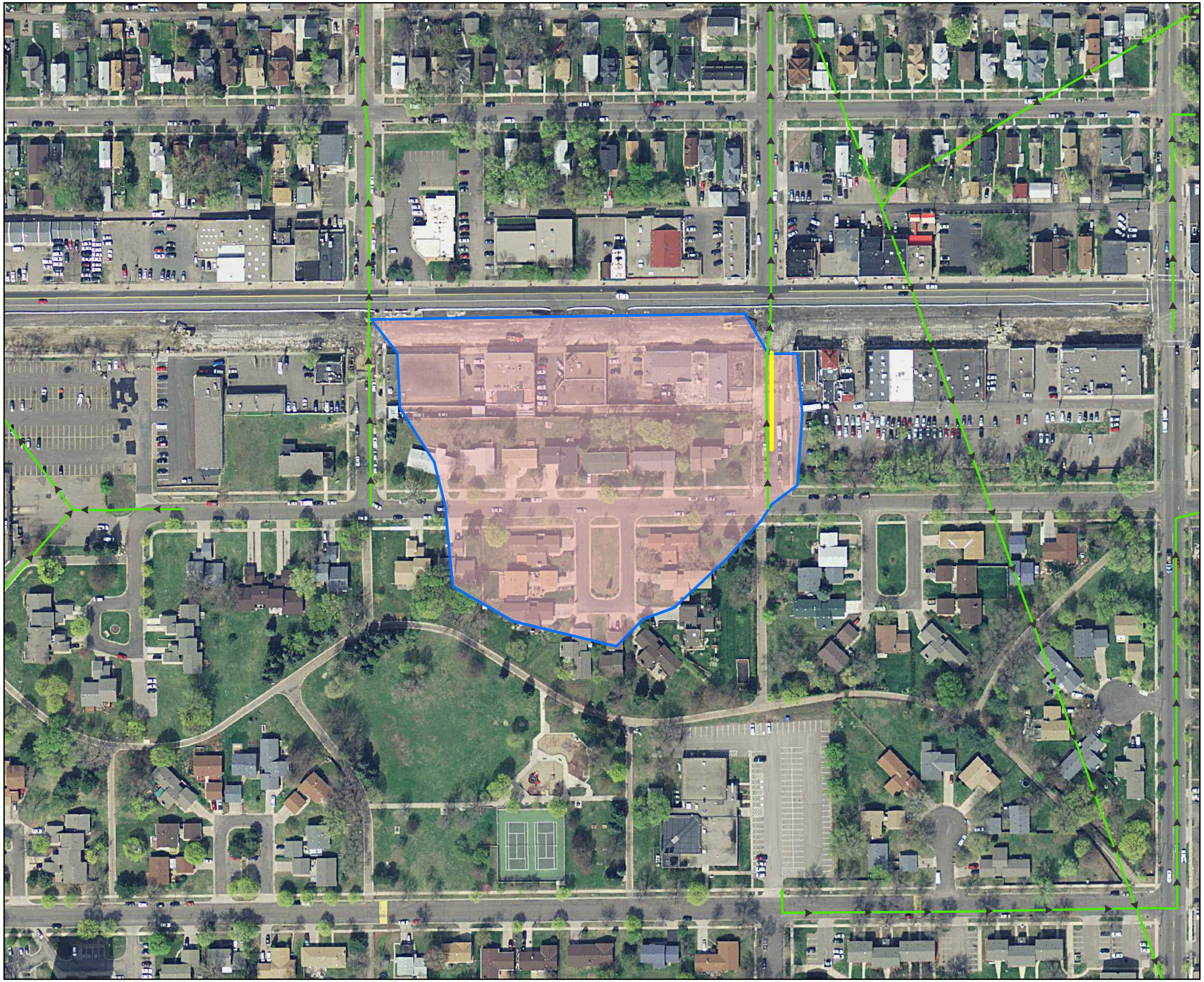
FIGURE 7-1
Hampden Park Infiltration BMP Drainage Area

Legend

➝	Storm Pipe
☆	Rain Gauge Location
☐	Hampden Park BMP
▨	Hampden Park BMP Drainage Area

wsb



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2018 Water Quantity and Quality Monitoring Program

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FIGURE 8-1

Arundel Street Infiltration BMP Drainage Area

Legend

- 🟨 Infiltration Trench
- → Storm Pipe
- ☆ Rain Gauge Location
- 🟥 Arundel Street System (6.4 ac)

wsb

File: K:\01610-100\GIS\Maps\Figures\2018\Figure 9-1 - Robie St Outfall Drainage Area.mxd, May 12, 2019 4:39:04 PM

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Figure 9-1
Robie Outfall Location & Drainage Area

N
W E
S

0 125 250 500
Feet

Legend

- ✦ Robie Outfall
- 🟩 Robie Outfall Drainage (118 acres)
- ➤ Storm Pipe

wsb

K:\01610-100\GIS\Maps\Figures\2018\Figure 10-1 Trout Brook Sanctuary Iron Enhanced Sand Filtration Ponds.mxd

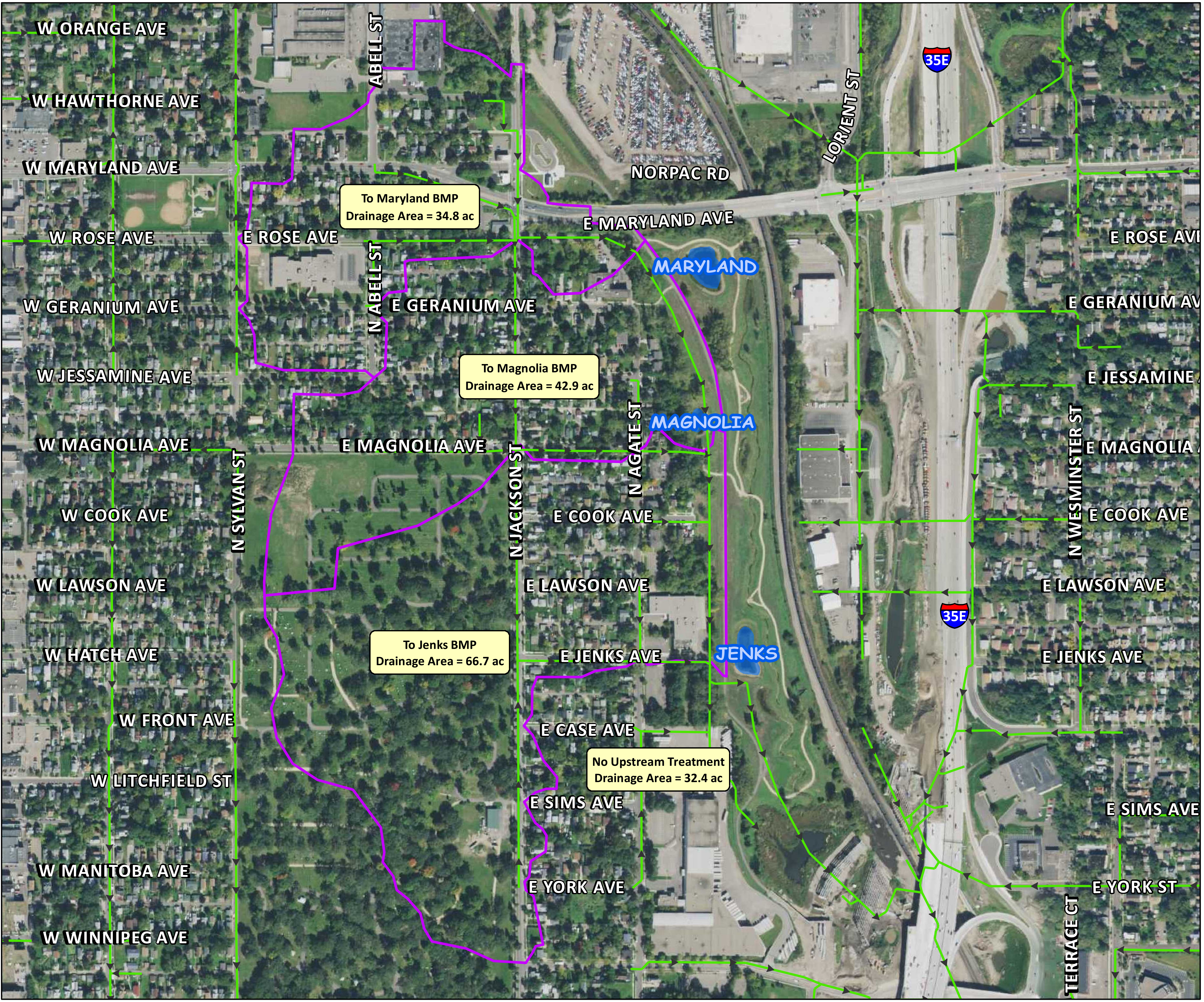

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Figure 10-1

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

N
W E
S

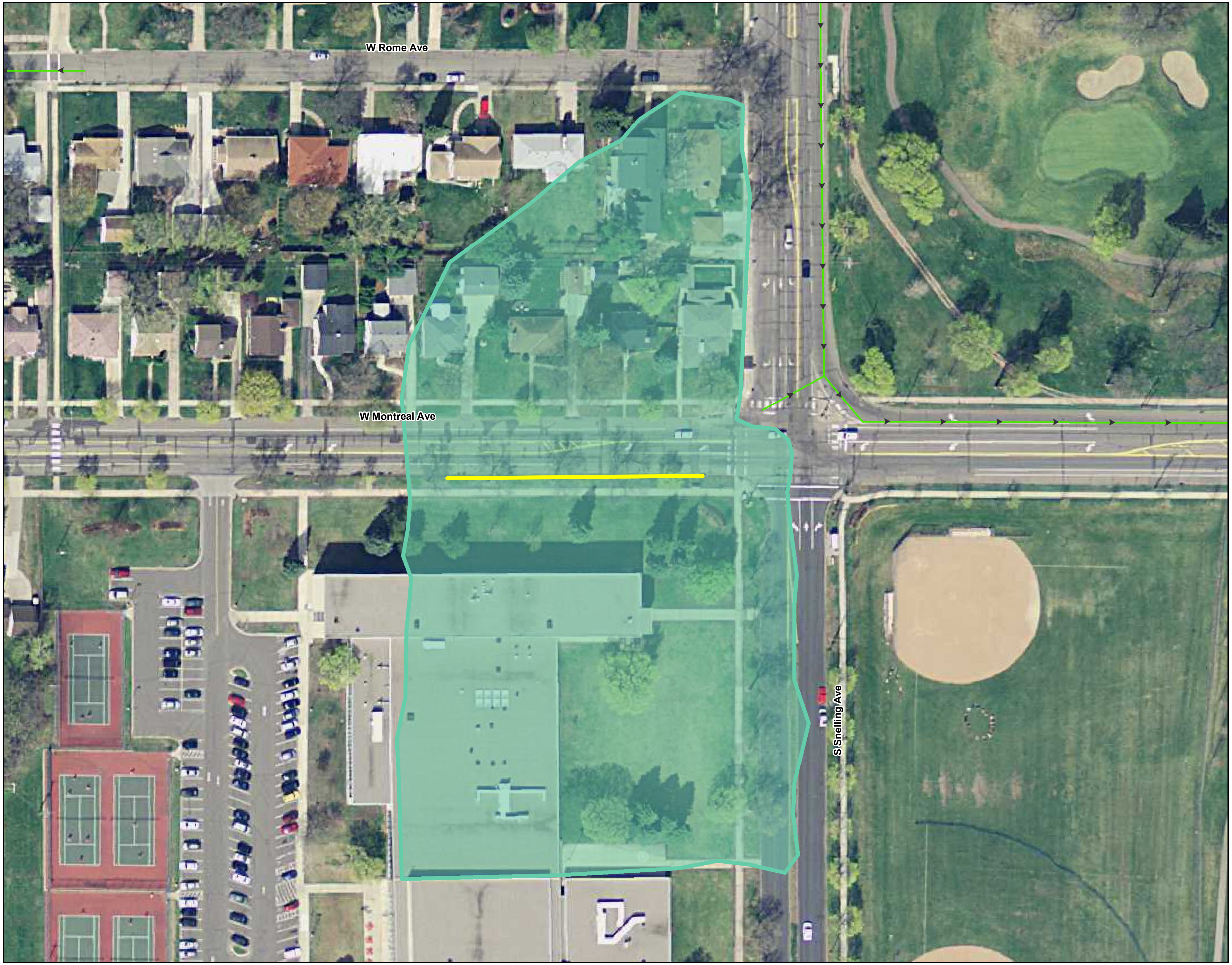
0 200 400 800
Feet

LEGEND

- → Storm Pipe
- ▭ Subwatershed to BMP
- 🟦 Iron Enhanced Sand Filtration Ponds

wsb

File: K:\01610-03\GIS\Maps\Volume Reduction\4.2 Storm Sewer.mxd, Feb 10, 2011 5:38:46 PM



City of St. Paul

2018 Water Quantity and Quality Monitoring Program

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FIGURE 11 - 1

Montreal Infiltration BMP Drainage Area

Legend

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

wsb

File: K:\01610-03\GIS\Maps\Volume Reduction\4.2 Storm Sewer.mxd, Feb 10, 2011 5:38:46 PM

City of St. Paul

2018 Water Quantity and Quality Monitoring Program

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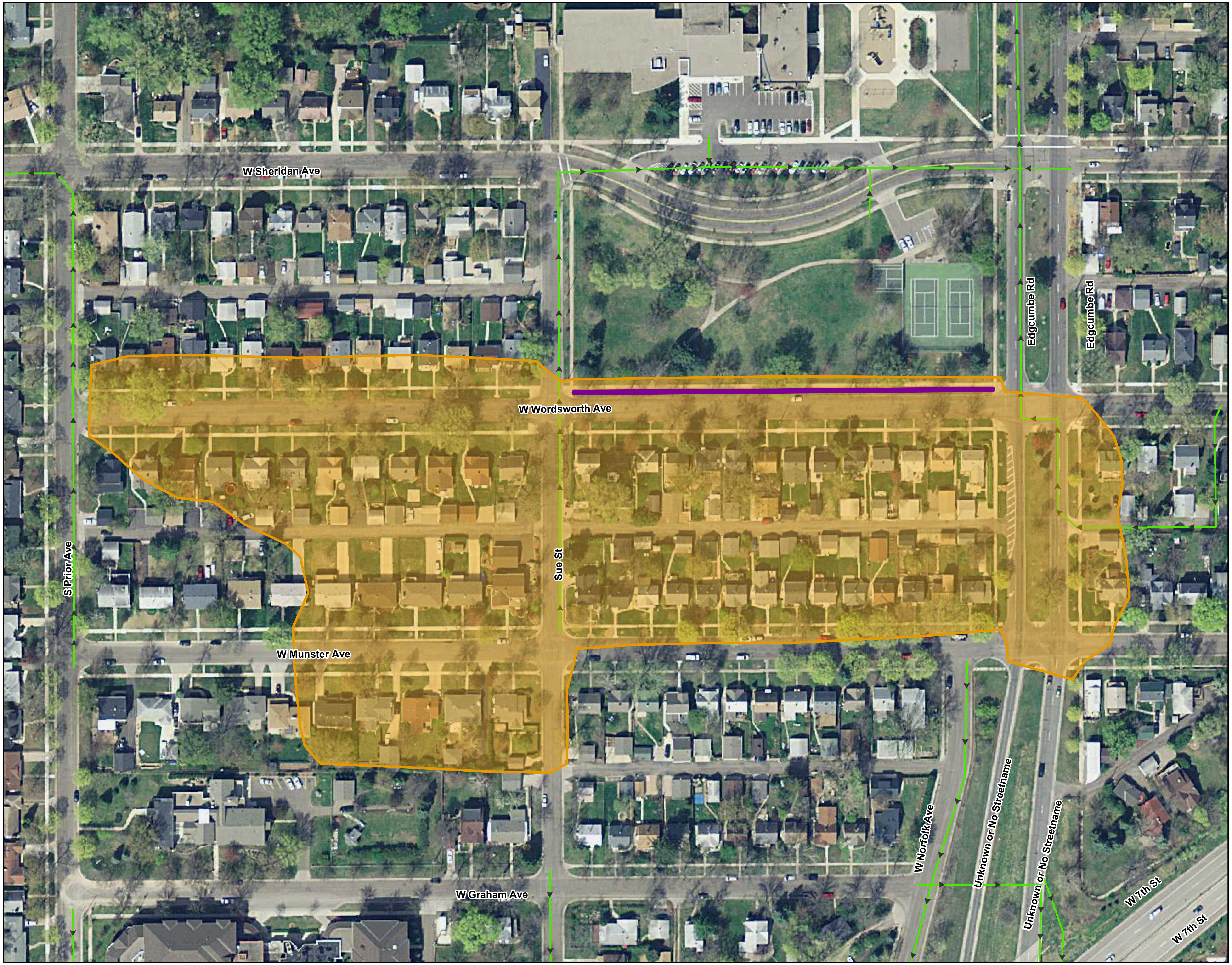
FIGURE 12 - 1

Wordsworth Infiltration BMP Drainage Area



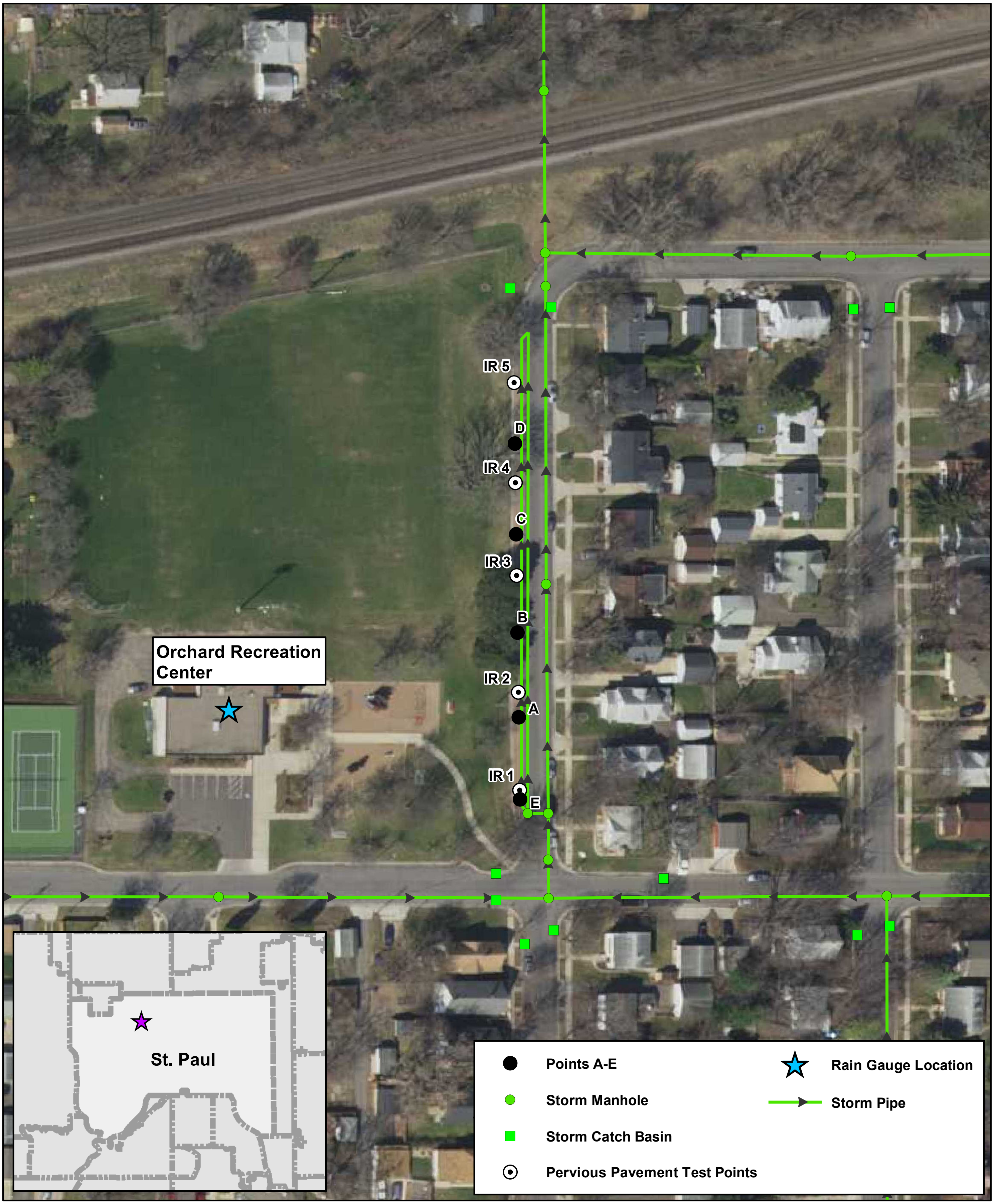
N
W E
S

0 125 250
Feet

Legend

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

wsb



Document Path: K:\01610-100\GIS\Maps\Figures\2018\Figure 13-1 Victoria Street.mxd Date Saved: 4/8/2019 1:53:10 PM

Figure 13-1 - Victoria Street Pervious Pavement Test Locations

2018 Water Quantity and Quality Monitoring Program
City of St Paul, MN

N

0 30 60 120 Feet

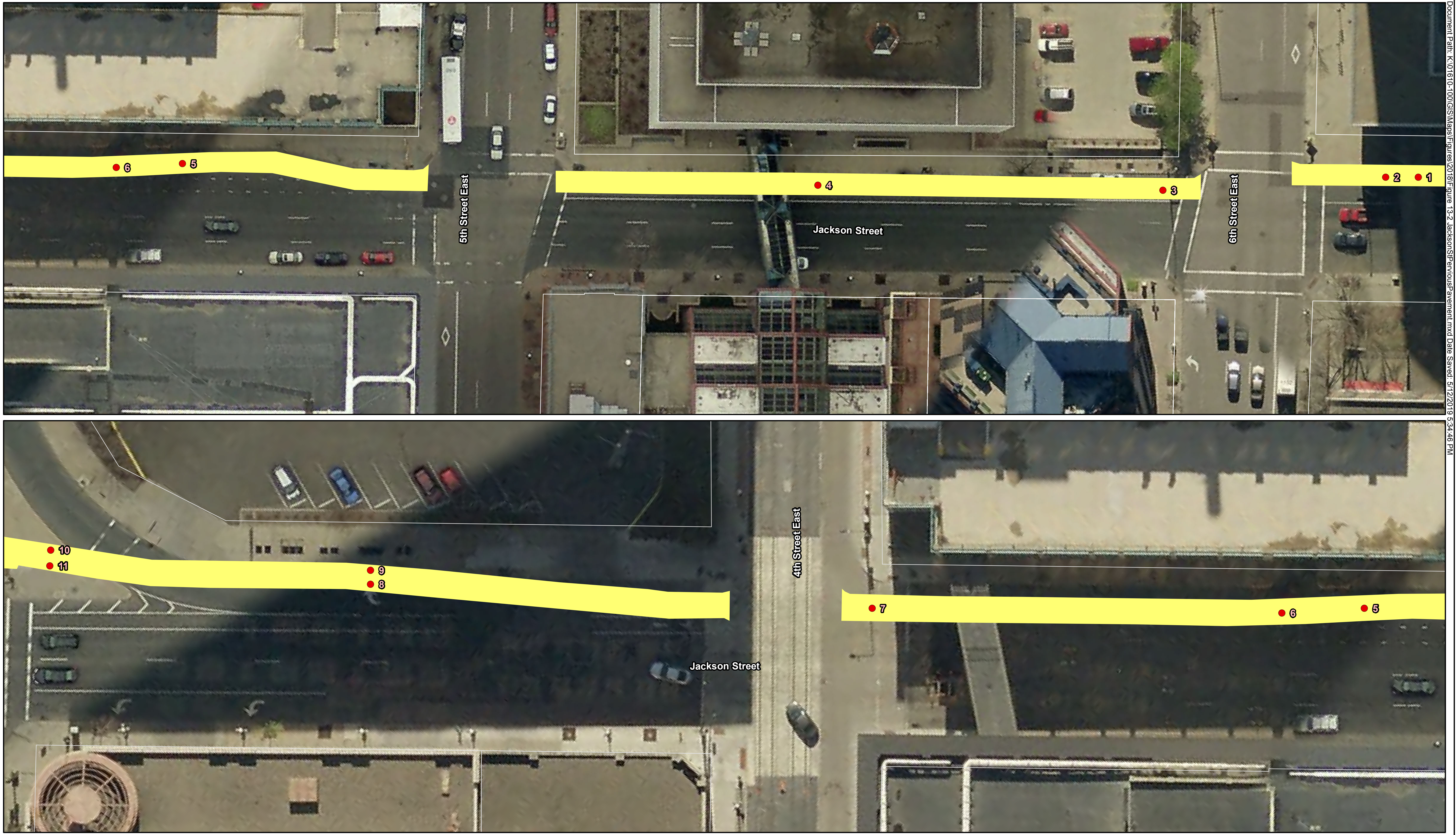


Figure 13-2 Jackson Street (pg 1of2)
JS-1 - JS-11 Pervious Test Locations

2018 Water Quantity and Quality Monitoring Program
City of Saint Paul, MN

● Pervious Pavement Testing Locations
🟨 Pervious Asphalt Bike Path

Document Path: K:\01610-100\GIS\Maps\Figures\2018\Figure 13-2 JacksonStPerviousPavement.mxd Date Saved: 5/12/2019 5:34:46 PM

Figure 13-2 Jackson Street (pg 2of2)
JS-12 - JS-18 Pervious Test Locations

2018 Water Quantity and Quality Monitoring Program
City of Saint Paul, MN

● Pervious Pavement Testing Locations
🟨 Pervious Asphalt Bike Path

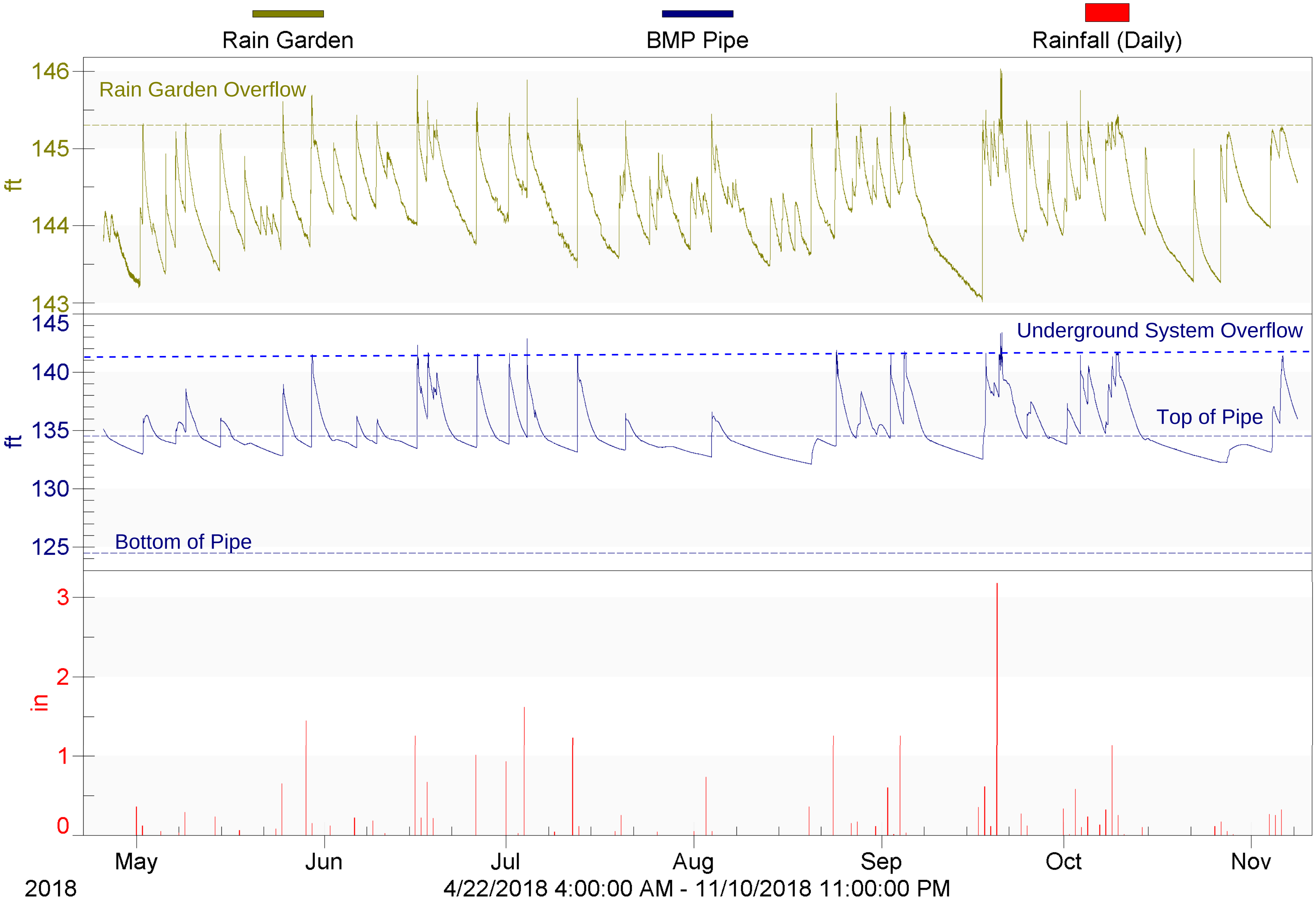
N
0 50 Feet
1 inch = 42 feet

Document Path: K:\01610-100\GIS\Maps\Figures\2018\Figure 13-3 JacksonStPerviousPavement (sec 2).mxd Date Saved: 5/12/2019 5:32:04 PM

Appendix A – Infiltration/Water Level Charts

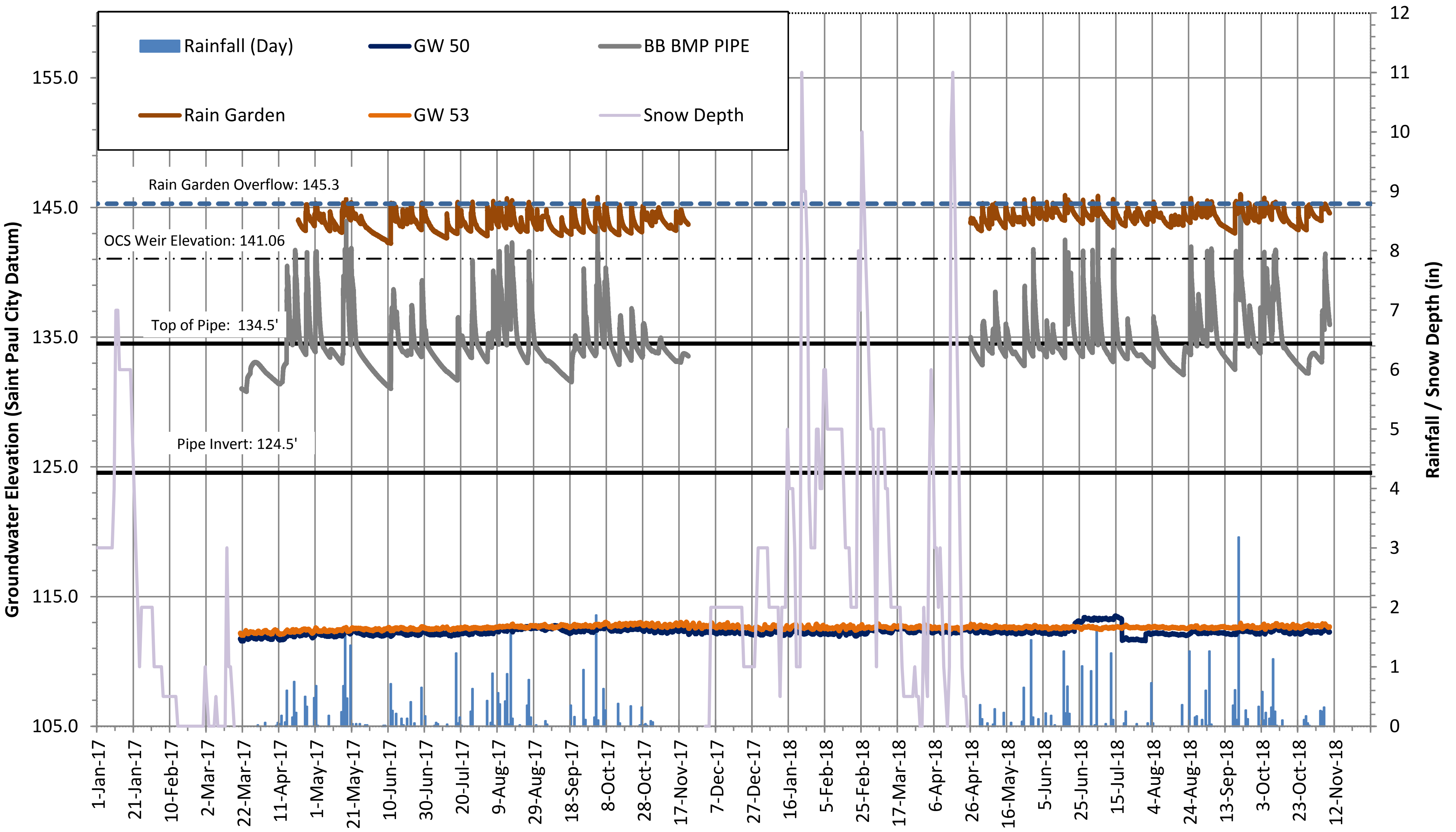
Chart A.1 Beacon Bluff

Water Level and Rainfall (SPCD)



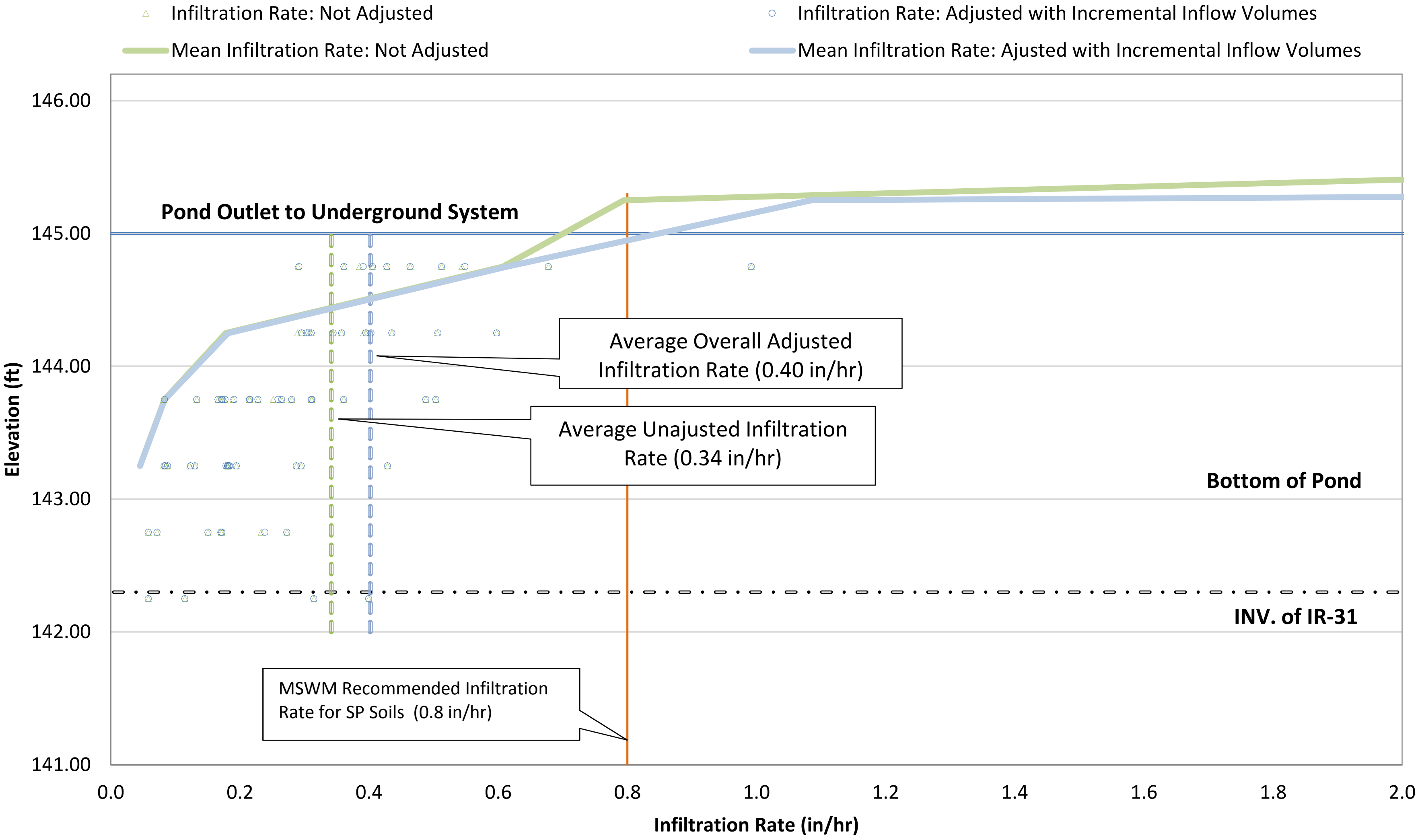
City of Saint Paul
2018 Beacon Bluff Groundwater and System Level
Chart A.2
WSB Job No.: 01610-100

Beacon Bluff
Groundwater and Infiltration System Level
St. Paul, MN



Beacon Bluff Raingarden Soil - Infiltration Rate Graph (IR-31)

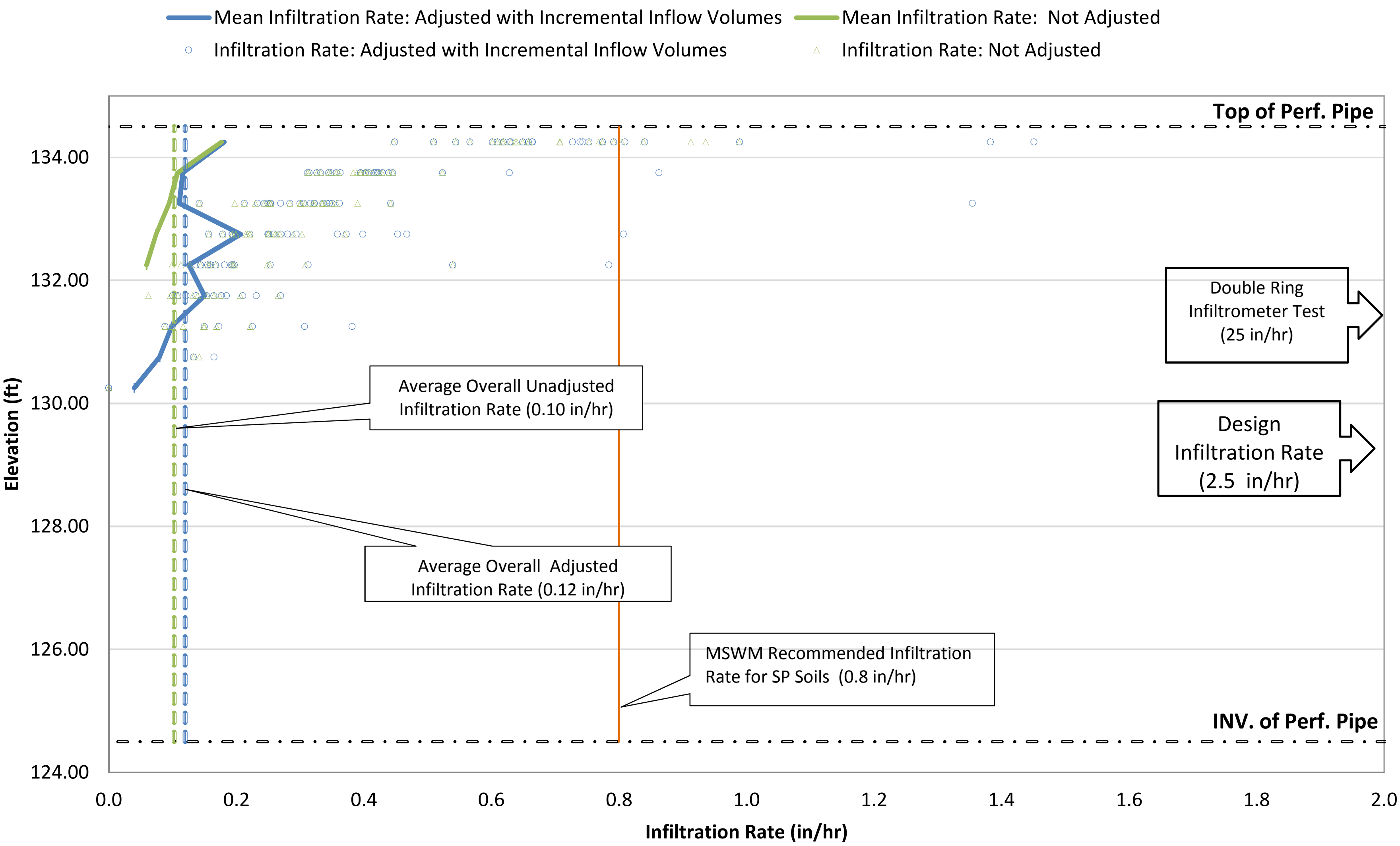
(Observed at 0.5 Foot Height Intervals)



City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.4
WSB Project No.: 01610-100

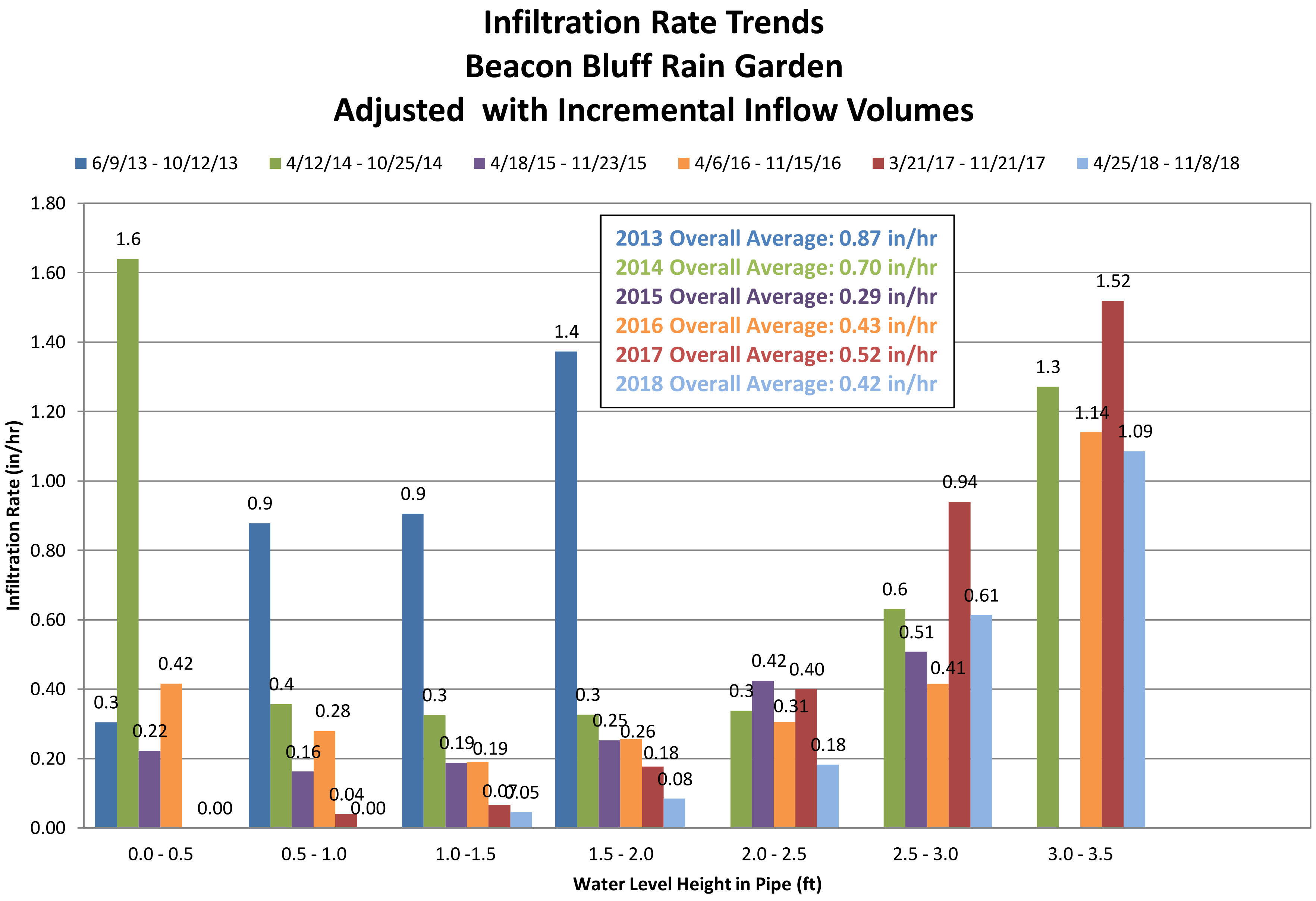
Beacon Bluff Underground System - Infiltration Rate Graph (BMP Pipe)

(Observed at 0.5 Foot Height Intervals)



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

City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.5
WSB Job No.: 01610-100
*2017 and 2018 data is from IR-31, previous years is from IR-33



City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.6
WSB Job No.: 01610-100

Infiltration Rate Trends
Beacon Bluff Underground System
Adjusted with Incremental Inflow Volumes

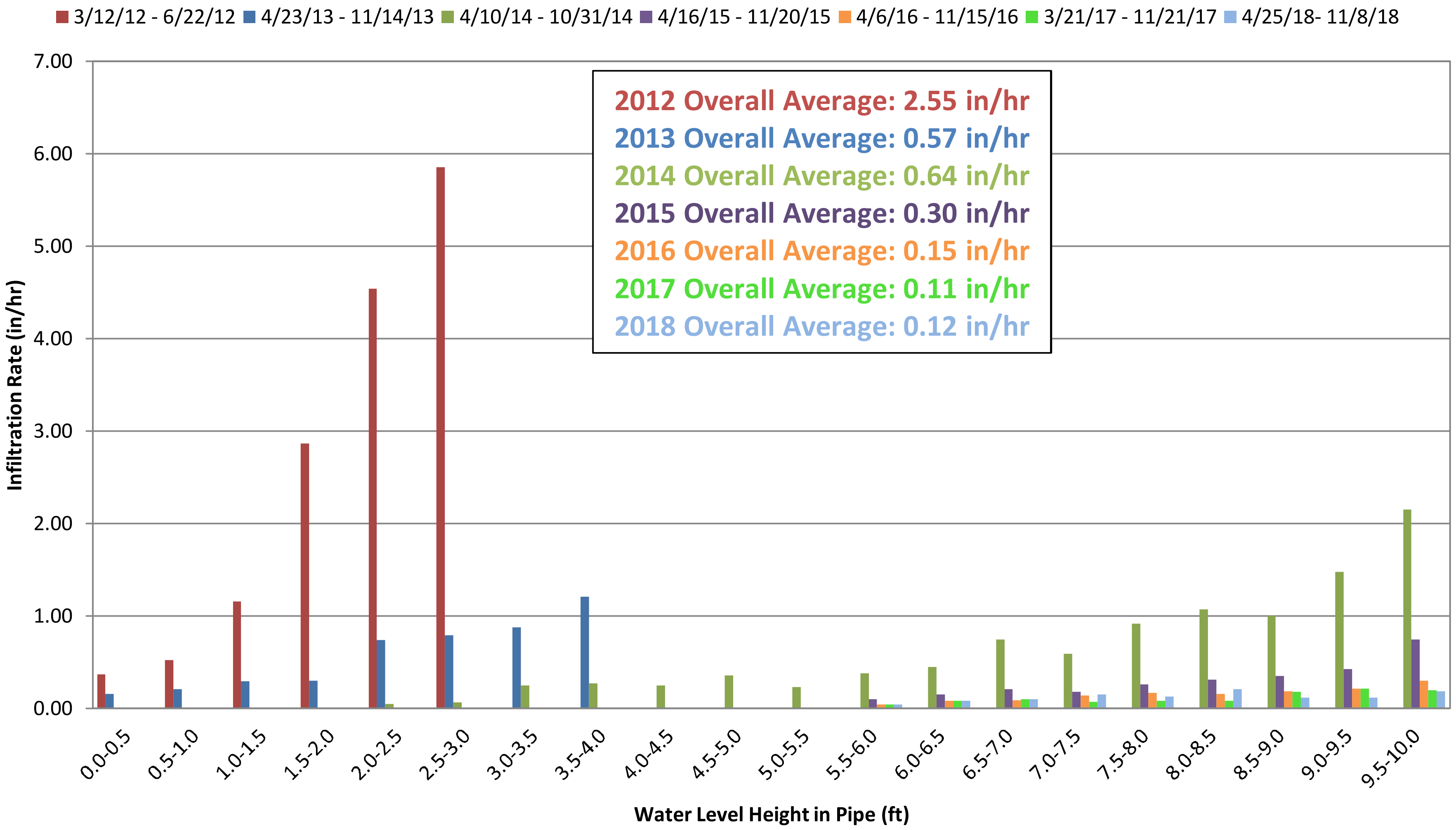
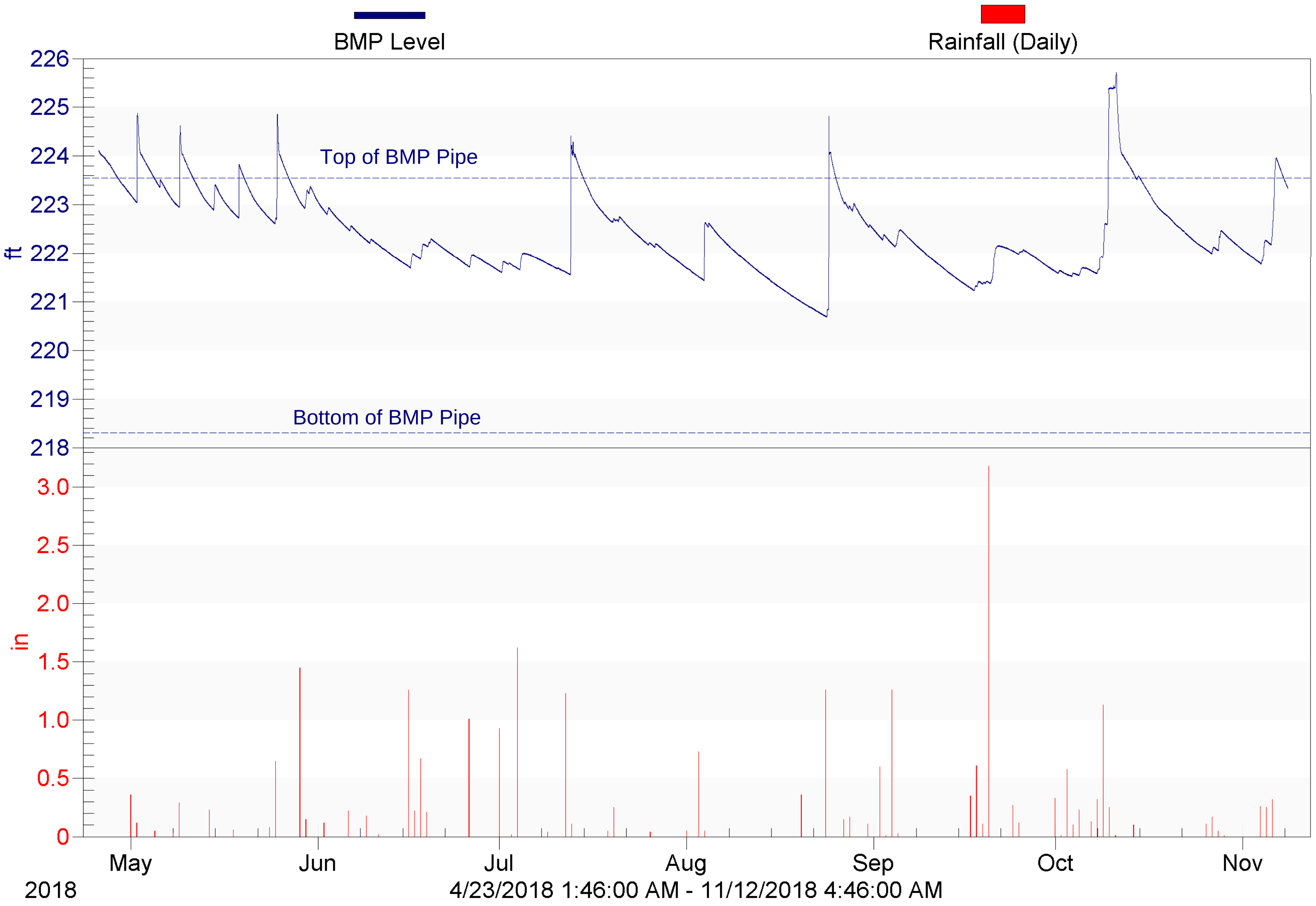


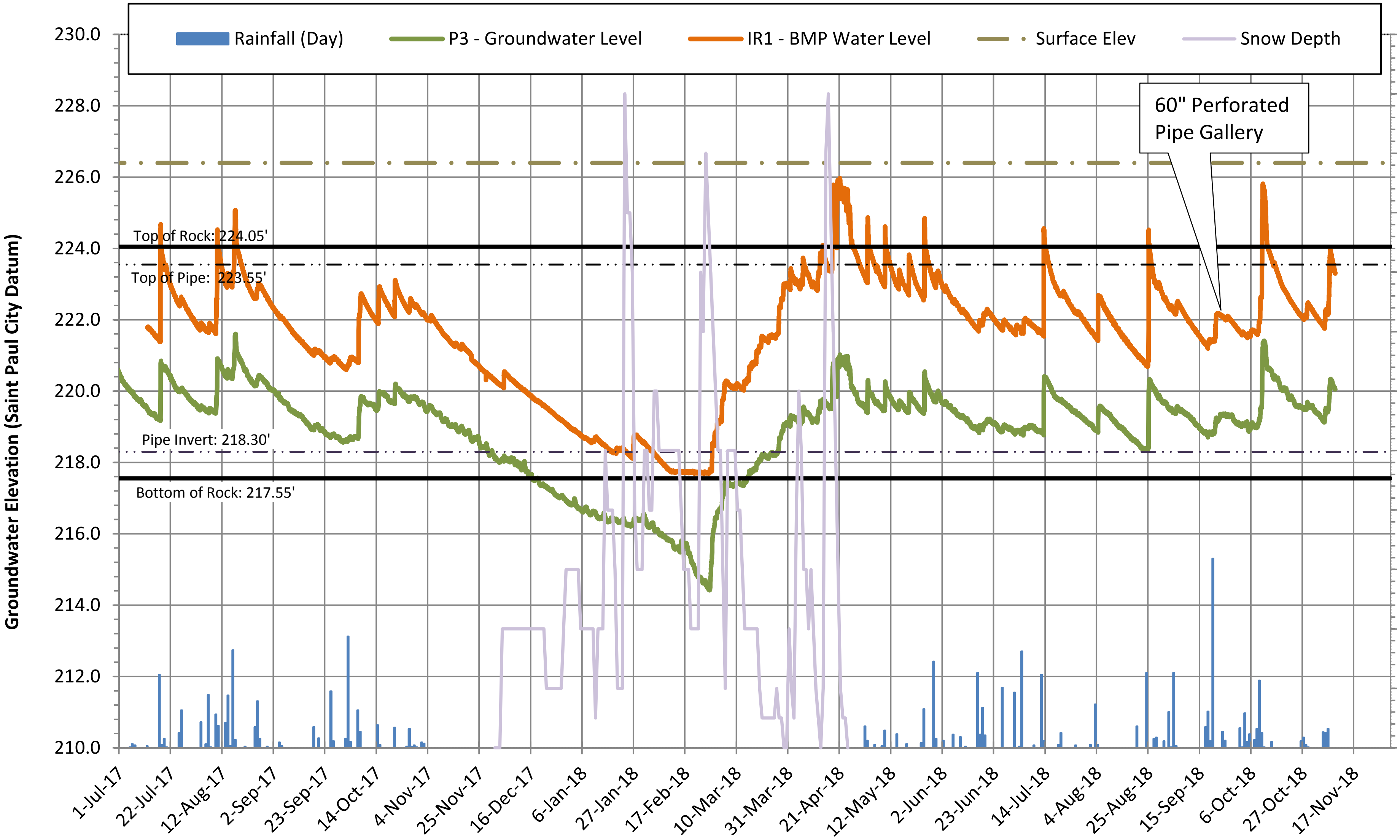
Chart A.7 Hillcrest Knoll Park

Water Level and Rainfall (SPCD)



City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.8
WSB Job No.: 01610-100

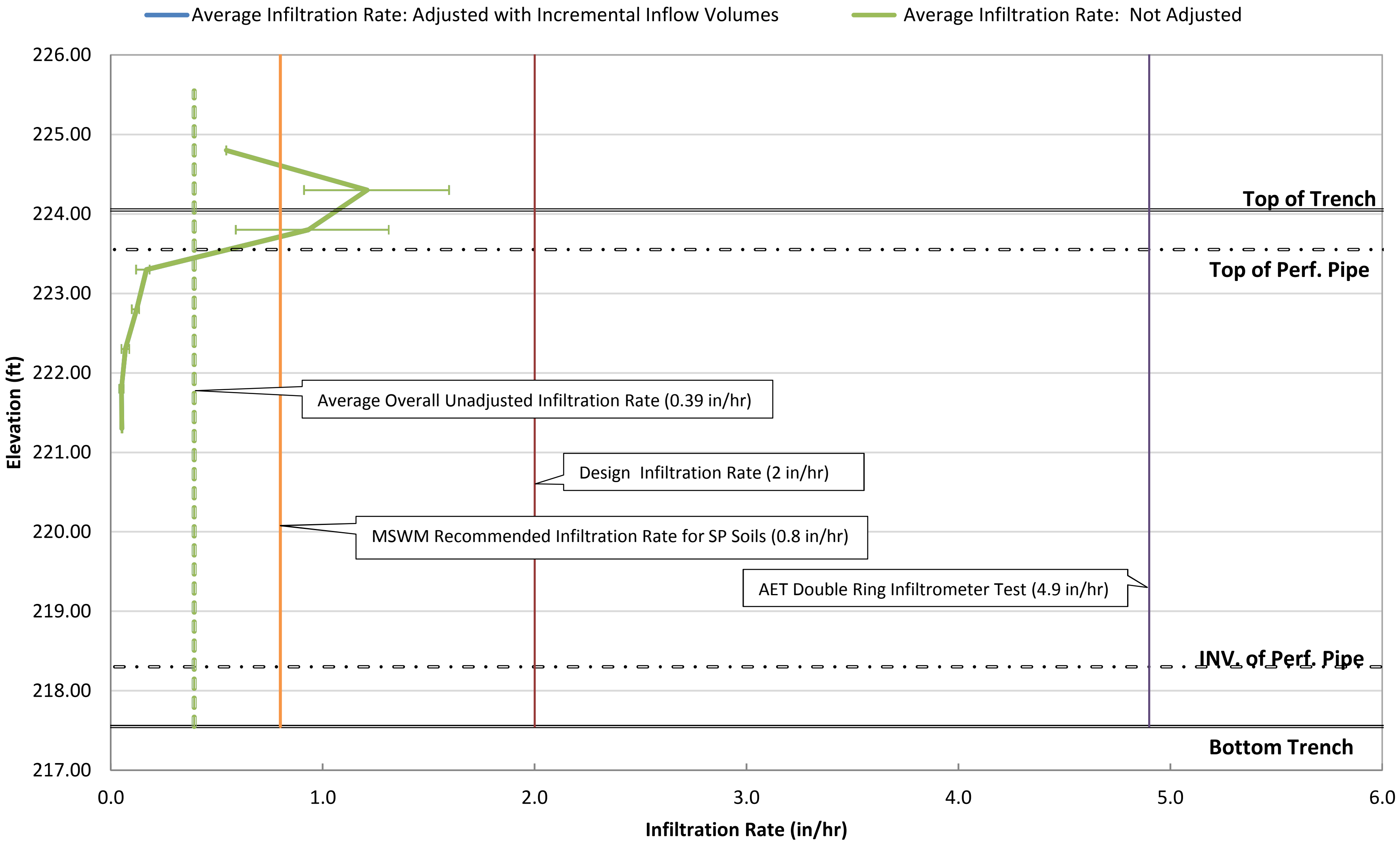
Hillcrest Knoll Park
Groundwater and Infiltration System Level
St. Paul, MN



City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.9
WSB Job No.: 01610-100

Hillcrest Knoll Park - Infiltration Rate Graph

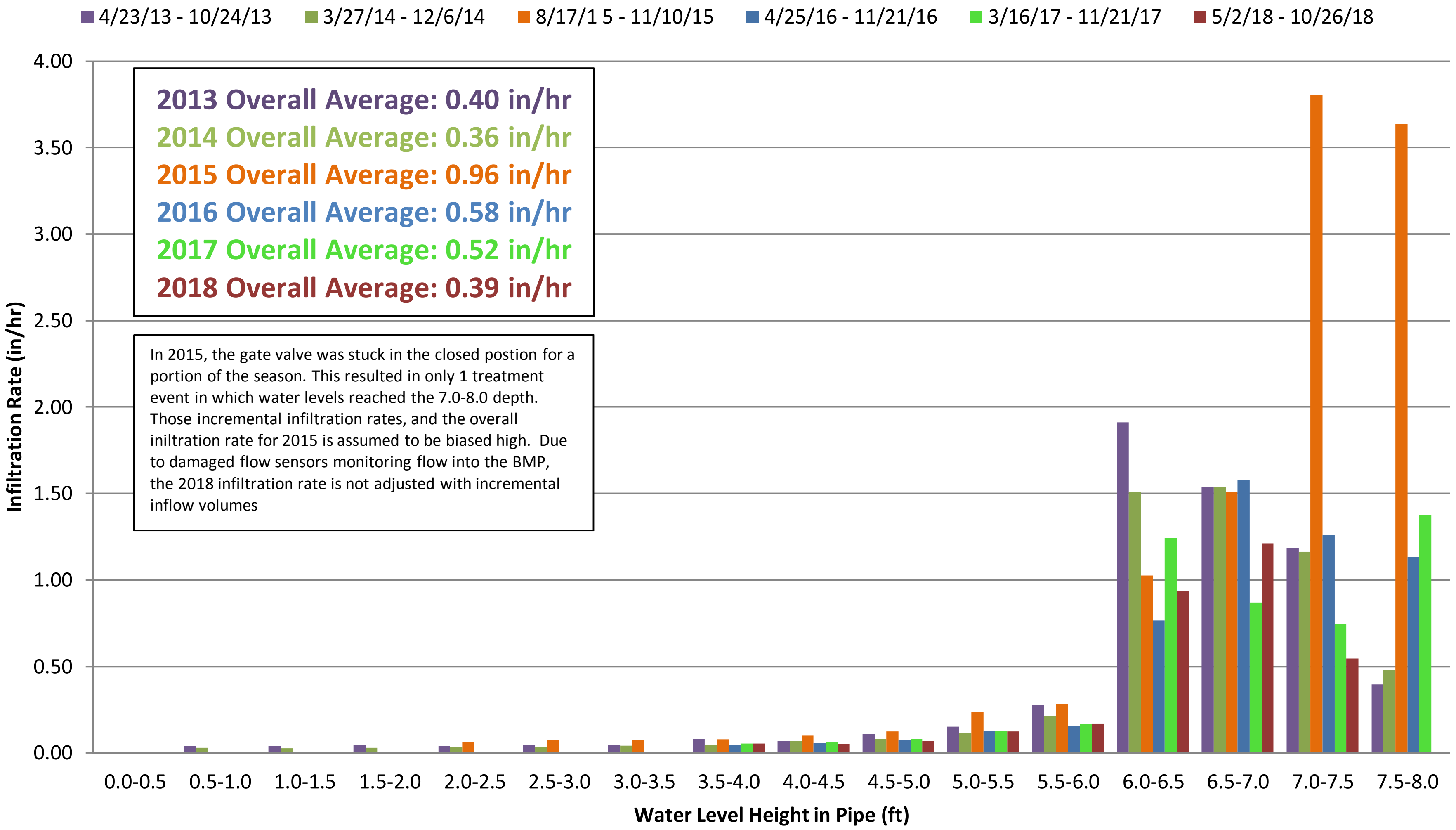
(Observed 0.5 Foot Height Increments)



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

City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.10
WSB Job No.: 01610-100

Infiltration Rate Trends
Hillcrest Knoll Park
Adjusted with Incremental Inflow Volumes

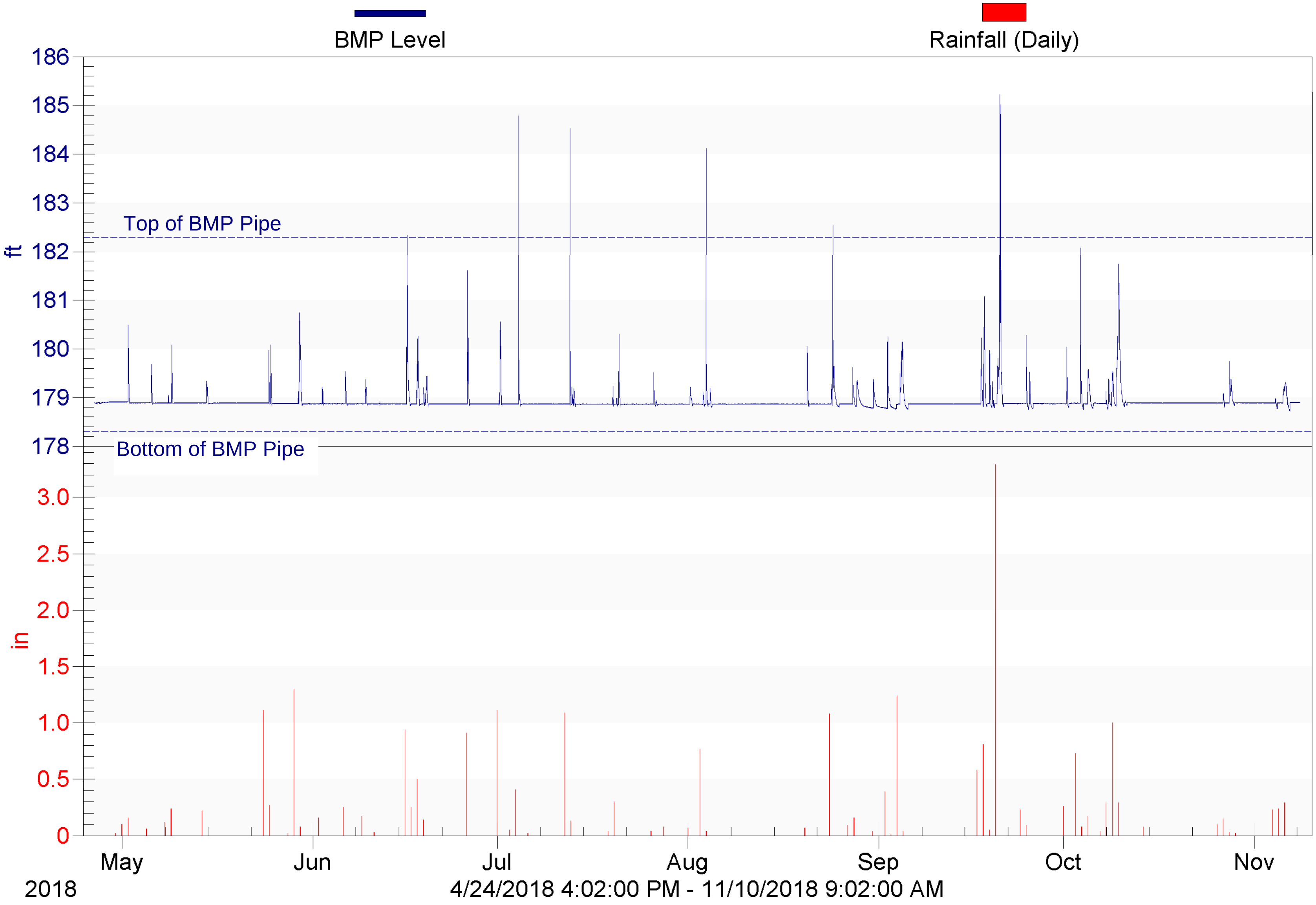


2013 Overall Average: 0.40 in/hr
2014 Overall Average: 0.36 in/hr
2015 Overall Average: 0.96 in/hr
2016 Overall Average: 0.58 in/hr
2017 Overall Average: 0.52 in/hr
2018 Overall Average: 0.39 in/hr

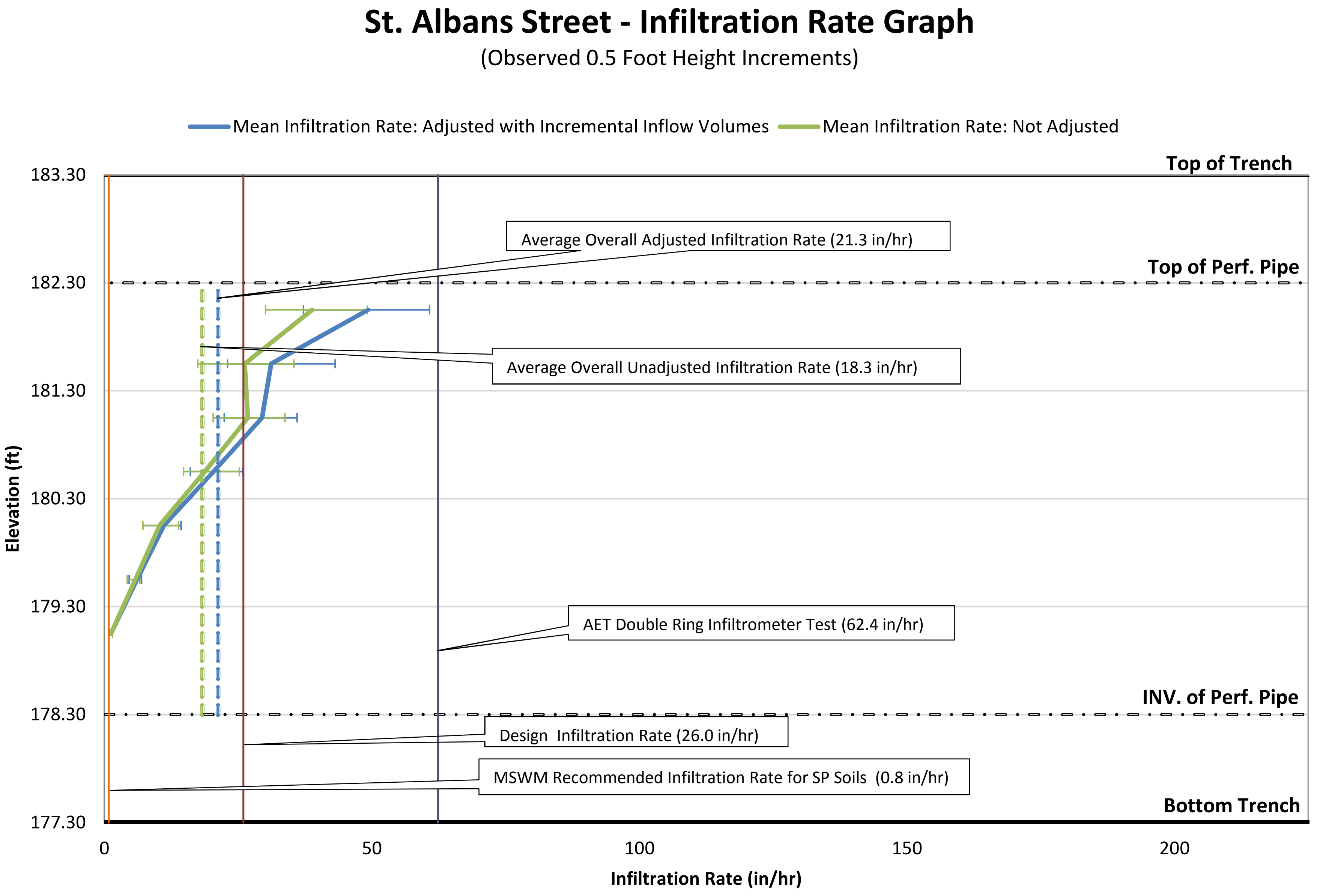
In 2015, the gate valve was stuck in the closed postion for a portion of the season. This resulted in only 1 treatment event in which water levels reached the 7.0-8.0 depth. Those incremental infiltration rates, and the overall iniltration rate for 2015 is assumed to be biased high. Due to damaged flow sensors monitoring flow into the BMP, the 2018 infiltration rate is not adjusted with incremental inflow volumes

Chart A.11 St. Albans

Water Level and Rainfall (SPCD)



City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.12
WSB Job No.: 01610-100



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'

City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.13
WSB Project No.: 01610-100

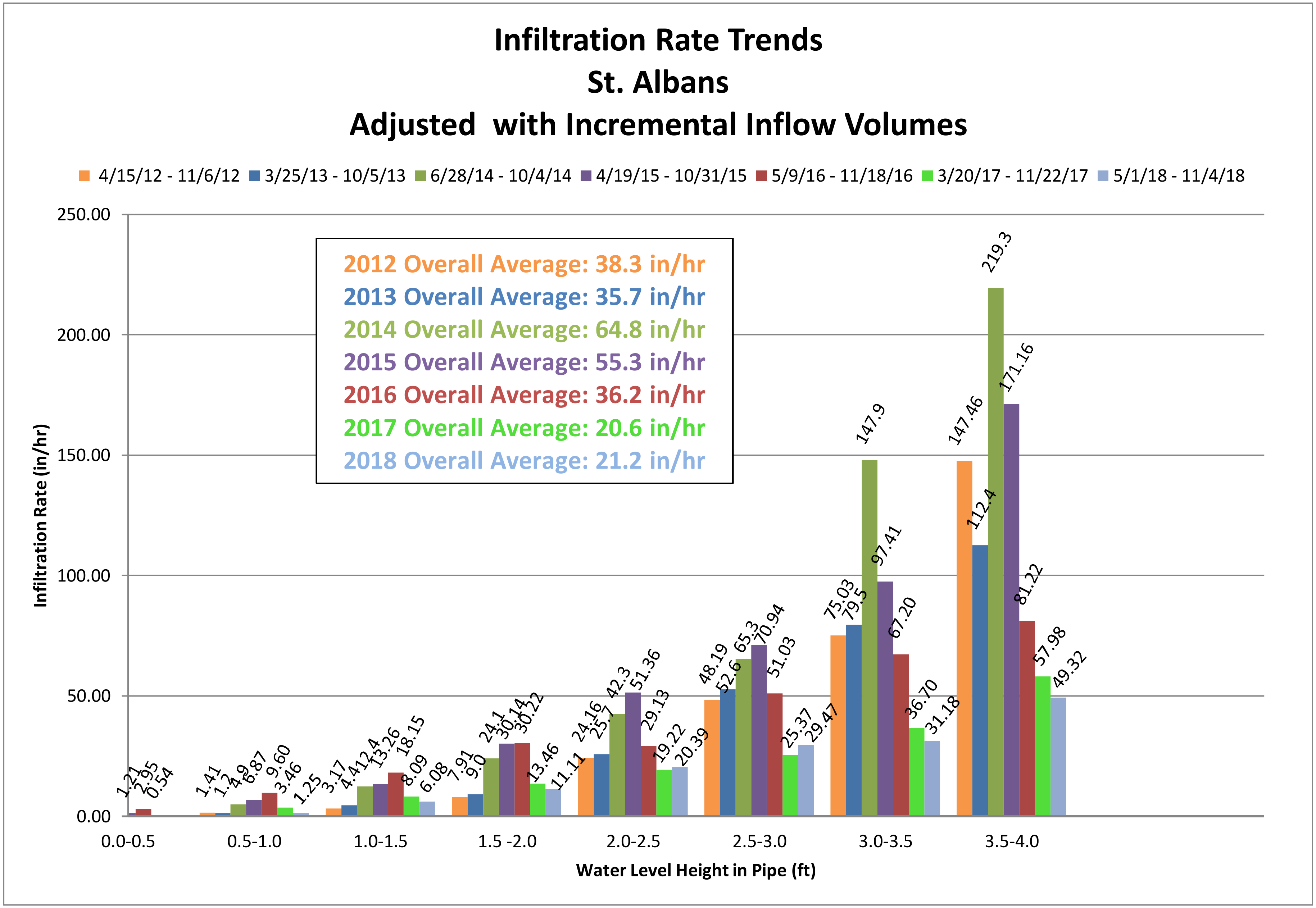


Chart A.14 Hampden Park

BMP Water Level and Rainfall

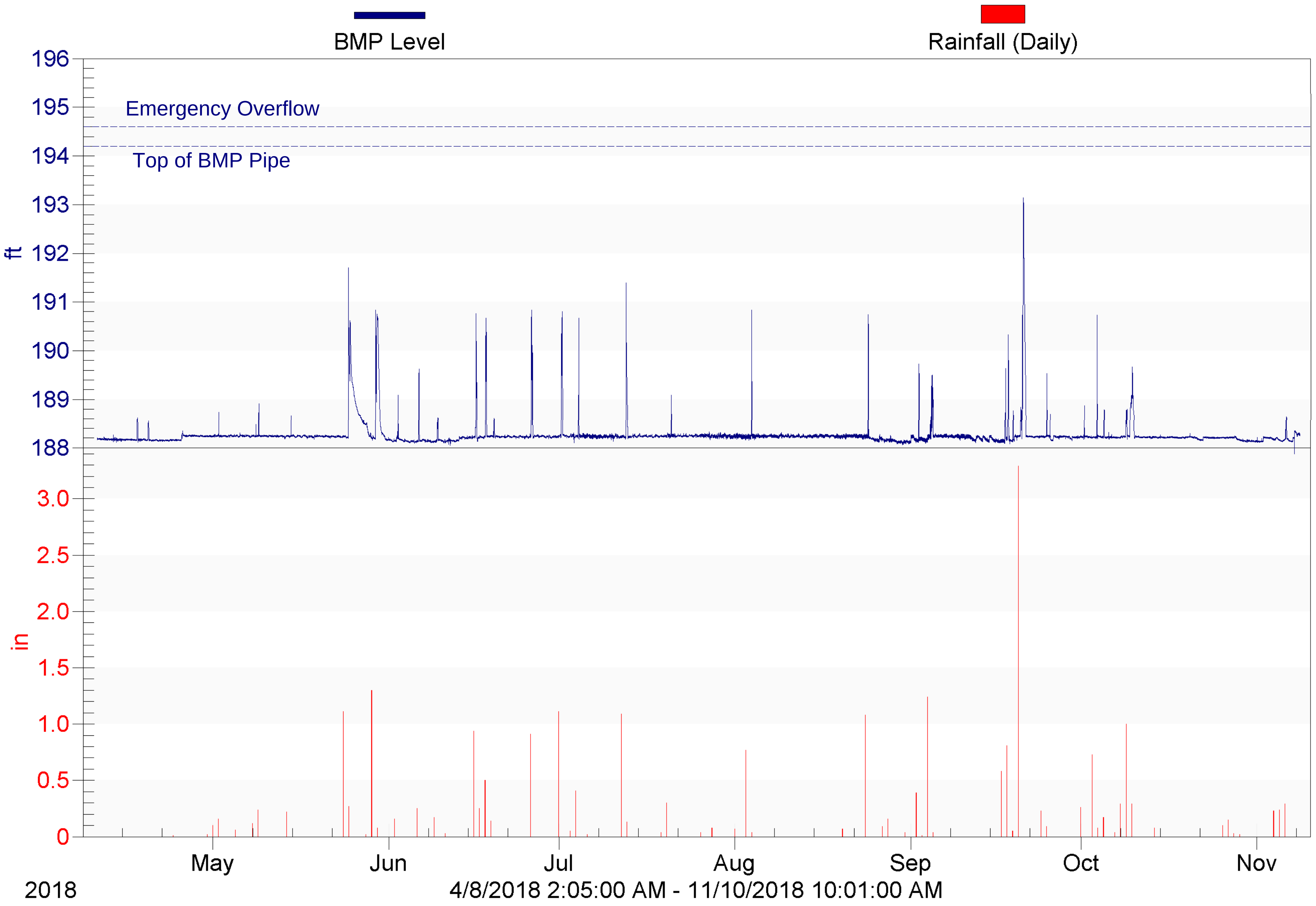
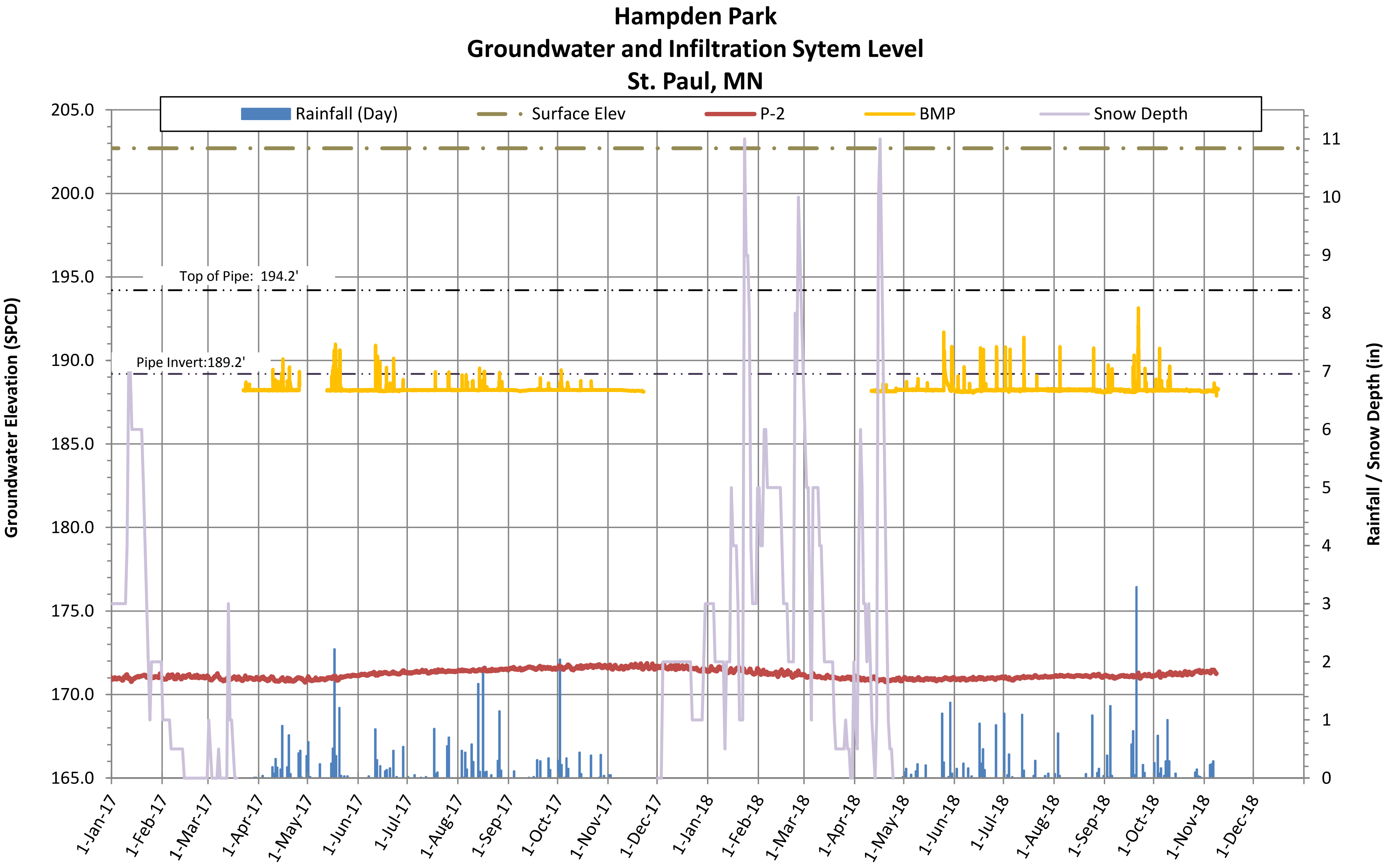


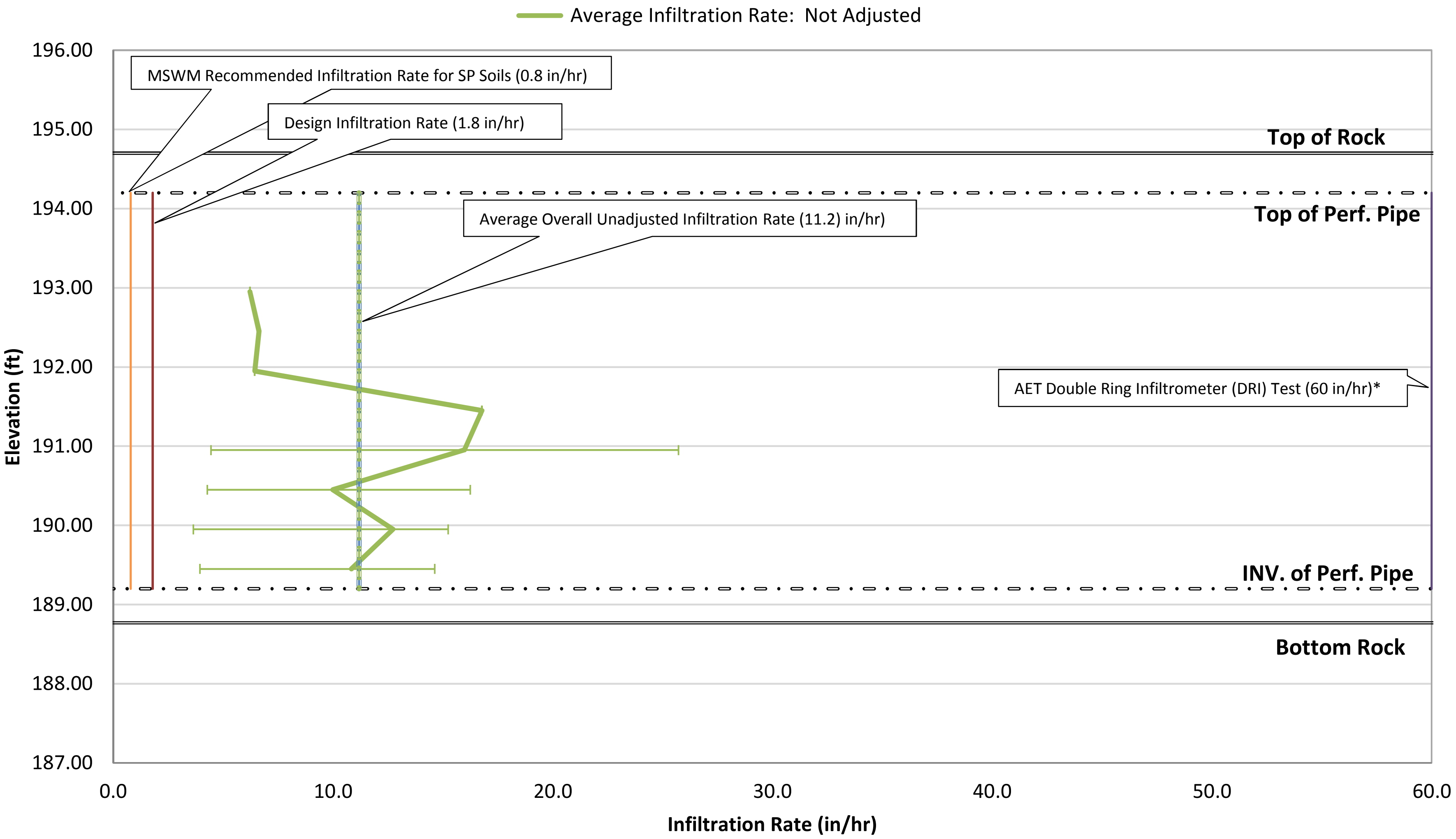
Chart A.15
WSB Job No.: 01610-100



City of Saint Paul
2018 Water Quality and Quantity Monitoring
Chart A.16
WSB Job No.: 01610-100

Hampden Park - Infiltration Rate Graph

(Observed 0.5 Foot Height Increments)



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.

City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.17
WSB Job No.: 01610-100

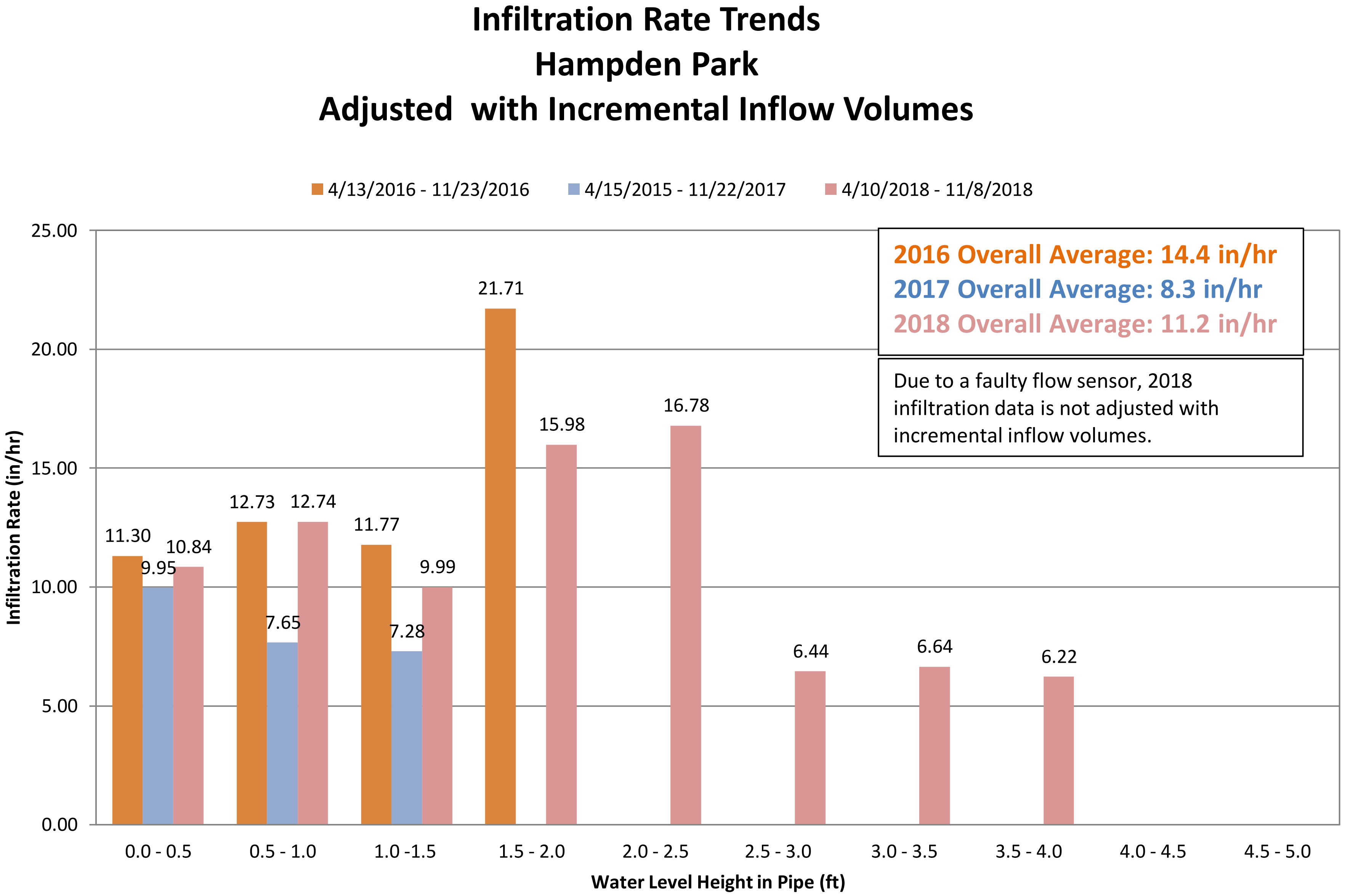
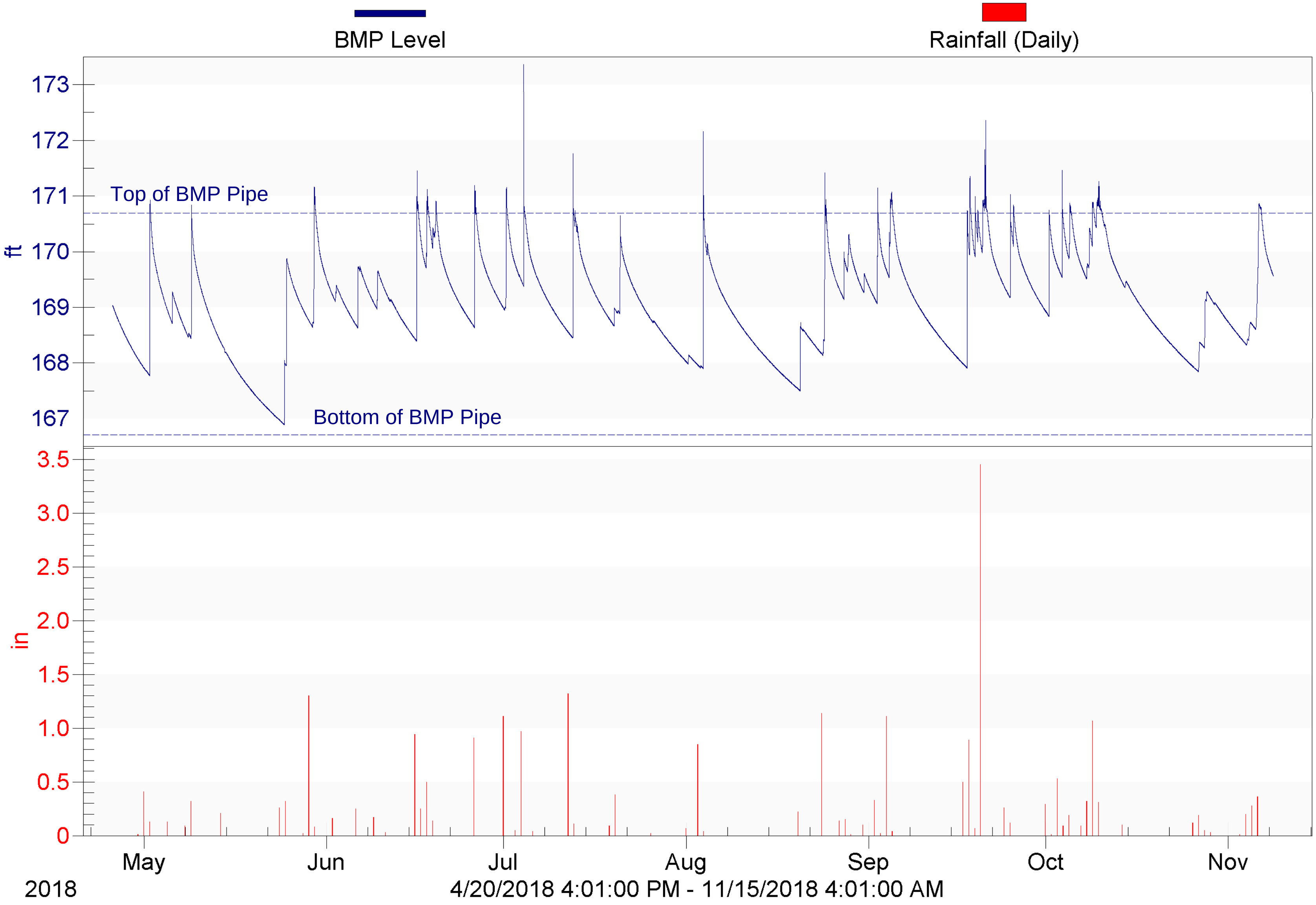


Chart A. 18 Arundel

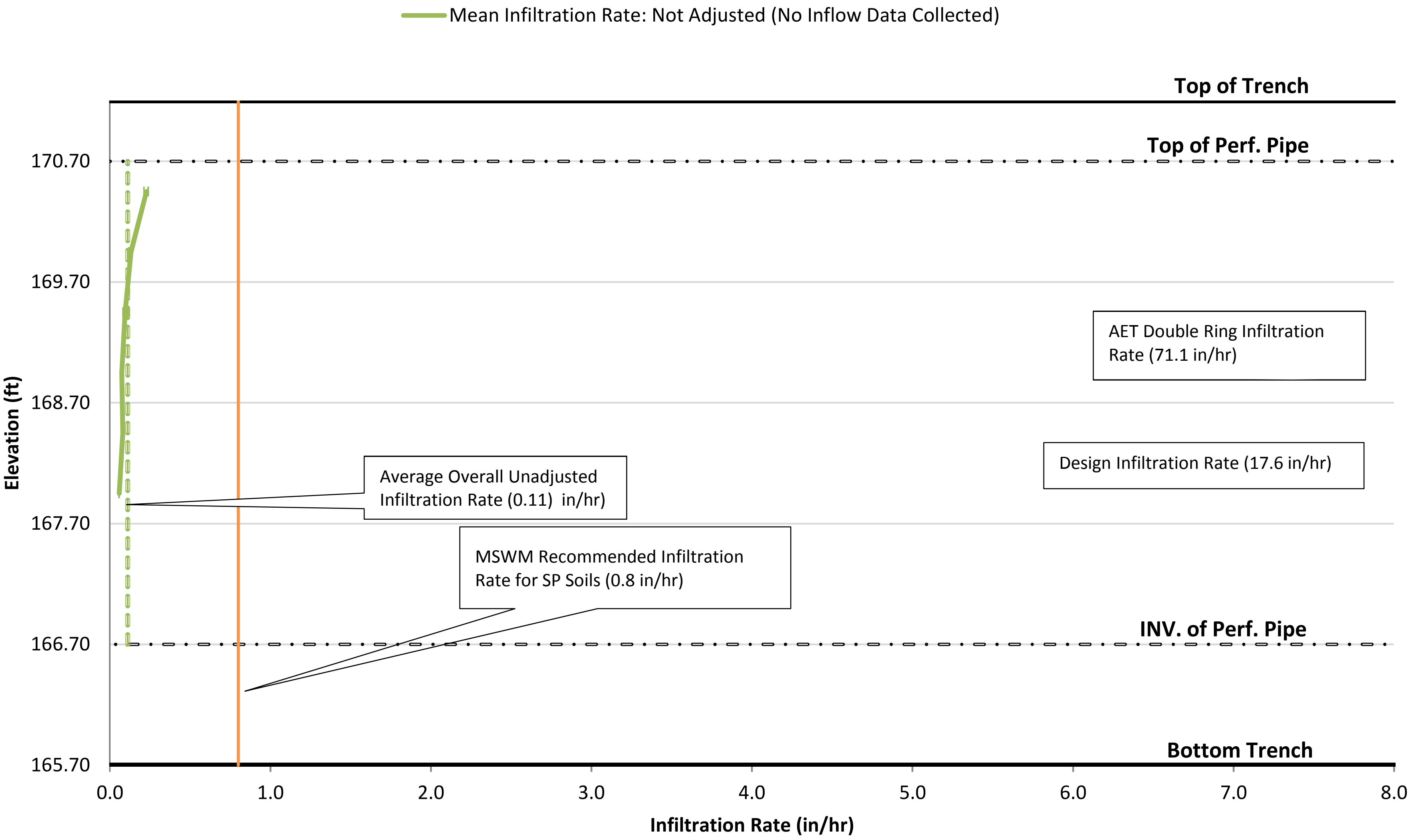
Water Level and Rainfall (SPCD)



City of Saint Paul
2018 Water Quality and Quantity
Chart A.19
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
2018 Water Quality and Quantity Report
Chart A.20
WSB Job NO.: 01610-100

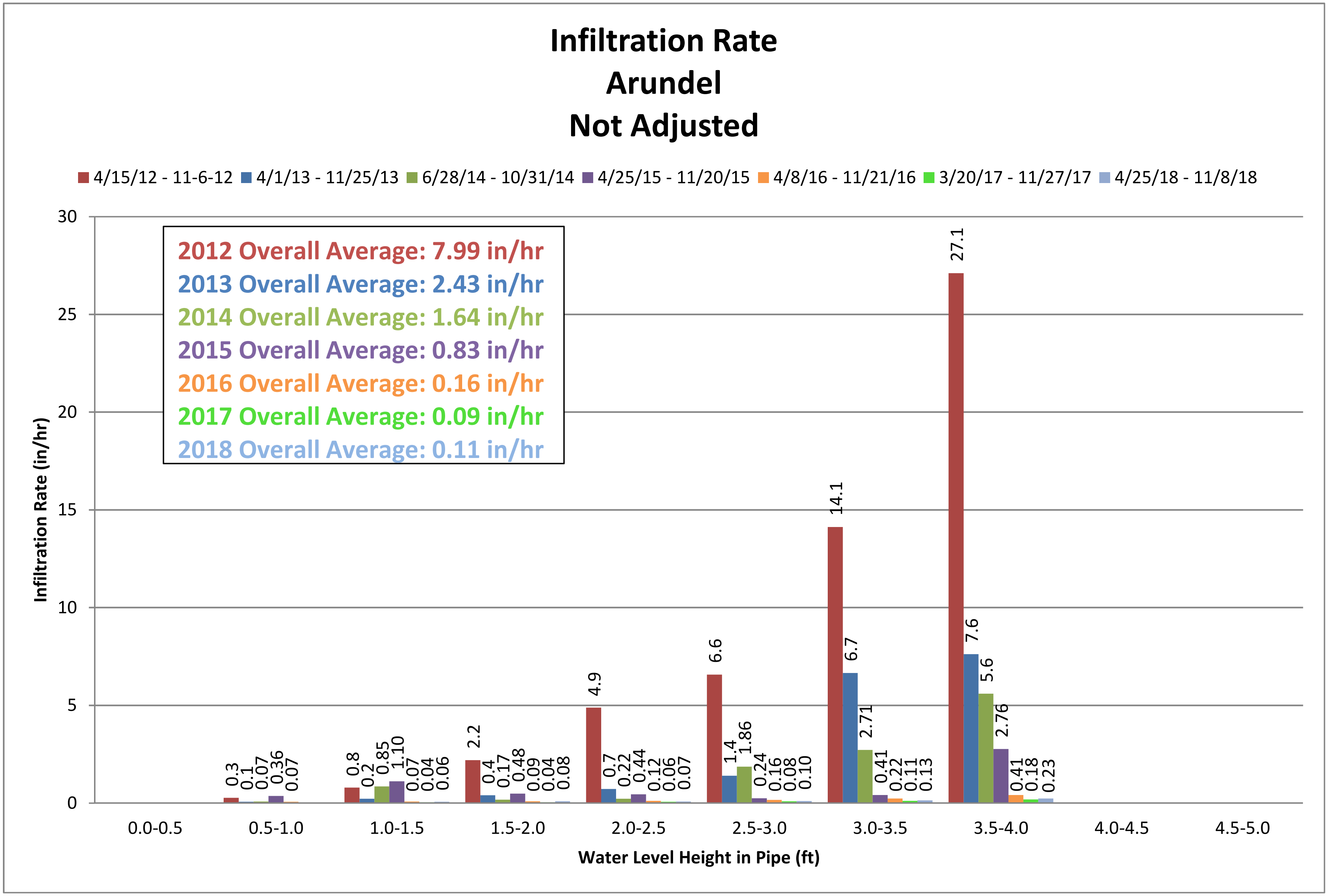


Chart A.21 TBNS - Maryland Pond

Pond Level and Rainfall (SPCD)

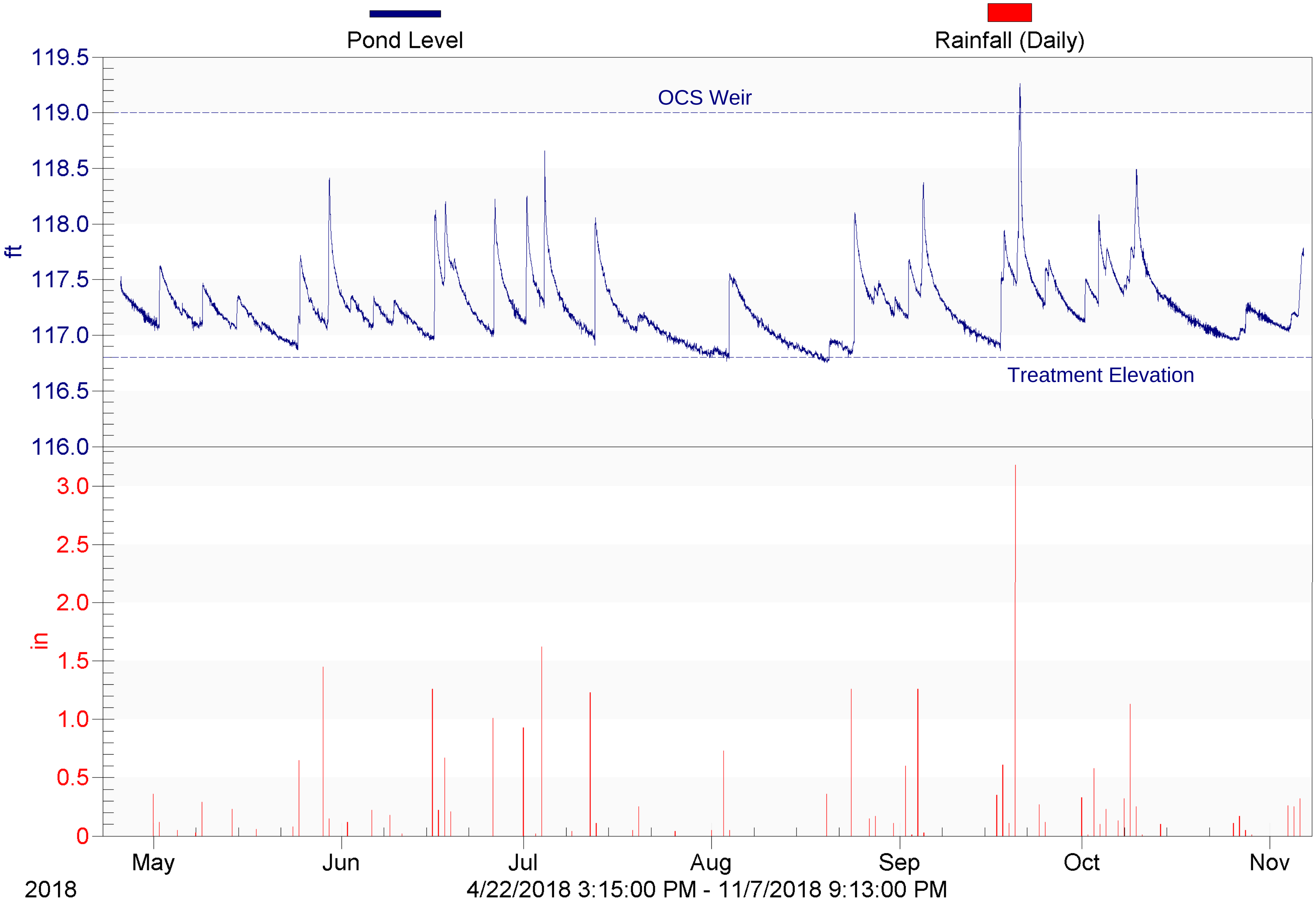


Chart A.22 TBNS - Magnolia

Pond Level and Rainfall (SPCD)

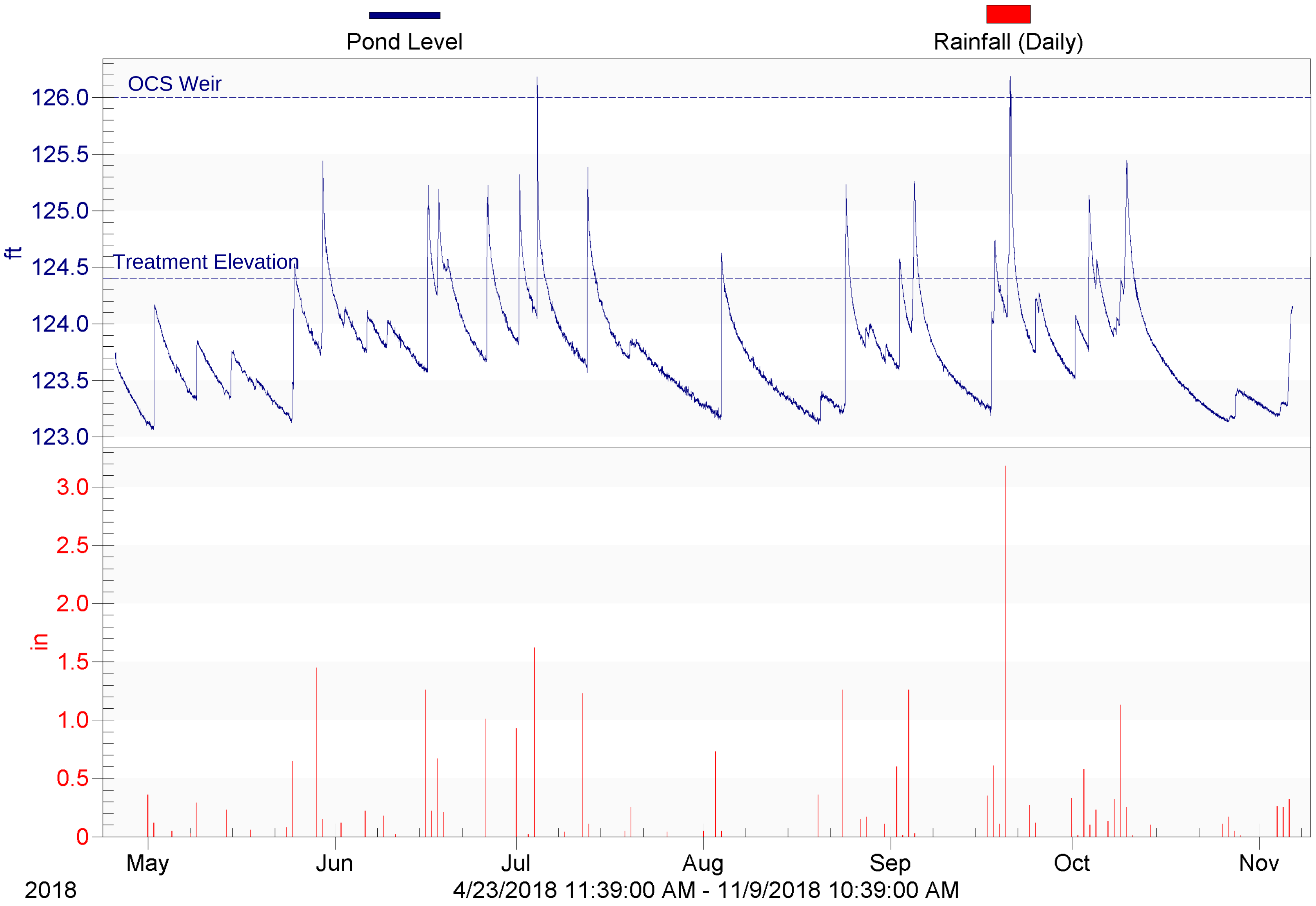


Chart A.23 TBNS - Jenks

Pond Level and Rainfall (SPCD)

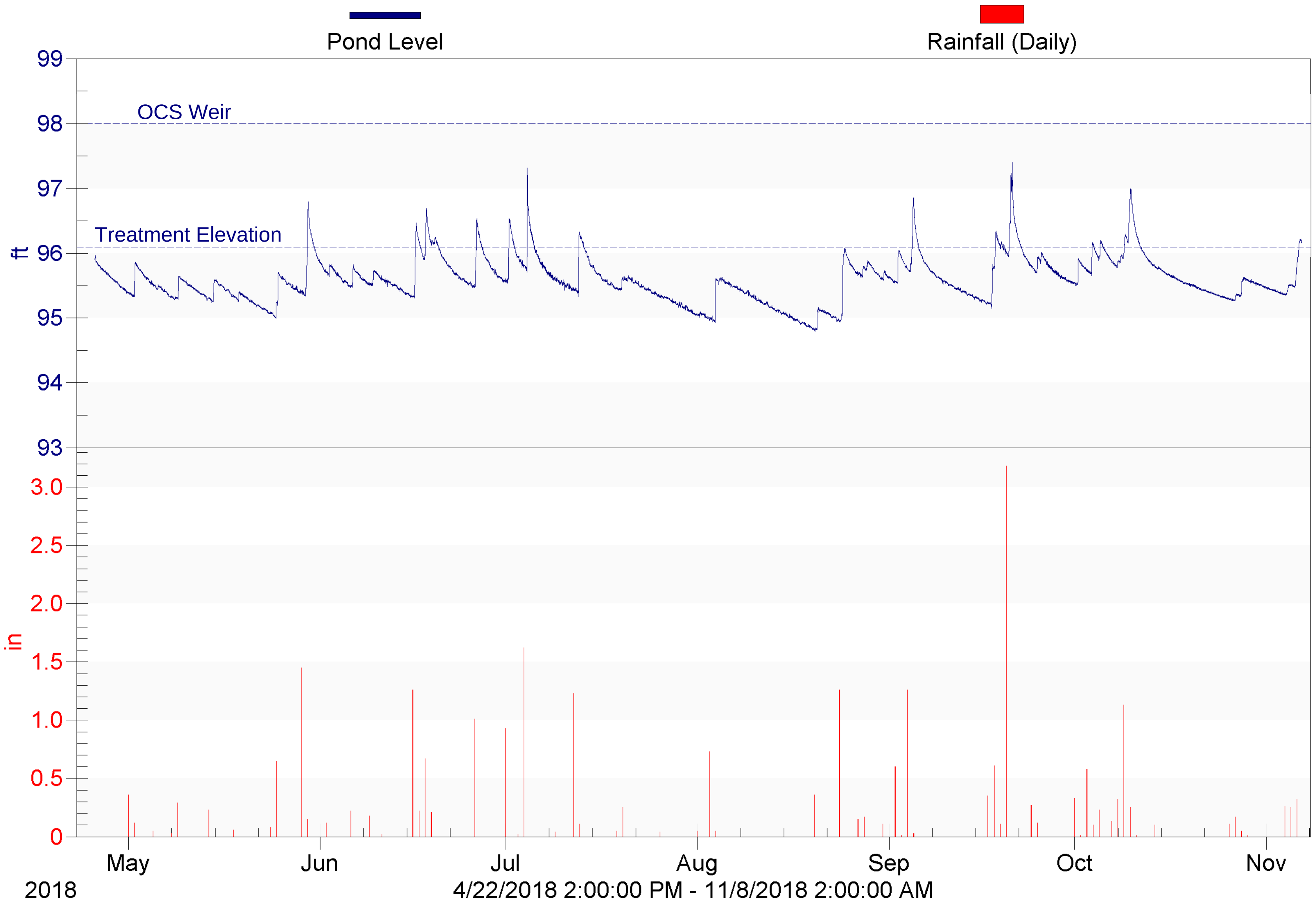
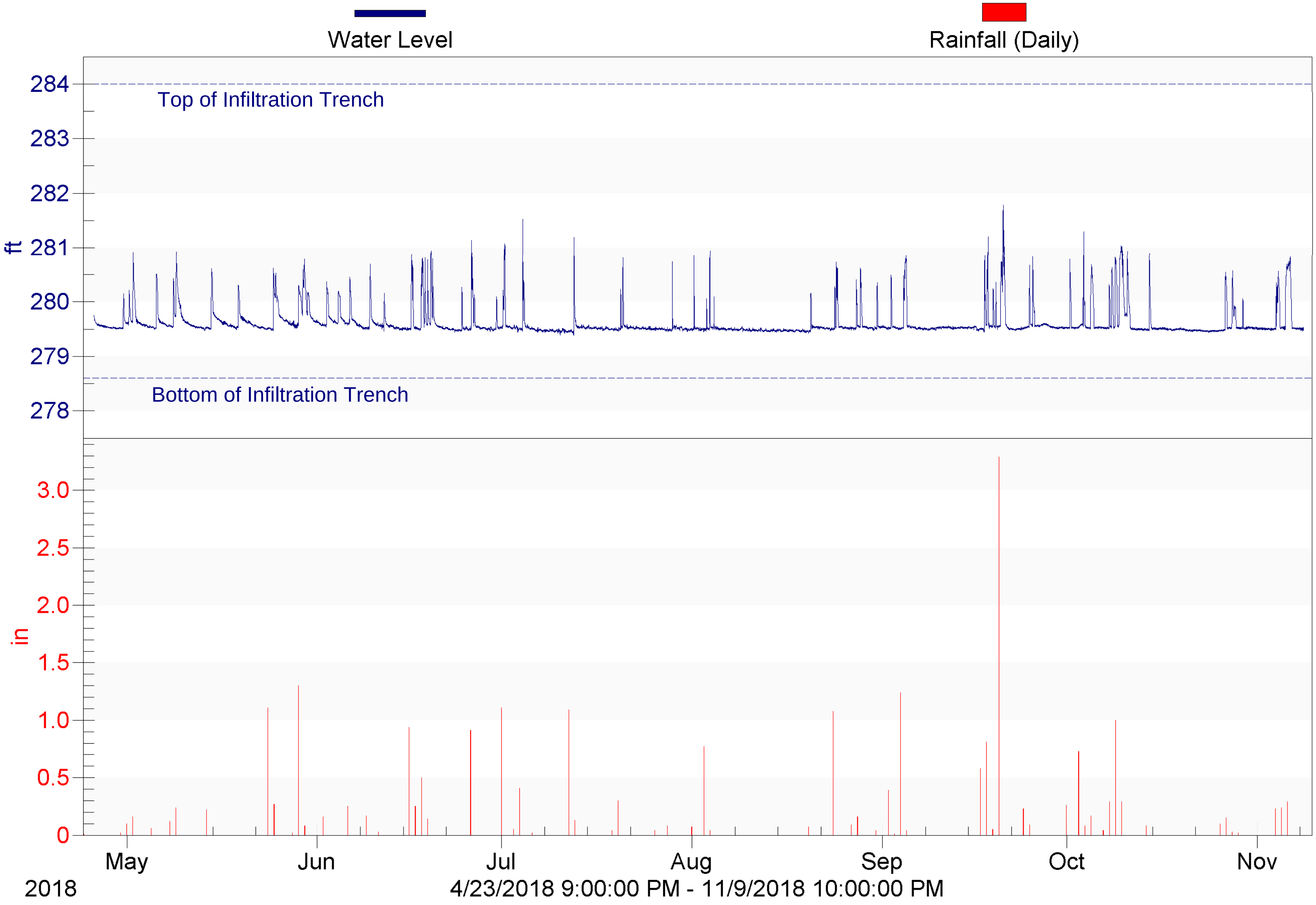


Chart A.24 Montreal Trench

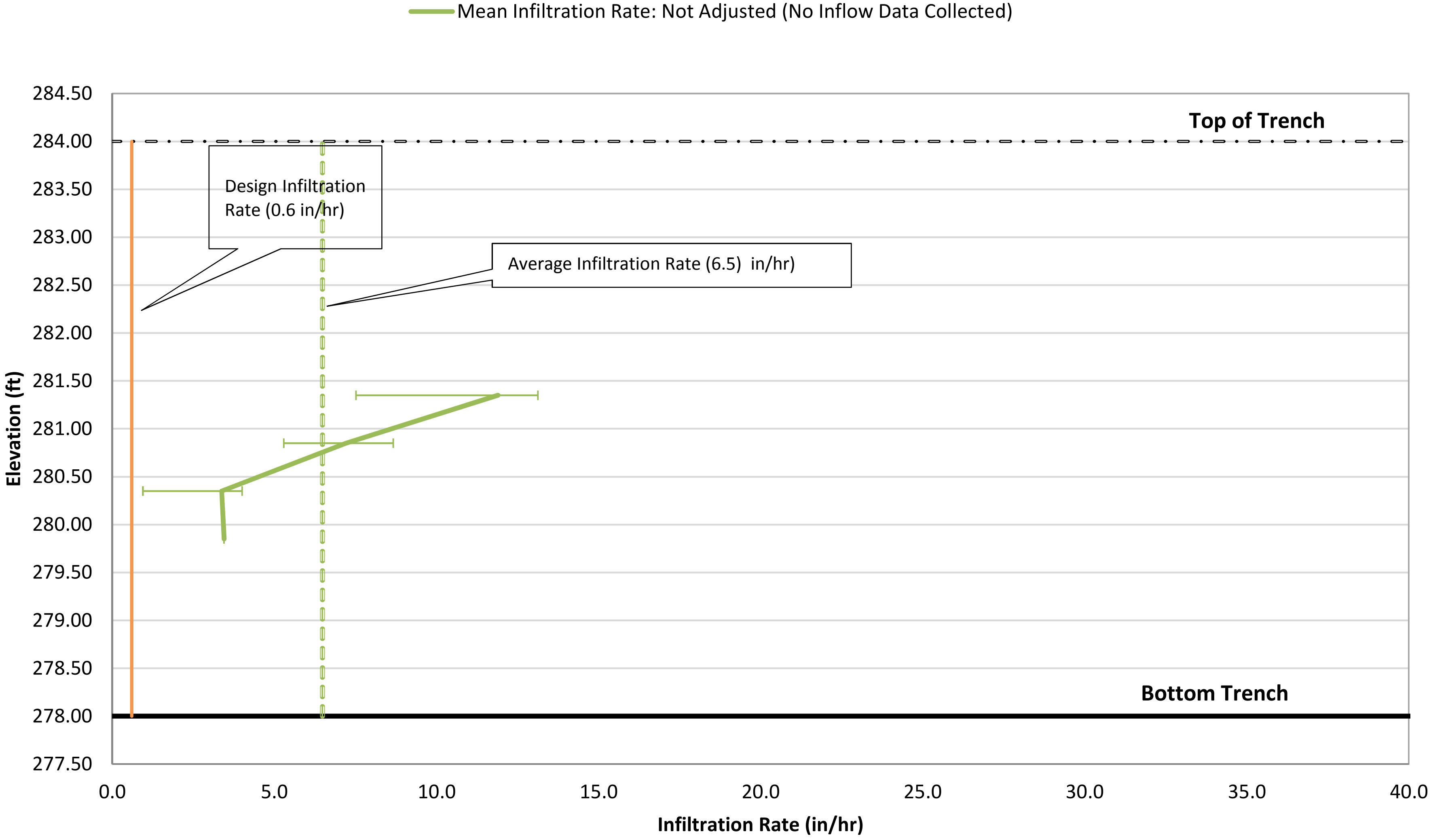
Trench Water Level and Rainfall (SPCD)



City of Saint Paul
2018 Water Quality and Quantity
Chart A.25
WSB Job No.: 01610-100

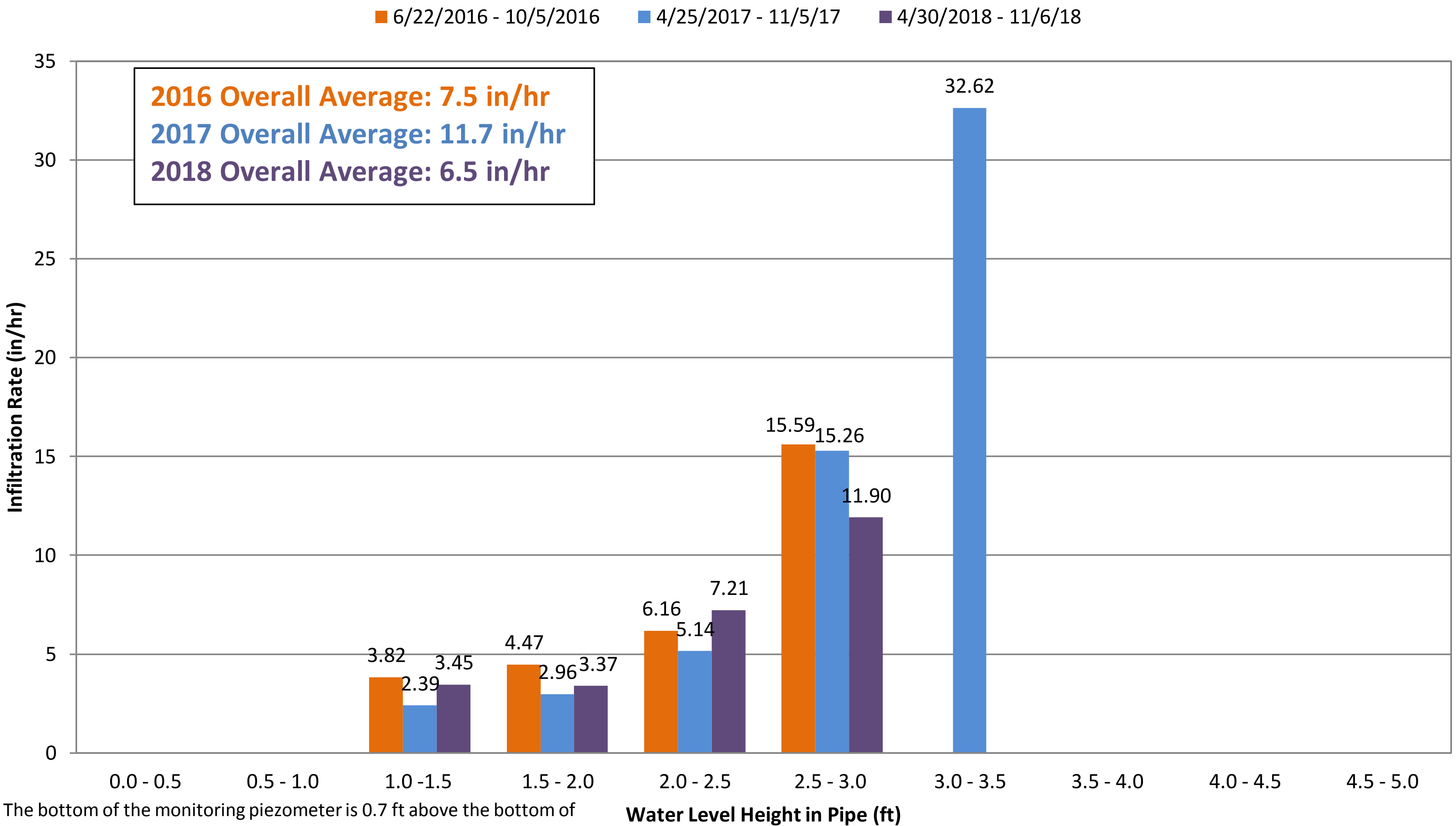
Montreal Trench - Infiltration Rate Graph

(Observed at Incremental 0.5 Foot Elevations)



Error Bars Represent 25th and 75th Percentiles

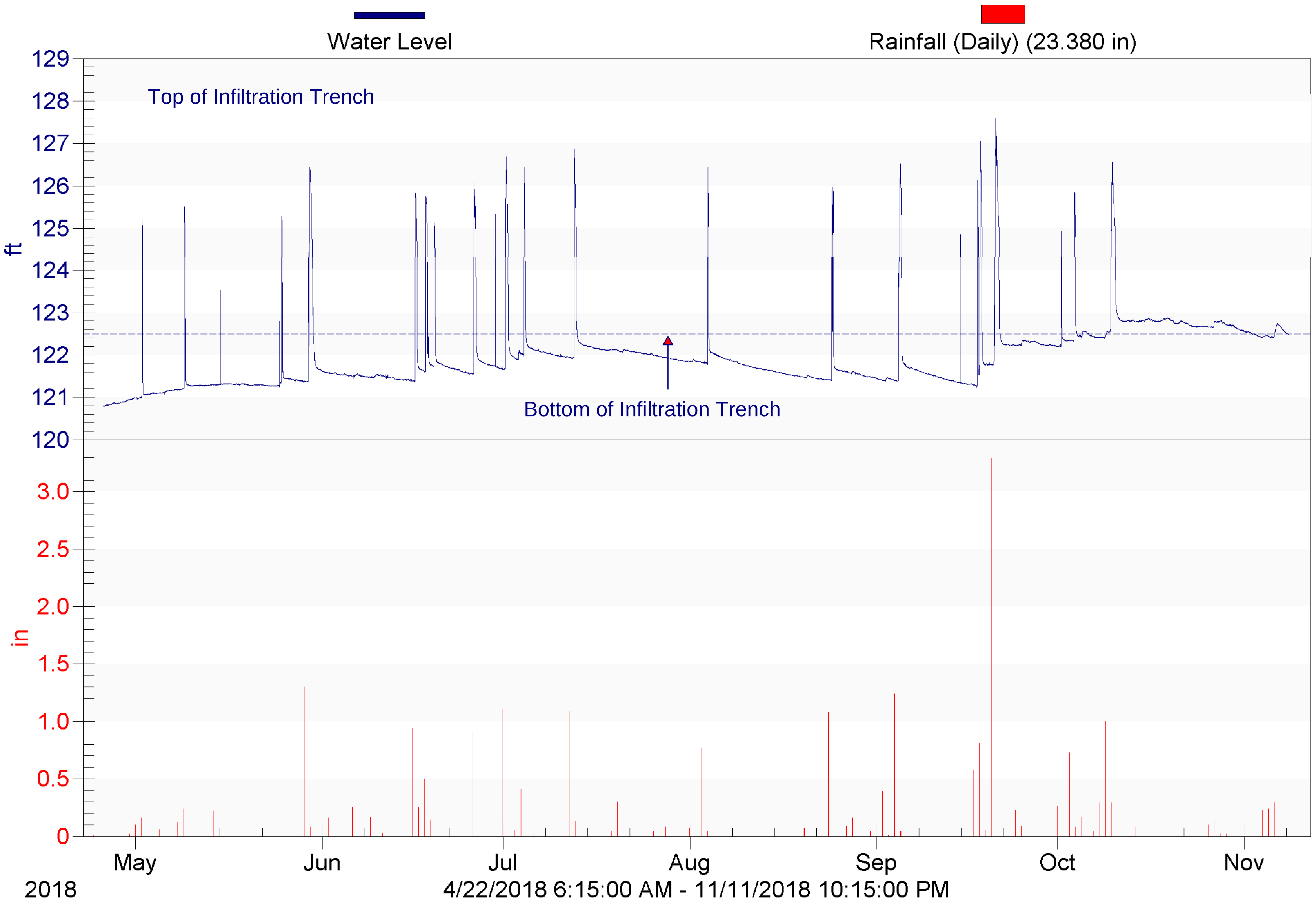
Infiltration Rate Trends
Montreal Infiltration Trench
Not Adjusted



* The bottom of the monitoring piezometer is 0.7 ft above the bottom of the trench, therefore the infiltration rate within that area is not calculated.

Chart A.27 Wordsworth Trench

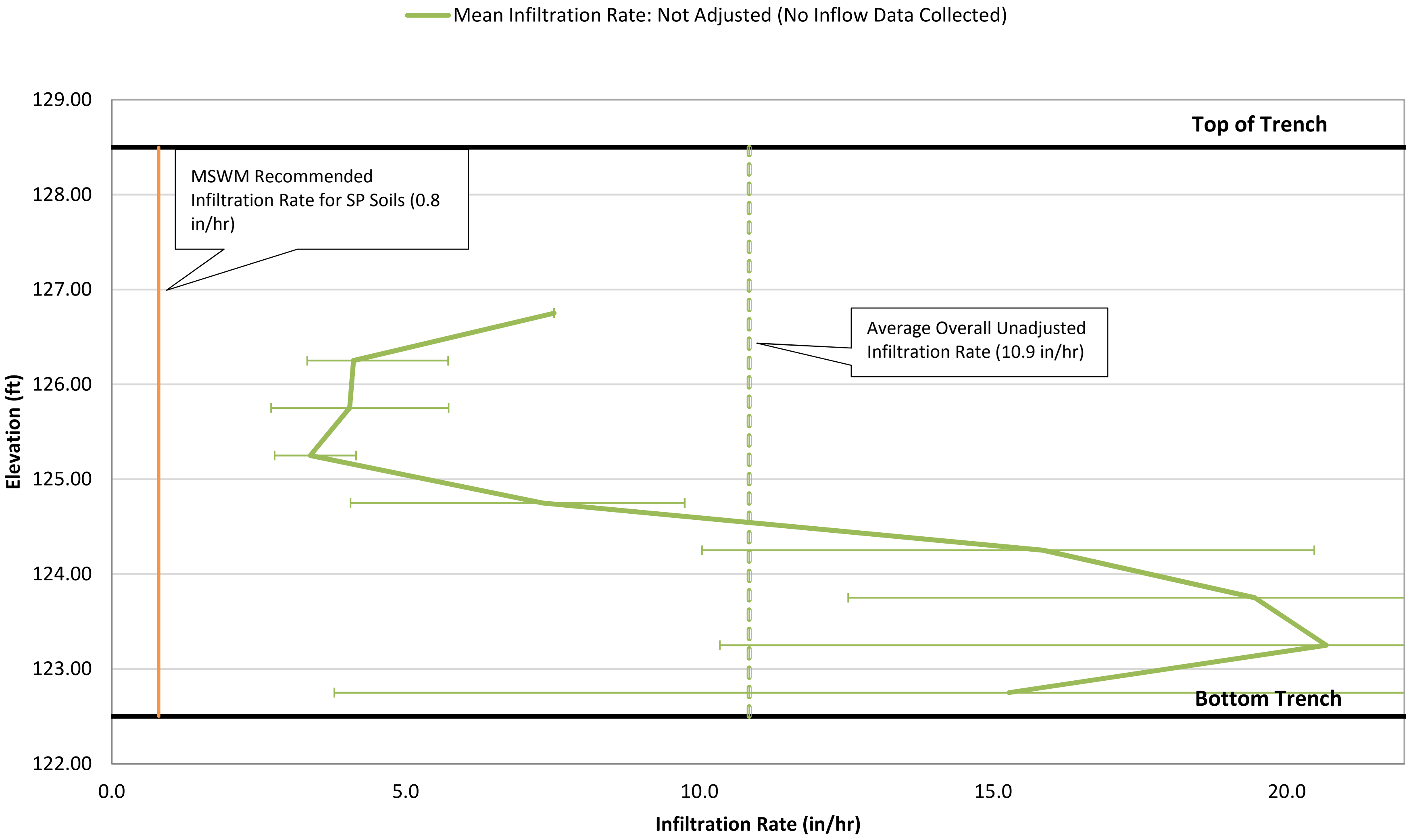
Trench Water Level and Rainfall (SPCD)



City of Saint Paul
2018 Water Quality and Quantity
Chart A.28
WSB Job No.: 01610-100

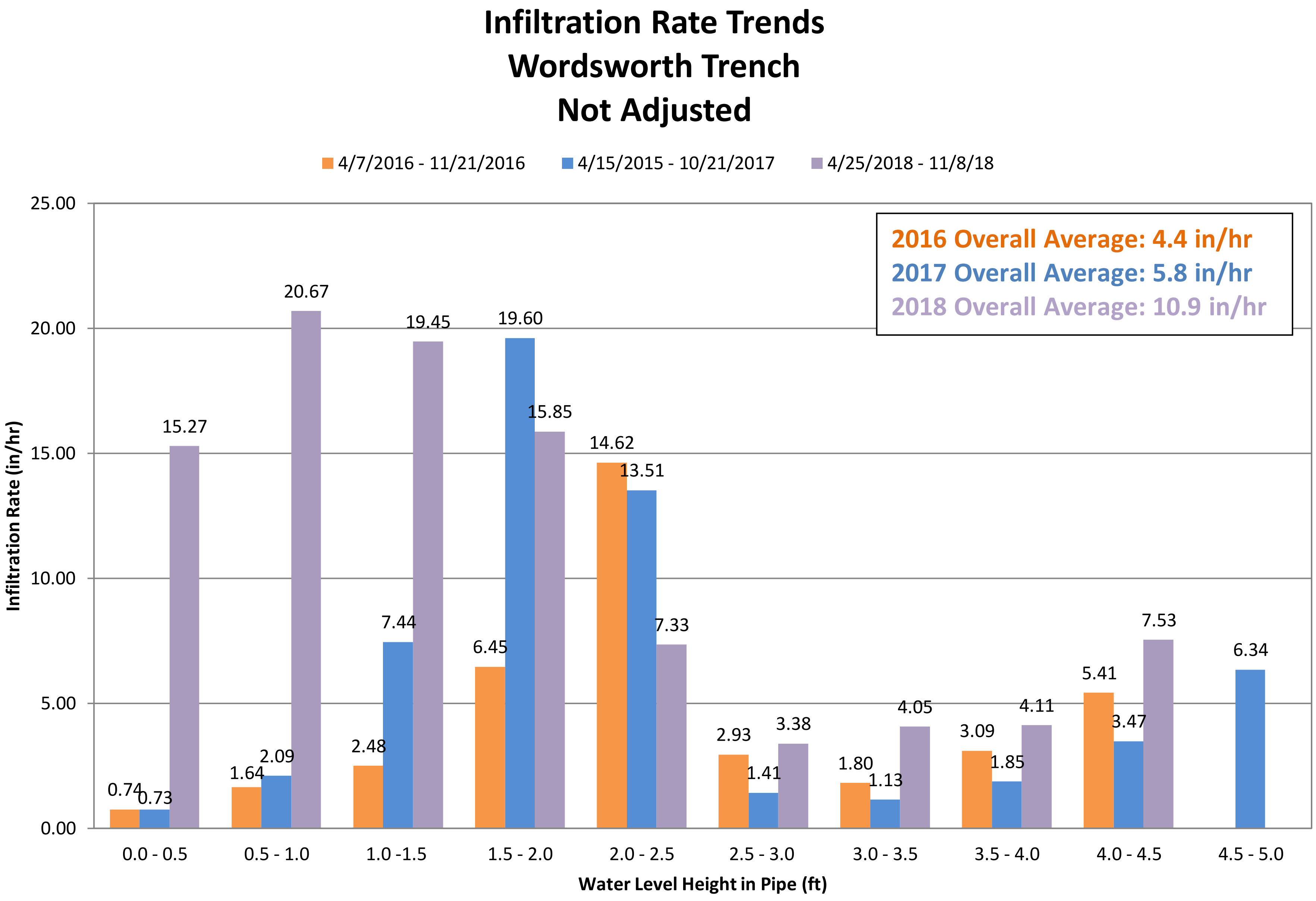
Wordsworth Trench - Infiltration Rate Graph

(Observed at Incremental 0.5 Foot Elevations)



Note:
Error Bars Represent 25th and 75th Percentiles

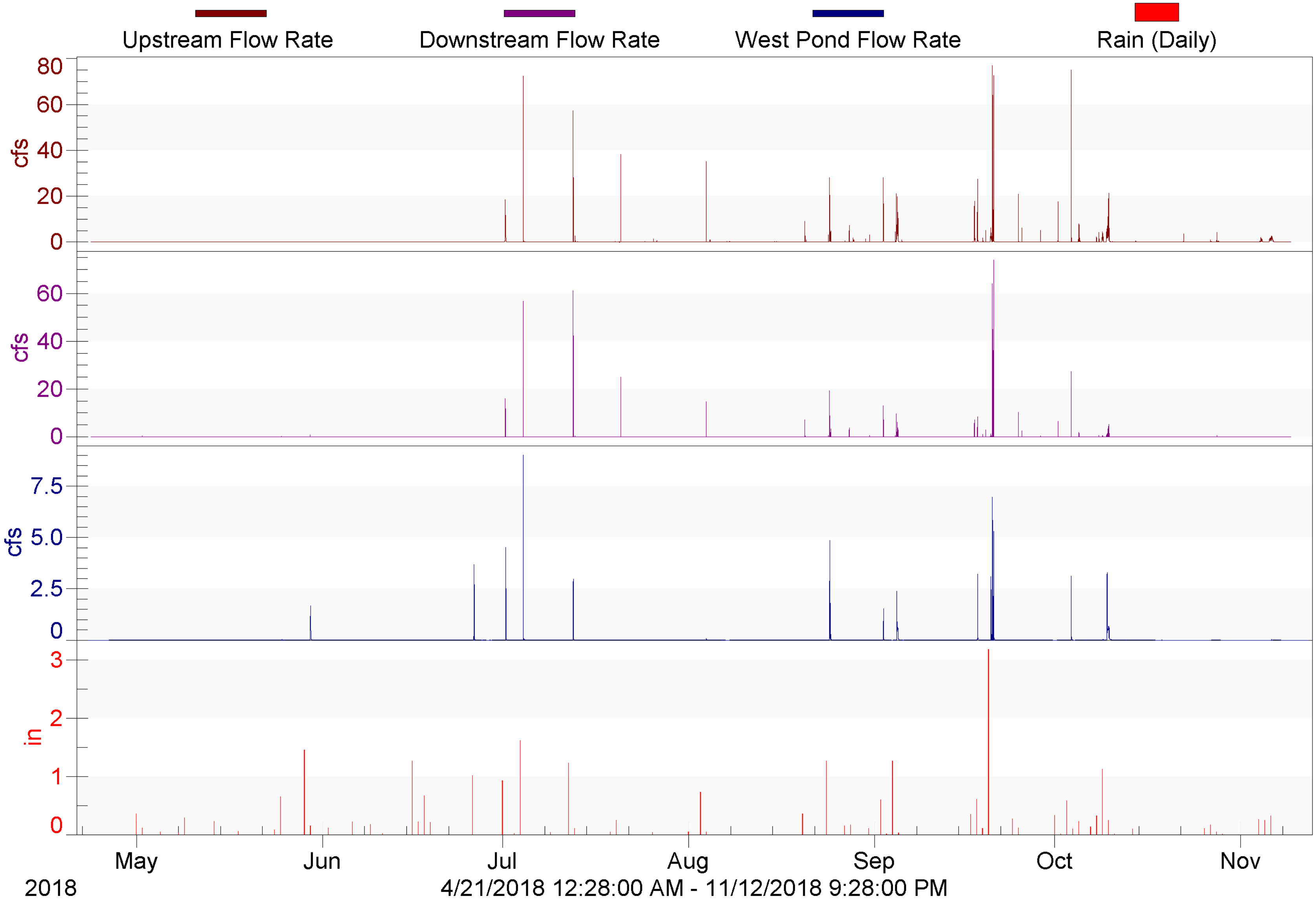
City of Saint Paul
2018 Water Quality and Quantity Report
Chart A.29
WSB Job No.: 01610-100



Appendix B – Flow Rate Charts

Chart B.1 Beacon Bluff

Flow Rates and Rainfall



City of Saint Paul
2018 Water Quality and Quantity Report
Chart B.2
WSB Project Number: 01610-100

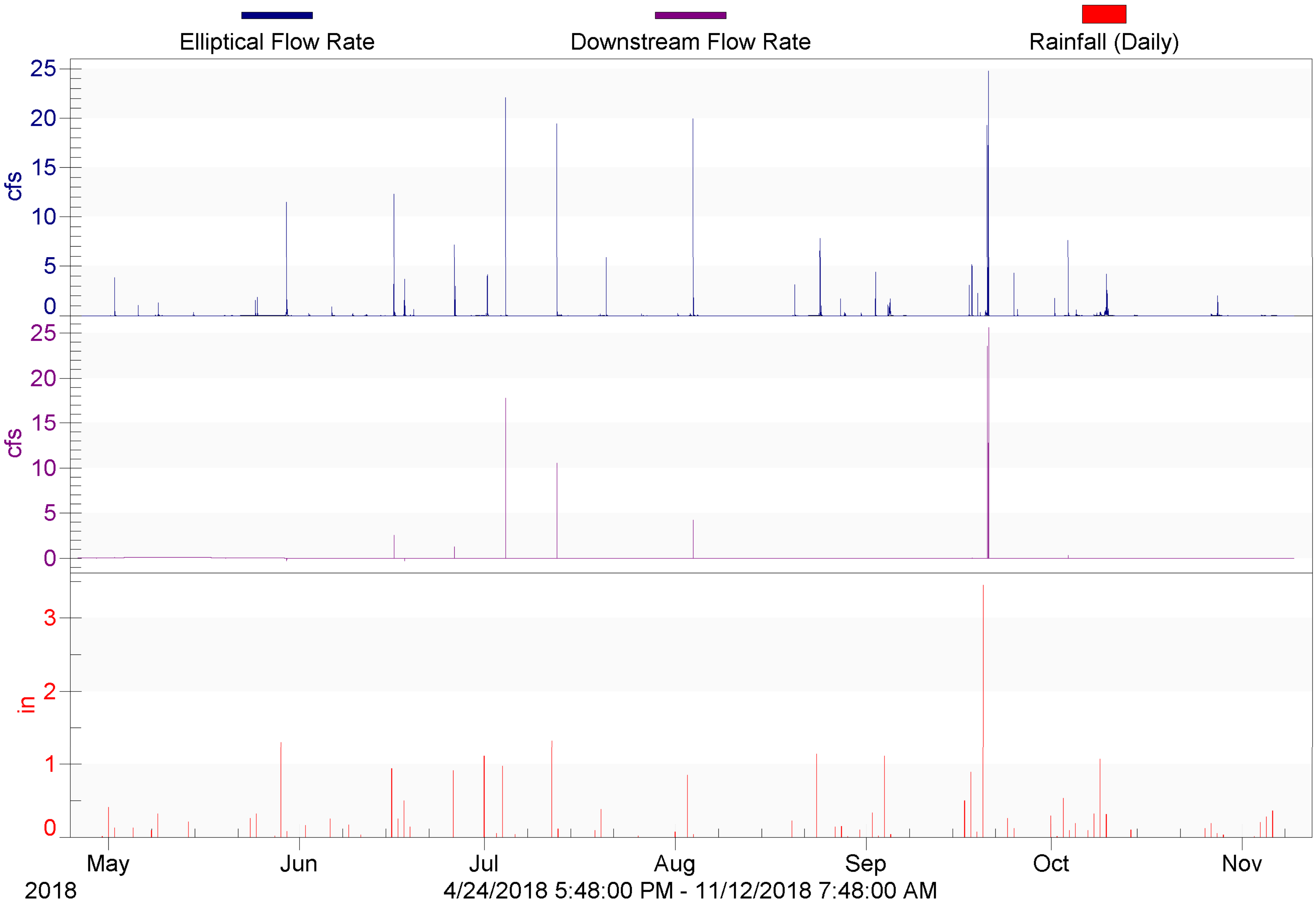
HILLCREST KNOLL PARK INFILTRATION SYSTEM FLOW EVENT SUMMARY

Rain				**Flow**
Start	End	Duration	Amount	Flandrau St. Runoff Volume (Upstream of Diversion) (1)
		(hr)	(in)	(cf)
5/14/2018 16:39	5/14/2018 22:11	5.53	0.23	11783.4
5/18/2018 19:38	5/18/2018 19:54	0.27	0.06	3073.9
5/24/2018 19:56	5/24/2018 20:44	0.80	0.08	4098.6
5/25/2018 3:03	5/25/2018 4:35	1.53	0.60	30739.2
5/29/2018 14:16	5/30/2018 8:32	18.27	1.57	80434.2
6/2/2018 11:09	6/2/2018 14:04	2.92	0.12	6147.8
6/6/2018 5:37	6/6/2018 8:35	2.97	0.22	11271.0
6/9/2018 11:23	6/9/2018 15:39	4.27	0.17	8709.4
6/16/2018 6:13	6/16/2018 12:07	5.90	1.26	64552.3
6/17/2018 20:38	6/19/2018 12:46	40.13	1.08	55330.6
6/26/2018 2:02	6/26/2018 6:14	4.20	1.01	51744.3
7/1/2018 8:44	7/1/2018 12:39	3.92	0.90	46108.8
7/4/2018 9:41	7/4/2018 10:31	0.83	1.58	80946.6
7/12/2018 17:56	7/12/2018 20:55	2.98	1.23	63015.4
7/13/2018 1:21	7/13/2018 6:13	4.87	0.08	4098.6
7/20/2018 3:18	7/20/2018 16:08	12.83	0.25	12808.0
8/3/2018 21:00	8/3/2018 23:26	2.43	0.73	37399.4
8/4/2018 11:45	8/4/2018 13:08	1.38	0.05	2561.6
8/20/2018 7:40	8/20/2018 8:49	1.15	0.35	17931.2
8/24/2018 5:26	8/24/2018 16:32	11.10	1.25	64040.0
8/27/2018 17:38	8/27/2018 18:12	0.57	0.14	7172.5
8/28/2018 8:04	8/28/2018 12:44	4.67	0.17	8709.4
8/31/2018 2:40	8/31/2018 4:12	1.53	0.11	5635.5
9/2/2018 8:43	9/2/2018 10:35	1.87	0.60	30739.2
9/4/2018 9:32	9/4/2018 22:00	12.47	1.24	63527.7
9/17/2018 14:18	9/17/2018 17:48	3.50	0.35	17931.2
9/18/2018 0:33	9/18/2018 23:55	23.37	0.61	31251.5
9/19/2018 10:46	9/19/2018 12:30	1.73	0.09	4610.9
9/20/2018 4:30	9/20/2018 19:55	15.42	3.17	162405.4
9/24/2018 22:03	9/25/2018 12:15	14.20	0.39	19980.5
10/1/2018 11:52	10/1/2018 13:10	1.30	0.33	16906.6
10/3/2018 17:33	10/3/2018 17:55	0.37	0.55	28177.6
10/4/2018 20:53	10/5/2018 9:02	12.15	0.32	16394.2
10/7/2018 20:42	10/10/2018 4:56	56.23	1.74	89143.7
10/14/2018 12:22	10/14/2018 13:13	0.85	0.10	5123.2
10/26/2018 20:00	10/27/2018 23:56	27.93	0.27	13832.6
10/28/2018 4:46	10/28/2018 7:02	2.27	0.05	2561.6
11/4/2018 2:42	11/4/2018 14:09	11.45	0.22	11271.0
11/5/2018 15:12	11/6/2018 13:16	22.07	0.54	27665.3
Subtotals:			**25.6**	**1219834**

Flow to the BMP was modeled using P8 Software

Chart B.3 St. Albans

Flow Rates and Rainfall



City of Saint Paul
2018 Water Quality and Quantity Report
Chart B.4
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)	(%)
5/1/2018 23:09	5/2/2018 1:00	1.85	0.52	5/1/2018 23:17	5/2/2018 2:15	2.97	4845.0	3246.1	0.0	8091.09	8091.1	100.0%
5/5/2018 18:25	5/5/2018 18:57	0.53	0.13	5/5/2018 18:31	5/5/2018 20:15	1.73	906.9	607.6	0.0	1514.52	1514.5	100.0%
5/8/2018 12:18	5/8/2018 12:48	0.50	0.05	5/8/2018 12:45	5/8/2018 15:15	2.50	155.8	104.4	0.0	260.18	260.2	100.0%
5/8/2018 22:41	5/9/2018 2:14	3.55	0.35	5/8/2018 23:45	5/9/2018 3:30	3.75	3381.4	2265.5	0.0	5646.89	5646.9	100.0%
5/14/2018 16:56	5/14/2018 20:56	4.00	0.21	5/14/2018 17:15	5/14/2018 21:15	4.00	1072.5	718.6	0.0	1791.14	1791.1	100.0%
5/24/2018 19:44	5/24/2018 20:40	0.93	0.26	5/24/2018 19:49	5/24/2018 23:00	3.18	1868.2	1251.7	0.0	3119.86	3119.9	100.0%
5/25/2018 2:59	5/25/2018 4:32	1.55	0.30	5/25/2018 3:08	5/25/2018 5:45	2.62	2545.7	1705.6	0.0	4251.38	4251.4	100.0%
5/29/2018 14:34	5/30/2018 0:33	9.98	1.34	5/29/2018 15:00	5/30/2018 2:00	11.00	20325.8	13618.3	0.0	33944.07	33944.1	100.0%
6/2/2018 11:04	6/2/2018 13:58	2.90	0.16	6/2/2018 11:15	6/2/2018 16:15	5.00	630.0	422.1	0.0	1052.13	1052.1	100.0%
6/6/2018 5:26	6/6/2018 6:45	1.32	0.24	6/6/2018 5:39	6/6/2018 9:30	3.85	1548.8	1037.7	0.0	2586.49	2586.5	100.0%
6/9/2018 11:12	6/9/2018 15:01	3.82	0.17	6/9/2018 12:30	6/9/2018 18:15	5.75	861.9	577.5	0.0	1439.32	1439.3	100.0%
6/16/2018 6:02	6/16/2018 11:20	5.30	0.93	6/16/2018 6:15	6/16/2018 12:30	6.25	17037.1	11414.8	0.0	28451.93	28451.9	100.0%
6/17/2018 22:50	6/18/2018 5:55	7.08	0.73	6/17/2018 23:00	6/18/2018 6:45	7.75	8421.8	5642.6	0.0	14064.46	14064.5	100.0%
6/19/2018 5:16	6/19/2018 11:44	6.47	0.13	6/19/2018 8:00	6/19/2018 13:15	5.25	1029.1	689.5	0.0	1718.64	1718.6	100.0%
6/26/2018 1:53	6/26/2018 6:13	4.33	0.89	6/26/2018 2:00	6/26/2018 7:30	5.50	15907.7	10658.2	0.0	26565.88	26565.9	100.0%
7/1/2018 5:41	7/1/2018 12:34	6.88	1.09	7/1/2018 6:00	7/1/2018 14:00	8.00	15355.1	10287.9	0.0	25642.94	25642.9	100.0%
7/3/2018 14:37	7/3/2018 14:58	0.35	0.05	7/3/2018 15:00	7/3/2018 16:30	1.50	26.9	18.0	0.0	44.92	44.9	100.0%
7/4/2018 9:42	7/4/2018 10:21	0.65	0.74	7/4/2018 9:45	7/4/2018 14:00	4.25	16834.9	11279.4	23342.1	28114.32	4772.3	17.0%
7/12/2018 17:52	7/12/2018 19:06	1.23	1.31	7/12/2018 17:56	7/12/2018 19:30	1.57	18241.3	12221.7	14248.8	30462.92	16214.1	53.2%
7/13/2018 1:21	7/13/2018 10:39	9.30	0.11	7/13/2018 1:45	7/13/2018 12:15	10.50	519.5	348.1	0.0	867.65	867.6	100.0%
7/19/2018 11:38	7/19/2018 18:32	6.90	0.09	7/19/2018 12:15	7/19/2018 22:00	9.75	498.6	334.1	0.0	832.65	832.7	100.0%
7/20/2018 2:38	7/20/2018 8:57	6.32	0.06	7/20/2018 2:45	7/20/2018 11:15	8.50	110.0	73.7	0.0	183.77	183.8	100.0%
7/20/2018 17:35	7/20/2018 18:39	1.07	0.32	7/20/2018 17:41	7/20/2018 21:30	3.82	4299.1	2880.4	0.0	7179.48	7179.5	100.0%
8/1/2018 6:42	8/1/2018 8:02	1.33	0.07	8/1/2018 7:30	8/1/2018 12:30	5.00	232.7	155.9	0.0	388.67	388.7	100.0%
8/3/2018 21:02	8/3/2018 21:42	0.67	0.80	8/3/2018 21:10	8/4/2018 0:30	3.33	14610.8	9789.3	3780.1	24400.10	20620.0	84.5%
8/20/2018 7:51	8/20/2018 8:36	0.75	0.19	8/20/2018 8:23	8/20/2018 10:45	2.37	2211.9	1482.0	0.0	3693.85	3693.8	100.0%
8/24/2018 3:02	8/24/2018 12:17	9.25	1.01	8/24/2018 5:45	8/24/2018 14:30	8.75	16392.8	10983.2	0.0	27375.98	27376.0	100.0%
8/24/2018 15:23	8/24/2018 16:31	1.13	0.09	8/24/2018 15:30	8/24/2018 18:00	2.50	948.4	635.4	0.0	1583.77	1583.8	100.0%
8/27/2018 17:41	8/27/2018 18:03	0.37	0.12	8/27/2018 17:56	8/27/2018 19:00	1.07	1098.4	735.9	0.0	1834.26	1834.3	100.0%
8/28/2018 8:01	8/28/2018 12:38	4.62	0.15	8/28/2018 8:45	8/28/2018 15:00	6.25	1313.2	879.8	0.0	2192.98	2193.0	100.0%
8/31/2018 2:37	8/31/2018 3:12	0.58	0.10	8/31/2018 2:45	8/31/2018 4:15	1.50	617.2	413.5	0.0	1030.70	1030.7	100.0%
9/2/2018 9:15	9/2/2018 10:29	1.23	0.32	9/2/2018 9:24	9/2/2018 12:00	2.60	4553.5	3050.9	0.0	7604.40	7604.4	100.0%
9/4/2018 6:39	9/4/2018 21:59	15.33	1.10	9/4/2018 10:00	9/4/2018 23:45	13.75	13831.3	9267.0	0.0	23098.23	23098.2	100.0%
9/17/2018 14:21	9/17/2018 16:05	1.73	0.48	9/17/2018 14:36	9/17/2018 18:30	3.90	5294.1	3547.1	0.0	8841.20	8841.2	100.0%
9/18/2018 0:19	9/18/2018 3:35	3.27	0.74	9/18/2018 0:45	9/18/2018 5:15	4.50	11300.0	7571.0	0.0	18871.03	18871.0	100.0%
9/18/2018 23:36	9/19/2018 0:00	0.40	0.15	9/18/2018 23:53	9/19/2018 1:15	1.37	1751.6	1173.6	0.0	2925.23	2925.2	100.0%
9/19/2018 10:41	9/19/2018 11:38	0.95	0.05	9/19/2018 10:54	9/19/2018 12:00	1.10	202.0	135.3	0.0	337.28	337.3	100.0%
9/20/2018 3:20	9/20/2018 20:05	16.75	3.41	9/20/2018 5:00	9/20/2018 21:15	16.25	48878.3	32748.5	0.0	81626.84	32366.3	39.7%
9/24/2018 21:58	9/24/2018 22:37	0.65	0.25	9/24/2018 22:04	9/24/2018 23:30	1.43	2898.4	1941.9	0.0	4840.35	4840.3	100.0%
9/25/2018 11:36	9/25/2018 12:09	0.55	0.09	9/25/2018 12:00	9/25/2018 13:00	1.00	504.1	337.8	0.0	841.92	841.9	100.0%
10/1/2018 11:52	10/1/2018 13:05	1.22	0.29	10/1/2018 12:13	10/1/2018 14:15	2.03	3622.5	2427.1	0.0	6049.57	6049.6	100.0%
10/3/2018 17:31	10/3/2018 17:51	0.33	0.49	10/3/2018 17:36	10/3/2018 20:15	2.65	8755.1	5865.9	0.0	14621.02	14621.0	100.0%
10/4/2018 20:55	10/5/2018 7:00	10.08	0.27	10/4/2018 21:45	10/5/2018 10:00	12.25	2007.7	1345.2	0.0	3352.89	3352.9	100.0%
10/7/2018 20:50	10/8/2018 8:30	11.67	0.19	10/7/2018 21:30	10/8/2018 11:15	13.75	1590.3	1065.5	0.0	2655.83	2655.8	100.0%
10/8/2018 20:12	10/9/2018 1:24	5.20	0.26	10/8/2018 20:30	10/9/2018 4:30	8.00	3291.7	2205.4	0.0	5497.13	5497.1	100.0%
10/9/2018 10:17	10/10/2018 1:02	14.75	1.13	10/9/2018 11:15	10/10/2018 3:15	16.00	18876.8	12647.4	0.0	31524.24	31524.2	100.0%
10/10/2018 4:37	10/10/2018 4:53	0.27	0.06	10/10/2018 4:45	10/10/2018 6:45	2.00	1074.8	720.1	0.0	1794.88	1794.9	100.0%
10/14/2018 13:08	10/14/2018 13:43	0.58	0.10	10/14/2018 13:15	10/14/2018 18:45	5.50	43.9	29.4	0.0	73.32	73.3	100.0%
10/26/2018 19:41	10/27/2018 1:31	5.83	0.14	10/26/2018 21:00	10/27/2018 4:15	7.25	1143.3	766.0	0.0	1909.26	1909.3	100.0%
10/27/2018 21:11	10/27/2018 23:41	2.50	0.17	10/27/2018 21:30	10/28/2018 0:37	3.12	1973.9	1322.5	0.0	3296.34	3296.3	100.0%
10/28/2018 4:47	10/28/2018 5:20	0.55	0.04	10/28/2018 5:15	10/28/2018 10:00	4.75	275.4	184.5	0.0	459.94	459.9	100.0%
11/3/2018 23:42	11/4/2018 15:56	16.23	0.21	11/4/2018 1:00	11/4/2018 17:00	16.00	316.8	212.3	0.0	529.10	529.1	100.0%
11/5/2018 15:04	11/6/2018 11:25	20.35	0.62	11/5/2018 15:30	11/6/2018 13:15	21.75	1298.8	870.2	0.0	2169.06	2169.1	100.0%
Subtotals			**23.3**				**307333**	**205913**	**90632**	**513246**	**422614**	**82%**

City of Saint Paul
2018 Water Quality and Quantity Report
Chart B.5
WSB Project Number: 01610-100

HAMPDEN PARK INFILTRATION SYSTEM FLOW EVENT SUMMARY

Rain				Flow	
Start	End	Duration	Amount	Hampden and Raymond St. Runoff Volume (Upstream of Diversion) (1)	Percent Captured
		(hr)	(in)	(cf)	(%)
5/1/2018 23:09	5/2/2018 1:00	1.85	0.52	3049.0	100.0%
5/5/2018 18:25	5/5/2018 18:57	0.53	0.13	435.6	100.0%
5/8/2018 12:18	5/8/2018 12:48	0.50	0.05	1306.8	100.0%
5/8/2018 22:41	5/9/2018 2:14	3.55	0.35	3484.8	100.0%
5/14/2018 16:56	5/14/2018 20:56	4.00	0.21	3049.2	100.0%
5/24/2018 19:44	5/24/2018 20:40	0.93	0.26	15681.6	100.0%
5/25/2018 2:59	5/25/2018 4:32	1.55	0.30	3920.4	100.0%
5/29/2018 14:34	5/30/2018 0:33	9.98	1.33	19602.0	100.0%
6/2/2018 11:04	6/2/2018 13:58	2.90	0.16	2178.0	100.0%
6/6/2018 5:26	6/6/2018 6:45	1.32	0.24	3484.8	100.0%
6/9/2018 11:12	6/9/2018 15:01	3.82	0.17	2178.0	100.0%
6/16/2018 6:02	6/16/2018 11:20	5.30	0.94	13068.0	100.0%
6/17/2018 22:50	6/18/2018 5:55	7.08	0.73	9147.6	100.0%
6/19/2018 5:16	6/19/2018 12:28	7.20	0.14	2178.0	100.0%
6/26/2018 1:53	6/26/2018 6:13	4.33	0.91	12632.4	100.0%
7/1/2018 8:43	7/1/2018 12:34	3.85	1.10	15681.6	100.0%
7/3/2018 14:37	7/3/2018 14:58	0.35	0.05	435.6	100.0%
7/4/2018 9:42	7/4/2018 15:15	5.55	0.97	5662.8	100.0%
7/12/2018 17:52	7/12/2018 20:37	2.75	1.32	15246.0	100.0%
7/13/2018 1:21	7/13/2018 1:40	0.32	0.04	1742.4	100.0%
7/19/2018 17:46	7/19/2018 18:32	0.77	0.07	435.6	100.0%
7/20/2018 17:35	7/20/2018 18:39	1.07	0.32	4356.0	100.0%
8/1/2018 6:42	8/1/2018 8:02	1.33	0.07	871.2	100.0%
8/3/2018 21:02	8/3/2018 23:18	2.27	0.82	10890.0	100.0%
8/20/2018 7:51	8/20/2018 8:40	0.82	0.20	871.2	100.0%
8/24/2018 5:26	8/24/2018 16:31	11.08	1.13	15246.0	100.0%
8/27/2018 17:41	8/27/2018 18:03	0.37	0.12	871.2	100.0%
8/28/2018 8:01	8/28/2018 12:38	4.62	0.15	2178.0	100.0%
8/31/2018 2:37	8/31/2018 3:12	0.58	0.10	435.6	100.0%
9/2/2018 9:15	9/2/2018 10:29	1.23	0.32	5227.2	100.0%
9/4/2018 9:31	9/4/2018 21:59	12.47	1.10	17424.0	100.0%
9/17/2018 14:21	9/17/2018 17:47	3.43	0.50	7840.8	100.0%
9/18/2018 0:19	9/19/2018 0:00	23.68	0.90	12196.8	100.0%
9/20/2018 3:20	9/20/2018 20:05	16.75	3.43	56627.9	100.0%
9/24/2018 21:58	9/25/2018 12:09	14.18	0.37	3920.4	100.0%
10/1/2018 11:52	10/1/2018 13:05	1.22	0.29	3484.8	100.0%
10/3/2018 17:31	10/3/2018 17:51	0.33	0.49	10018.8	100.0%
10/4/2018 20:55	10/5/2018 7:00	10.08	0.27	3049.2	100.0%
10/7/2018 20:50	10/9/2018 1:24	28.57	0.47	23522.4	100.0%
10/14/2018 13:08	10/14/2018 13:43	0.58	0.10	871.2	100.0%
10/26/2018 19:41	10/28/2018 0:11	28.50	0.32	3484.8	100.0%
11/3/2018 23:42	11/4/2018 15:56	16.23	0.21	3049.2	100.0%
11/5/2018 15:04	11/6/2018 13:17	22.22	0.63	7405.2	100.0%
Subtotals:			**25.6**	**328442**	**100%**

Flow to BMP was modeled using P8 Software

Chart B.6 TBNS - Maryland Pond

Flow Rates and Rainfall

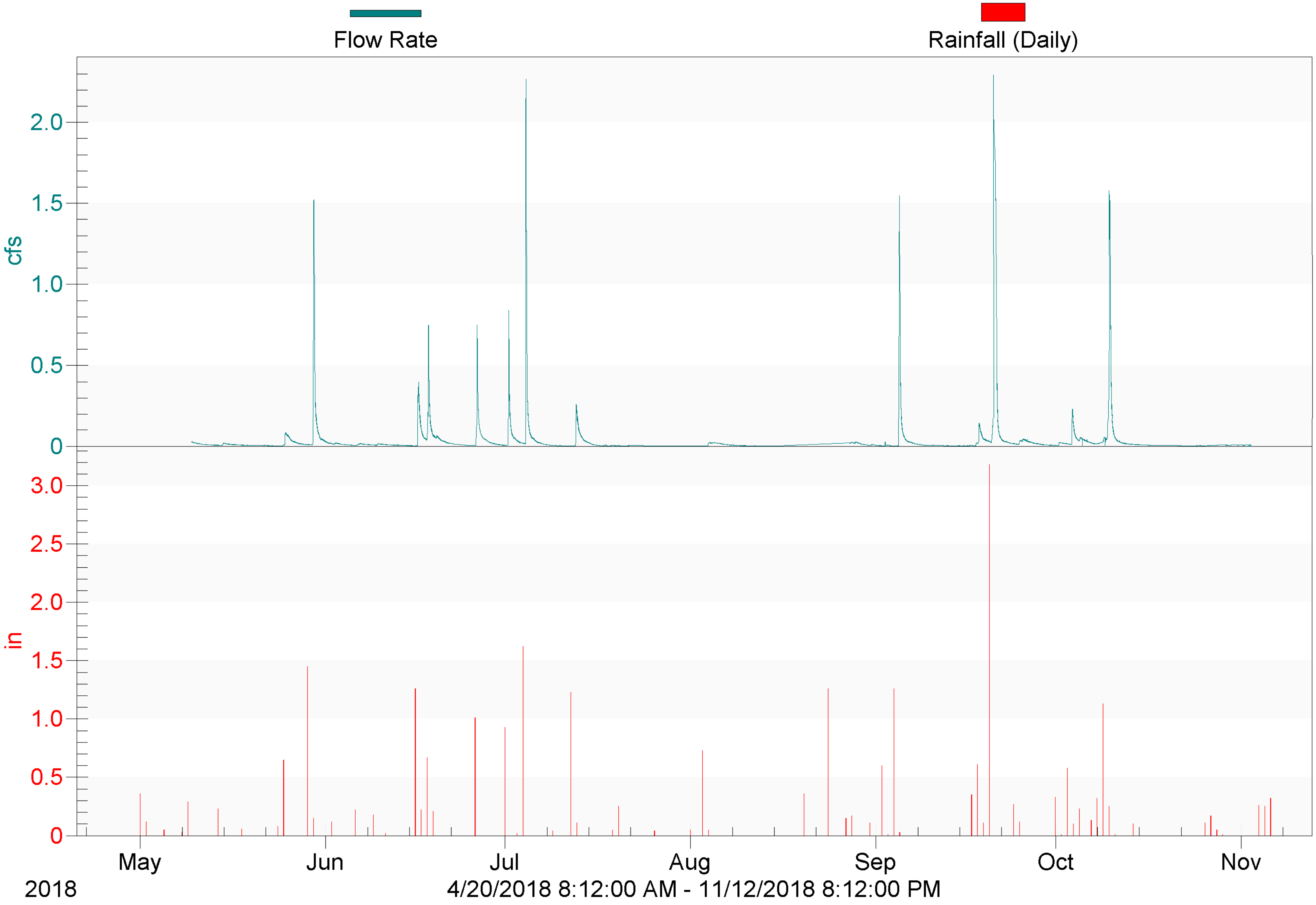


Chart B.7 TBNS - Magnolia Pond

Flow Rates and Rainfall

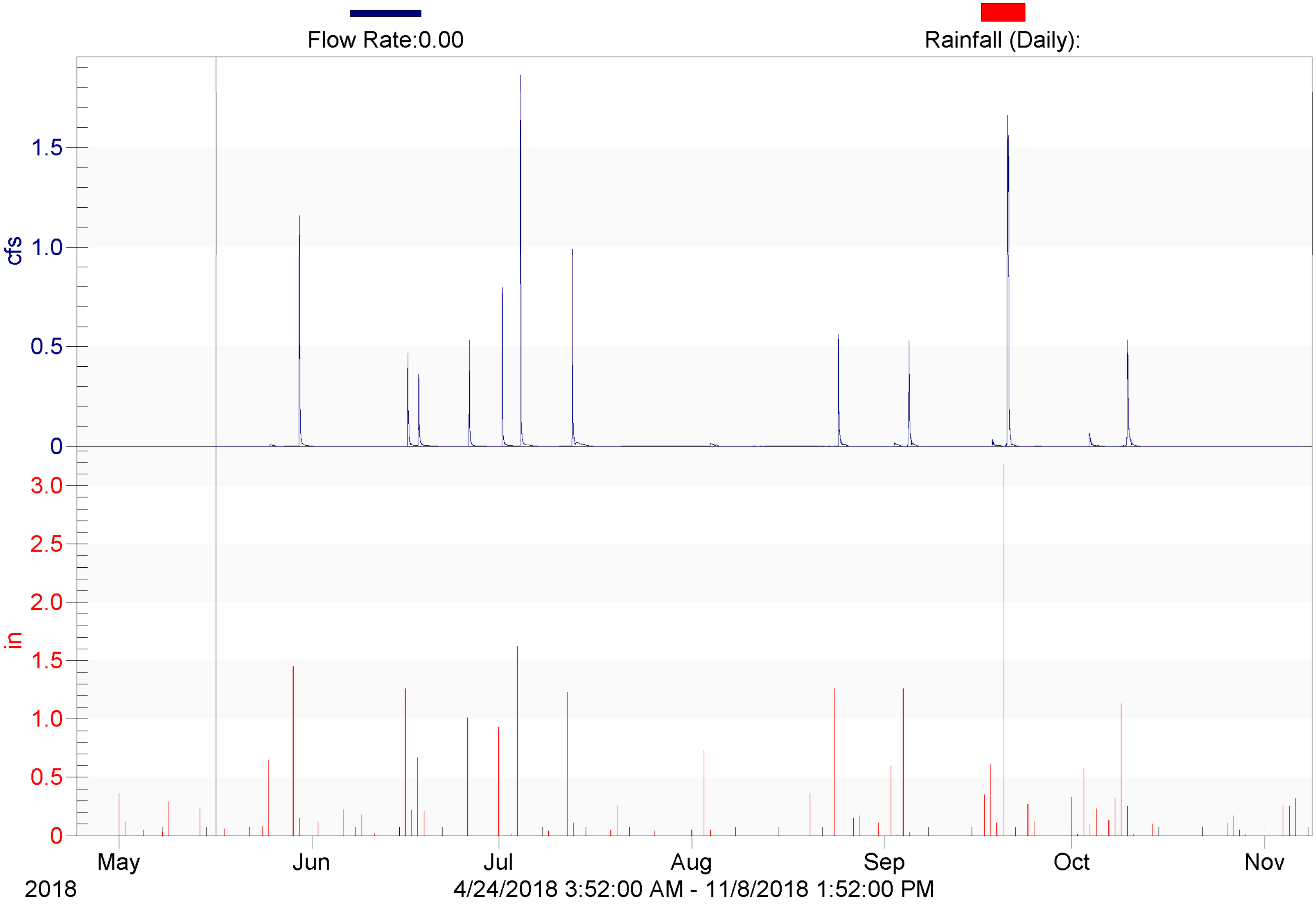
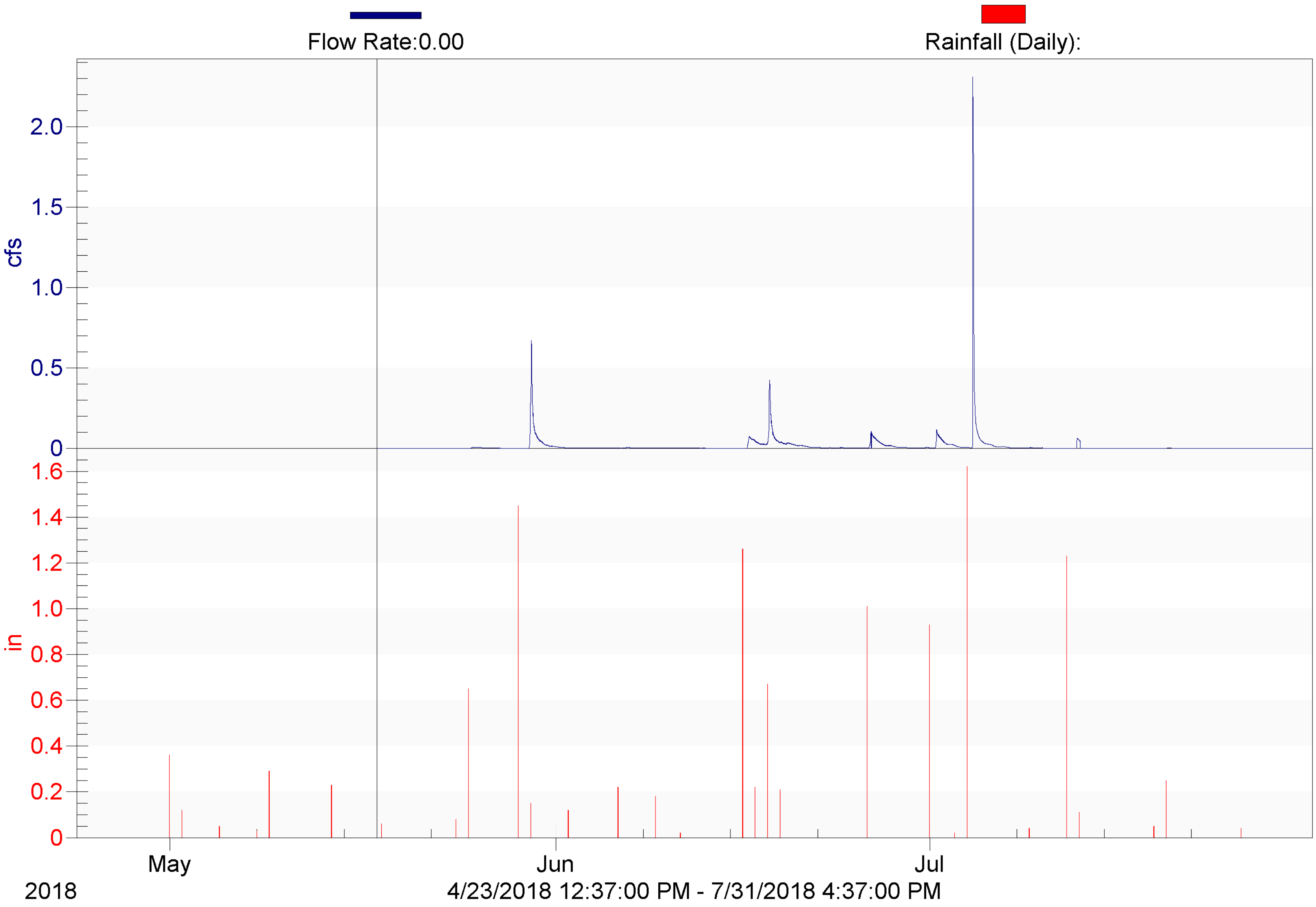


Chart B.8 TBNS - Jenks

Flow Rates and Rainfall



Appendix C – Water Quality Summary and Pollutant Load Calculations

City of Saint Paul
2018 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 (mg/L)	Lead (mg/L)	Zinc (mg/L)	Sulfate (mg/L)	pH	CBOD (mg/L)	E. Coli (MPN/ 100 mL)
2648717		2/14/2018 15:04	211.0	8400.0	105.0	0.58	0.005 <	5902.5	1.32	7.40	0.090 <	222	0.0433	0.0211	0.29400	42.00	6.40	53.0 >	
2655565		3/14/2018 13:00	71.0		33.0	0.50		125.5		2.64	0.213								
2662534		4/13/2018 13:06	280.0	516.0	131.0	0.92	0.220	180.3	0.51	4.83	1.059	71	0.0541	0.1120	0.26200	16.02	7.40	14.5	1414
2674440	5/29/2018 18:21	5/30/2018 16:05	59.0		38.0	0.68	0.164	12.1		4.04	0.331	28	0.0167	0.0071	0.06820				
2673990	5/30/2018 9:02	5/30/2018 9:02	15.0	102.0	10.0	0.24	0.086	12.2	0.73	2.24	0.960	12 J	0.0078	0.0055	0.03660	9.00	6.80	14.3	2420 >
2683932	7/4/2018 9:56	7/5/2018 11:46	192.0	47.0	47.0	0.46	0.073	2.4	0.08	2.50	0.274	8 J	0.0224	0.0437	0.10400			4.8	
2686155		7/13/2018 10:03		109.0		0.24	0.179	8.9	0.04 J	1.00	1.094	35	0.0069	0.0009	0.01210			3.6	2420 >
2692605	8/3/2018 21:31	8/4/2018 0:01	28.0		10.0	0.28	0.194	3.3		1.30	0.361	17 J	0.0091	0.0095	0.05030				
2697927	8/24/2018 6:02	8/24/2018 13:48	116.0		26.0	0.32		3.3		1.49	0.254								
2699195	8/28/2018 8:31	8/28/2018 15:23	946.0		76.0 J	0.93		10.4		1.75	0.558								
2699193	8/31/2018 3:17	8/31/2018 5:19				0.37	0.132	6.5		2.86	1.124								
2700046	9/4/2018 13:32	9/4/2018 20:17	52.0		12.0	0.15	0.056	5.0		0.67	0.182	16 J	0.0070	0.0116	0.03370				
2703599	9/17/2018 14:47	9/17/2018 20:09	139.0		49.5	0.65		7.0		3.13	0.093 <								
2703600	9/18/2018 1:17	9/18/2018 5:47	81.0		26.0	0.30		4.3		1.58	0.359								
2704856	9/20/2018 5:12	9/20/2018 14:35	141.0		39.0	0.44		3.0		1.72	0.182								
2707558	10/1/2018 12:32	10/1/2018 13:48	64.0	53.0	23.0	0.29	0.117	3.1	0.20	1.37	0.324	12 J	0.0096	0.0150	0.04790			9.0 >	
2710726	10/3/2018 17:42	10/3/2018 21:38	294.0		61.0	0.64		3.6		3.02	0.308								
MINIMUM			**15.0**	**47.0**	**10.0**	**0.15**	**0.056**	**2.4**	**0.04**	**0.67**	**0.09**	**8**	**0.0**	**0.0**	**0.0**	**9.0**	**6.80**	**3.6**	**1414**
AVERAGE			**205.3**	**165.4**	**41.5**	**0.46**	**0.136**	**24.4**	**0.31**	**2.26**	**0.48**	**25**	**0.0**	**0.0**	**0.1**	**12.5**	**7.10**	**9.3**	**2085**
MEDIAN			**98.5**	**102.0**	**35.5**	**0.41**	**0.132**	**5.7**	**0.20**	**1.99**	**0.33**	**17**	**0.0**	**0.0**	**0.0**	**12.5**	**7.1**	**9.0**	**2420**
MAXIMUM			**946.0**	**516.0**	**131.0**	**0.93**	**0.220**	**180.3**	**0.73**	**4.83**	**1.12**	**71**	**0.1**	**0.1**	**0.3**	**16.0**	**7.40**	**14.5**	**2420**

Laboratory analysis was completed by Metroplian Council Environmental Services
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)
> - Analyte exceeded the maximum dection level (was not fully diluted prior to analysis)

City of Saint Paul
2018 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	Ammonia as N	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)	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 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	mg/L	In.	cf	cf	cf	cf	cf	cf	cf			lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5/2/2018 0:00	5/2/2018 3:45	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.47	44441	0	44441	59	2123	0	46623	95.3%	100.0%	325.3	95.3	1.17	0.29	14.8	5.69	1.10
5/5/2018 18:45	5/5/2018 21:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.05	4728	0	4728	43	226	0	4997	94.6%	100.0%	34.9	10.2	0.13	0.03	1.6	0.61	0.12
5/9/2018 0:30	5/9/2018 5:00	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.29	27421	0	27421	68	1310	0	28799	95.2%	100.0%	200.9	58.8	0.72	0.18	9.1	3.51	0.68
5/14/2018 17:15	5/14/2018 22:45	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.22	20802	0	20802	86	994	0	21882	95.0%	100.0%	152.7	44.7	0.55	0.14	6.9	2.67	0.52
5/18/2018 19:56	5/18/2018 22:30	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.06	5673	0	5673	45	271	0	5989	94.7%	100.0%	41.8	12.2	0.15	0.04	1.9	0.73	0.14
5/24/2018 20:06	5/25/2018 0:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.08	7564	0	7564	70	361	0	7995	94.6%	100.0%	55.8	16.3	0.20	0.05	2.5	0.98	0.19
5/25/2018 3:11	5/25/2018 7:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.60	56734	204	56529	188	2710	0	59428	95.1%	99.7%	414.6	121.4	1.49	0.37	18.9	7.25	1.41
5/29/2018 14:51	5/30/2018 3:51	**15**	**102**	**10**	**0.24**	**0.086**	**12.2**	**0.73**	**2.24**	**0.960**	1.51	142780	391	142388	15995	6820	22855	142349	84.7%	86.0%	133.3	88.9	2.13	0.76	108.4	19.91	8.53
6/2/2018 11:26	6/2/2018 16:00	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.12	11347	0	11347	72	542	0	11961	94.8%	100.0%	83.4	24.4	0.30	0.07	3.8	1.46	0.28
6/6/2018 5:46	6/6/2018 10:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.22	20802	0	20802	78	994	0	21874	95.1%	100.0%	152.6	44.7	0.55	0.14	6.9	2.67	0.52
6/9/2018 12:26	6/9/2018 17:45	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.17	16075	0	16075	0	768	0	16842	95.4%	100.0%	117.5	34.4	0.42	0.10	5.3	2.06	0.40
6/16/2018 6:26	6/16/2018 14:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	1.21	114413	0	114413	0	5465	24677	95201	95.4%	79.4%	664.2	194.5	2.39	0.59	30.2	11.62	2.26
6/17/2018 20:51	6/18/2018 7:00	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.71	67135	0	67135	0	3207	7037	63305	95.4%	90.0%	441.6	129.4	1.59	0.39	20.1	7.73	1.50
6/18/2018 23:06	6/19/2018 14:45	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.32	30258	0	30258	4376	1445	0	36080	81.6%	100.0%	251.7	73.7	0.90	0.22	11.5	4.40	0.85
6/26/2018 2:06	6/26/2018 8:18	112	76	33	0.4	0.10	5	0.4	2.0	0.38	1.00	94556	0	94556	20532	4517	11012	108592	74.7%	90.8%	757.6	221.9	2.72	0.67	34.5	13.25	2.57
7/1/2018 9:00	7/1/2018 14:50	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.90	72950	50880	22070	15008	3485	0	40562	27.6%	44.4%	283.0	82.9	1.02	0.25	12.9	4.95	0.96
7/3/2018 15:30	7/3/2018 17:00	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.02	187	2	186	26	9	0	221	81.9%	99.3%	1.5	0.5	0.01	0.00	0.1	0.03	0.01
7/4/2018 9:56	7/4/2018 12:39	**192**	**47**	**47**	**0.46**	**0.073**	**2.4**	**0.08**	**2.50**	**0.274**	1.58	109387	38775	70612	19869	5225	33670	62037	66.9%	46.1%	743.6	182.0	1.78	0.28	9.3	9.68	1.06
7/12/2018 18:06	7/12/2018 23:00	112	76	33	0.4	0.10	5	0.4	2.0	0.38	1.21	91313	81099	10214	4776	4362	2195	17156	37.3%	17.1%	119.7	35.1	0.43	0.11	5.4	2.09	0.41
7/13/2018 1:45	7/13/2018 4:00	112	**109**	33	**0.24**	**0.179**	**8.9**	**0.04** J	**1.00**	**1.094**	0.05	3714	229	3485	43	177	0	3706	94.0%	94.2%	25.9	7.6	0.06	0.04	2.1	0.23	0.25
7/13/2018 10:15	7/13/2018 12:30	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.03	767	6	762	45	37	0	843	89.8%	99.4%	5.9	1.7	0.02	0.01	0.3	0.10	0.02
7/19/2018 12:00	7/19/2018 14:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.02	230	2	228	44	11	0	283	77.0%	99.3%	2.0	0.6	0.01	0.00	0.1	0.03	0.01
7/19/2018 18:00	7/19/2018 20:07	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.03	662	3	659	41	32	0	731	89.5%	99.5%	5.1	1.5	0.02	0.00	0.2	0.09	0.02
7/20/2018 6:26	7/20/2018 9:42	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.04	614	4	610	58	29	0	698	86.3%	99.4%	4.9	1.4	0.02	0.00	0.2	0.09	0.02
7/20/2018 15:41	7/20/2018 18:00	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.20	21958	13804	8154	48	1049	0	9251	88.1%	40.1%	64.5	18.9	0.23	0.06	2.9	1.13	0.22
7/26/2018 15:30	7/26/2018 21:45	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.02	2478	13	2465	118	118	0	2701	90.8%	99.5%	18.8	5.5	0.07	0.02	0.9	0.33	0.06
8/1/2018 7:30	8/1/2018 13:45	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.05	420	9	411	116	20	0	547	68.5%	98.5%	3.8	1.1	0.01	0.00	0.2	0.07	0.01
8/3/2018 21:15	8/4/2018 0:51	**28**	76	**10**	**0.28**	**0.194**	**3.3**	0.4	**1.30**	**0.361**	0.72	41120	16200	24920	514	1964	0	27398	90.8%	62.8%	47.9	17.1	0.48	0.33	5.6	2.22	0.62
8/4/2018 12:26	8/4/2018 15:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.05	3053	21	3031	7	146	0	3184	95.2%	99.3%	22.2	6.5	0.08	0.02	1.0	0.39	0.08
8/20/2018 7:45	8/20/2018 11:08	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.35	26970	9605	17365	62	1288	0	18715	92.8%	66.1%	130.6	38.2	0.47	0.12	5.9	2.28	0.44
8/24/2018 5:45	8/24/2018 8:21	**116**	76	**26**	**0.37**	0.10	**3.3**	0.4	**1.49**	**0.254**	0.10	6096	462	5634	49	291	0	5974	94.3%	92.8%	43.3	9.7	0.14	0.04	1.2	0.56	0.09
8/24/2018 10:41	8/24/2018 19:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	1.15	79298	35883	43414	17398	3788	11934	52666	55.1%	52.4%	367.4	107.6	1.32	0.33	16.7	6.43	1.25
8/27/2018 1:30	8/27/2018 2:28	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.01	520	4	516	18	25	0	559	92.0%	99.2%	3.9	1.1	0.01	0.00	0.2	0.07	0.01
8/27/2018 17:51	8/27/2018 20:16	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.14	9947	2910	7037	50	475	0	7561	93.0%	72.2%	52.8	15.4	0.19	0.05	2.4	0.92	0.18
8/28/2018 8:30	8/28/2018 14:26	112	76	**76**	**0.93**	0.10	**10.4**	0.4	**1.75**	**0.558**	0.17	13018	69	12948	113	622	0	13683	94.6%	99.5%	95.5	64.9	0.79	0.08	8.9	1.49	0.48
8/31/2018 2:51	8/31/2018 5:16	112	76	33	**0.37**	**0.132**	**6.5**	0.4	**2.86**	**1.124**	0.11	6512	332	6181	47	311	0	6538	94.5%	95.2%	45.6	13.4	0.15	0.05	2.7	1.17	0.46
9/2/2018 8:56	9/2/2018 12:27	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.60	59704	18201	41503	1513	2852	1465	44402	90.2%	69.3%	309.8	90.7	1.11	0.28	14.1	5.42	1.05
9/4/2018 10:00	9/4/2018 12:06	**52**	76	**12**	**0.15**	**0.056**	**5.0**	0.4	**0.67**	**0.182**	0.07	5204	274	4930	0	249	0	5179	95.2%	95.0%	16.8	3.9	0.05	0.02	1.6	0.22	0.06
9/4/2018 12:49	9/4/2018 23:52	112	76	33	0.4	0.10	5	0.4	2.0	0.38	1.16	173946	33884	140063	15959	8309	45192	119139	83.6%	60.1%	831.2	243.4	2.99	0.74	37.8	14.54	2.82
9/17/2018 14:21	9/17/2018 17:40	**139**	76	**50**	**0.65**	0.10	**7.0**	0.4	**3.13**	**0.093** <	0.33	37737	11966	25771	62	1803	0	27636	93.2%	69.8%	239.8	85.4	1.12	0.17	12.1	5.40	0.16
9/18/2018 1:00	9/18/2018 6:06	**81**	76	**26**	**0.30**	0.10	**4.3**	0.4	**1.58**	**0.359**	0.49	55912	12419	43493	5996	2671	2657	49503	81.2%	76.7%	250.3	80.3	0.93	0.31	13.3	4.88	1.11
9/19/2018 0:00	9/19/2018 1:48	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.10	2783	655	2128	37	133	0	2298	92.5%	77.8%	16.0	4.7	0.06	0.01	0.7	0.28	0.05
9/19/2018 10:56	9/19/2018 13:31	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.08	8707	1989	6718	50	416	0	7184	93.5%	78.3%	50.1	14.7	0.18	0.04	2.3	0.88	0.17
9/20/2018 5:11	9/20/2018 21:40	**141**	76	**39**	**0.44**	0.10	**3.0**	0.4	**1.72**	**0.182**	3.15	324391	198752	125639	38245	15495	159170	20209	61.9%	5.3%	177.9	49.2	0.56	0.13	3.8	2.17	0.23
9/24/2018 22:11	9/25/2018 1:04	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.26	25821	8192	17629	55	1233	0	18918	93.2%	69.8%	132.0	38.7	0.47	0.12	6.0	2.31	0.45
9/25/2018 12:06	9/25/2018 14:36	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.09	8896	1037	7859	46	425	0	8330	94.3%	88.9%	58.1	17.0	0.21	0.05	2.6	1.02	0.20
10/1/2018 12:15	10/1/2018 14:38	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.33	39473	11824	27649	2	1885	0	29537	93.6%	71.4%	206.1	60.4	0.74	0.18	9.4	3.60	0.70
10/3/2018 17:41	10/3/2018 21:21	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.55	98807	33000	65807	2827	4720	0	73353	89.3%	69.0%	511.8	149.9	1.84	0.45	23.3	8.95	1.74
10/4/2018 21:41	10/5/2018 9:12	**64**	**53**	**23**	**0.29**	**0.117**	**3.1**	**0.20**	**1.37**	**0.324**	0.31	34740	2310	32430	346	1659	1165	33271	94.1%	90.5%	132.9	47.8	0.60	0.24	6.4	2.85	0.67
10/7/2018 21:26	10/8/2018 3:58	**294**	76	**61**	**0.64**	0.10	**3.6**	0.4	**3.02**	**0.308**	0.14	8937	48	8889	118	427	0	9434	94.2%	99.5%	173.1	35.9	0.38	0.06	2.1	1.78	0.18
10/8/2018 7:15	10/8/2018 11:47	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.11	14123	644	13479	86	675	0	14239	94.6%	95.7%	99.3	29.1	0.36	0.09	4.5	1.74	0.34
10/8/2018 20:41	10/9/2018 2:59	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.27	36783	1558	35225	126	1757	582	36527	94.9%	94.5%	254.8	74.6	0.92	0.23	11.6	4.46	0.87
10/9/2018 12:00	10/10/2018 8:06	112	76	33	0.4	0.10	5	0.4	2.0	0.38	1.20	223209	35813	187396	41194	10662	65525	173727	73.8%	63.2%	1212.0	355.0	4.35	1.08	55.1	21.20	4.12
10/14/2018 12:23	10/14/2018 15:11	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.10	1047	7	1040	54	50	0	1144	90.4%	99.4%	8.0	2.3	0.03	0.01	0.4	0.14	0.03
10/22/2018 12:00	10/22/2018 12:18	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.03	2226	9	2216	0	106	0	2323	95.4%	99.6%	16.2	4.7	0.06	0.01	0.7	0.28	0.06
10/26/2018 20:30	10/26/2018 20:46	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.09	62	1	61	0	3	0	64	95.4%	98.6%	0.4	0.1	0.00	0.00	0.0	0.01	0.00
10/26/2018 22:02	10/27/2018 2:52	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.15	4623	31	4592	21	221	0	4834	95.0%	99.4%	33.7	9.9	0.12	0.03	1.5	0.59	0.11
10/27/2018 21:41	10/28/2018 2:15	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.26	10867	607	10261	37	519	0	10817	94.8%	94.7%	75.5	22.1	0.27	0.07	3.4	1.32	0.26
11/4/2018 2:00	11/4/2018 18:57	112	76	33	0.4	0.10	5	0.4	2.0	0.38	0.53	21554	108	21446	0	1030	0	22475	95.4%	99.5%	156.8	45.9	0.56	0.14	7.1	2.74	0.53
11/5/2018 16:00	11/6/2018 14:37	112	76	33	0.4	0.10	5	0.4	2.0	0.38	-	75509	422	75086	386	3607	3410	75669	94.9%	95.2%	527.9	154.6	1.90	0.47	24.0	9.23	1.79
Sum											24.38	2,590,204	624,659	1,806,346	207,221	116,120	392,546	**1,737,142**			**11,406.3**	**3,404.1**	**42.5**	**10.8**	**599.8**	**214.9**	**45.4**
Average		112.2	77.8	34.5	0.41	0.120	5.62	0.26	1.89	0.467	0.41	1,743	10,411	30,106	3,454	83	3,022	28,952			190.1	56.7	0.71	0.18	5.0	2.2	0.8
Weighted Ave		111.8	75.5	32.7	0.40	0.099	5.08	0.41	1.95	0.380																	
STDEV		84.6	32.3	21.9	0.22	0.053	3.16	0.32	0.79	0.357																	
Median		98.5	77.5	26.0	0.37	0.117	4.30	0.14	1.72	0.324																	
Min		15.0	47.0	10.0	0.15	0.056	2.40	0.04	0.67	0.093																	
Max		294.0	109.0	76.0	0.93	0.194	12.20	0.73	3.13	1.124																	
Percent Capture of Total Runoff																		**59.6%**			**59.2%**	**60.4%**	**61.8%**	**63.2%**	**68.7%**	**63.9%**	**69.6%**

< 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)

* Flow events under 1000 cf runoff volume without samples are hidden from chart, but included in totals

City of Saint Paul
2018 Water Quality and Quantity Report
Table C.3
WSB Project Number: 01610-100

ROBIE 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 (mg/L)	Lead (mg/L)	Zinc (mg/L)	Sulfate (mg/L)	pH	CBOD (mg/L)	E. Coli (MPN/ 100 mL)
2662540	4/13/2018 12:45	4/13/2018 12:45	700.0	3268.0	270.0	1.35	0.169	1268	0.57	7.46	2.019	308	0.3640	0.3480	1.720	57.05	7.70	26.6	573
2673992	5/30/2018 9:27	5/30/2018 9:27	4.0	534.0	3.0	0.13	0.057	154.80	0.19	1.01	2.294	223	0.0043	0.0007	0.019	39.63	7.40	1.4	1120
2679646	6/16/2018 6:31	6/16/2018 6:52	30.0		11.0	0.25	0.120	4.54		1.48	0.309	20 J	0.0120	0.0088	0.059				
2686157	7/12/2018 18:16	7/12/2018 18:41	185.0	33.0	41.0	0.48	0.170	2.45	0.14	1.85	0.405	18 J	0.0332	0.0343	0.140	1.73		5.6	
2692603	8/3/2018 21:26	8/3/2018 21:45	53.0		18.0	0.25	0.129	2.30		1.07	0.364	16 J	0.0078	0.0061	0.046			3.5	
2697928	8/24/2018 16:26	8/24/2018 16:28				0.07		2.00 <		0.99	0.08 <								
2704335	9/20/2018 10:04	9/20/2018 10:04	18.0		8.0	0.11	0.075	11.95		0.68	0.322	13 J	0.0134	0.0085	0.061				
2710317	10/9/2018 14:11	10/9/2018 14:11	110.0	112.0	43.0	0.23	0.107	20.68	0.10	0.78	0.318	50	0.0522	0.0480	0.266		7.10	15.8	21600
MINIMUM			**4**	**33**	**3**	**0.07**	**0.057**	**2.0**	**0.10**	**0.68**	**0.080**	**13**	**0.00**	**0.00**	**0.02**	**1.73**	**7.10**	**1.4**	**573**
AVERAGE			**157**	**987**	**56**	**0.36**	**0.118**	**183.3**	**0.25**	**1.92**	**0.764**	**93**	**0.07**	**0.06**	**0.33**	**32.80**	**7.40**	**10.6**	**7764**
MEDIAN			**53**	**323**	**18**	**0.24**	**0.120**	**8.2**	**0.17**	**1.04**	**0.343**	**20**	**0.01**	**0.01**	**0.06**	**39.63**	**7.40**	**5.6**	**1120**
MAXIMUM			**700**	**3268**	**270**	**1.35**	**0.170**	**1267.9**	**0.57**	**7.46**	**2.294**	**308**	**0.36**	**0.35**	**1.72**	**57.05**	**7.70**	**26.6**	**21600**

Laboratory analysis was completed by Metroplian Council Environmental Services

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
2018 Water Quality and Quantity Report
Table C.4
WSB Project No.: 01610-100

ROBIE STREET OUTFALL VOLUME AND POLLUTANT SUMMARY

Event Time Interval		**Sampling Data**							**Event Loading and Volume Data**								
		TSS	VSS	TP	Ortho-P	Chloride	Total Kjeldahl Nitrogen	Nitrate + Nitrite as N	Interval Rain	Flow Volume	TSS	VSS	TP	Ortho-P	Chloride	Kjeldahl Nitrogen	Nitrate + Nitrite as N
Start	**End**	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	In.	cu-ft	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
5/1/18 23:17	5/1/18 23:19	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.16	109771.0	448.0	143.3	1.37	0.718	73.87	6.81	2.22
5/5/18 18:45	5/5/18 18:56	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.05	23522.4	96.0	30.7	0.29	0.154	15.83	1.46	0.48
5/9/18 0:15	5/9/18 0:45	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.29	81892.7	334.3	106.9	1.02	0.536	55.11	5.08	1.66
5/14/18 17:07	5/14/18 17:28	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.22	40946.3	167.1	53.5	0.51	0.268	27.56	2.54	0.83
5/18/18 19:41	5/18/18 19:45	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.06	24393.6	99.6	31.9	0.30	0.160	16.42	1.51	0.49
5/24/18 20:01	5/24/18 20:12	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.08	51836.3	211.6	67.7	0.65	0.339	34.88	3.22	1.05
5/25/18 3:08	5/25/18 3:16	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.6	68824.7	280.9	89.9	0.86	0.450	46.32	4.27	1.39
5/29/18 17:56	5/29/18 18:15	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	1.52	275734.4	1125.4	360.1	3.45	1.803	185.56	17.12	5.58
5/30/18 8:24	5/30/18 8:30	**4**	**3**	**0.13**	**0.057**	**154.8**	**1.01**	**2.294**	0.05	17424.0	4.4	3.3	0.14	0.062	168.38	1.10	2.50
6/2/18 11:24	6/2/18 11:27	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.12	30056.4	122.7	39.2	0.38	0.197	20.23	1.87	0.61
6/6/18 5:44	6/6/18 6:11	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.21	49658.3	202.7	64.8	0.62	0.325	33.42	3.08	1.00
6/9/18 11:54	6/9/18 13:17	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.18	32234.4	131.6	42.1	0.40	0.211	21.69	2.00	0.65
6/16/18 6:24	6/16/18 6:27	**30**	**11**	**0.25**	**0.120**	**4.5**	**1.48**	**0.309**	1.26	198197.7	371.2	136.1	3.09	1.485	56.17	18.31	3.82
6/17/18 22:54	6/17/18 23:01	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.76	49658.3	202.7	64.8	0.62	0.325	33.42	3.08	1.00
6/18/18 23:15	6/18/18 23:46	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.32	107593.0	439.2	140.5	1.35	0.704	72.41	6.68	2.18
6/26/18 2:07	6/26/18 2:10	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	1.01	191663.7	782.3	250.3	2.40	1.253	128.98	11.90	3.88
7/1/18 8:49	7/1/18 9:10	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.9	234788.0	958.3	306.6	2.94	1.535	158.00	14.58	4.75
7/4/18 9:44	7/4/18 9:46	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	1.61	204731.7	835.6	267.3	2.56	1.339	137.78	12.71	4.14
7/12/18 18:02	7/12/18 18:05	**185**	**41**	**0.48**	**0.170**	**2.5**	**1.85**	**0.405**	1.34	303612.7	3506.5	777.1	9.10	3.222	46.44	35.06	7.68
7/20/18 15:15	7/20/18 16:00	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.25	81892.7	334.3	106.9	1.02	0.536	55.11	5.08	1.66
8/1/18 7:15	8/1/18 7:45	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.05	10890.0	44.4	14.2	0.14	0.071	7.33	0.68	0.22
8/3/18 21:13	8/3/18 21:17	**53**	**18**	**0.25**	**0.129**	**2.3**	**1.07**	**0.364**	0.72	174675.3	577.9	196.3	2.73	1.407	25.08	11.67	3.97
8/4/18 12:30	8/4/18 12:45	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.05	10890.0	44.4	14.2	0.14	0.071	7.33	0.68	0.22
8/20/18 7:50	8/20/18 7:56	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.35	43124.3	176.0	56.3	0.54	0.282	29.02	2.68	0.87
8/24/18 5:35	8/24/18 5:48	*65*	*21*	**0.07**	*0.105*	**2.0** <	**0.99**	**0.080** <	1.25	241322.0	985.0	315.1	1.05	1.578	30.13	14.91	1.21
8/27/18 17:51	8/27/18 17:54	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.14	21344.4	87.1	27.9	0.27	0.140	14.36	1.33	0.43
8/28/18 8:37	8/28/18 9:00	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.17	27878.4	113.8	36.4	0.35	0.182	18.76	1.73	0.56
8/31/18 2:50	8/31/18 2:59	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.11	17424.0	71.1	22.8	0.22	0.114	11.73	1.08	0.35
9/2/18 8:49	9/2/18 9:00	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.6	66646.7	272.0	87.0	0.83	0.436	44.85	4.14	1.35
9/4/18 10:00	9/4/18 10:15	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	1.27	239144.0	976.1	312.3	2.99	1.564	160.94	14.85	4.84
9/17/18 14:31	9/17/18 14:39	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.35	103237.0	421.4	134.8	1.29	0.675	69.48	6.41	2.09
9/18/18 0:54	9/18/18 0:57	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.7	202553.7	826.7	264.5	2.53	1.325	136.31	12.57	4.10
9/20/18 5:45	9/20/18 6:15	**18**	**8**	**0.11**	**0.075**	**12.0**	**0.68**	**0.322**	3.18	910838.2	1023.5	454.9	6.25	4.265	679.50	38.67	18.31
9/25/18 11:41	9/25/18 11:50	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.39	77536.7	316.5	101.2	0.97	0.507	52.18	4.81	1.57
10/1/18 12:07	10/1/18 12:11	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.33	58370.3	238.2	76.2	0.73	0.382	39.28	3.62	1.18
10/3/18 17:37	10/3/18 17:39	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.55	107593.0	439.2	140.5	1.35	0.704	72.41	6.68	2.18
10/4/18 21:45	10/4/18 22:15	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.32	54014.3	220.5	70.5	0.68	0.353	36.35	3.35	1.09
10/7/18 21:00	10/10/18 5:15	**110**	**43**	**0.23**	**0.107**	**20.7**	**0.78**	**0.318**	1.76	382891.8	2629.3	1027.8	5.50	2.558	494.32	18.64	7.60
10/14/18 12:58	10/14/18 13:13	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.37	17424.0	71.1	22.8	0.22	0.114	11.73	1.08	0.35
10/26/18 22:03	10/26/18 23:13	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.58	68824.7	280.9	89.9	0.86	0.450	46.32	4.27	1.39
11/4/18 4:35	11/4/18 7:55	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.48	40946.3	167.1	53.5	0.51	0.268	27.56	2.54	0.83
11/5/18 16:30	11/5/18 17:29	*65*	*21*	*0.20*	*0.105*	*10.8*	*0.99*	*0.324*	0.54	133729.0	545.8	174.6	1.67	0.875	90.00	8.30	2.70
Sum									25.25	5189731	21182.6	6776.8	64.88	33.94	3492.5	322.2	105.0
Average		67	21	0.22	0.110	28.4	1.12	0.58									
Weighted Avg		65	21	0.20	0.105	10.8	0.99	0.32									
STDEV		69	17	0.14	0.040	56.2	0.41	0.76									
Min		4	3	0.07	0.057	2.0	0.68	0.08									
Max		185	43	0.48	0.170	154.8	1.85	2.29									

< 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

City of Saint Paul
2018 Water Quality and Quantity Report
Table C.5
WSB Project number 01610-100

MARYLAND POND WATER QUALITY SUMMARY

Date Composite Sampling Start	Date Composite Sampling End/ Grab Sample	Soluble Reactive Phosphorus (mg/L)			Total Phosphorus (mg/L)			Dissolved Phosphorus (mg/L)			Total Iron (mg/L)			Hardness (mg/L)			TSS (mg/L)		
		Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction
	4/13/2018 13:34	0.013	0.031	-138	0.463	0.135	71	0.034 J	0.063	-85	1.40	2.20	-57	47	82	-73	37	5	86
5/25/2018 3:41	5/27/2018 3:16	0.017	0.069	-306	0.188	0.158	16	0.034 J	0.092	-171	5.20	0.38 J	93	102	64	38	27	11	59
5/29/2018 20:25	5/31/2018 8:56	0.015	0.022	-47	0.225	0.108	52	0.048 J	0.041 J	15	0.47 J	1.40	-198	36	56	-55	13	7	46
	6/18/2018 10:28	0.030	0.039	-30	0.122	0.107	12	0.073	0.068	7	0.74	1.400	-89	38	63	-68	6	3	56
	6/18/2018 10:28	0.025	0.031	-24	0.106	0.103	3	0.056	0.052	7	0.71 J	1.30	-83	33	58	-74	5	3	40
6/17/2018 20:10	6/19/2018 14:13	0.016	0.044	-175	0.099	0.170	-72	0.032 J	0.023 J	28	0.70 J	3.30	-371	33	69	-111	10	13	-30
6/26/2018 4:43	6/27/2018 6:13	0.023	0.015	35	0.094	0.061	35	0.051	0.020 <	61	1.30	2.10	-62	31	70	-126	8 J	5 J	38
7/1/2018 11:38	7/2/2018 7:13	0.017	0.011	35	0.128	0.153	-20	0.032 J	0.020 <	38	1.10	3.10	-182	33	61	-86	6	7	-17
7/12/2018 18:23	7/13/2018 11:13	0.031	0.013	58	0.201	0.175	13	0.082	0.057	30	1.70	5.70	-235	23 J	55	-138	19 J	15	21
	7/25/2018 10:31	0.005 <	0.013	-160	0.107	0.131	-22	0.020 <	0.040 J	-100	5.80	0.68 J	88	94	33	65	15	9	40
9/4/2018 17:51	9/5/2018 7:16	0.021	0.018	14	0.117	0.130	-11	0.054	0.036 J	33	2.30	1.10	52	45	26	43	7	12	-71
9/18/2018 3:50	9/19/2018 4:01	0.017	0.043	-153	0.235	0.225	4	0.034 J	0.081	-138	7.10	2.20	69	72	27	63	17	12	29
9/20/2018 10:16	9/21/2018 10:01	0.013	0.032	-146	0.116	0.150	-29	0.020 J	0.027 J	-35	1.40	1.10	21	57	21 J	63	6	15	-150
10/3/2018 19:13	10/4/2018 4:57	*NA*	*NA*	*NA*	0.264	0.131	50	*NA*	*NA*	*NA*	8.20	1.10	87	49	20 J	59	22	13	41
10/9/2018 18:27	10/10/2018 11:12	0.031	0.037	-19	0.073	0.105	-44	0.053	0.066	-25	1.00	0.97 J	3	28	8 J	72	3	6	-100
MINIMUM		0.013	0.011	-306	0.073	0.061	-72	0.020	0.020	-171	0.47	0.38	-371	23	8	-138	3	3	-150
AVERAGE		0.020	0.031	-72	0.178	0.139	5	0.044	0.048	-20	2.51	2.00	-66	45	47	-25	14	10	-1
MEDIAN		0.017	0.031	-35	0.128	0.135	4	0.041	0.047	11	1.40	1.40	-57	36	56	-55	10	11	29
MAXIMUM		0.031	0.069	58	0.463	0.225	71	0.082	0.092	61	8.20	5.70	93	102	82	72	37	15	86

Laboratory analysis was completed by Metropolian Council Environmental Services

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

Post-treatment samples were collected from the drain tile outlet to the OCS

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
Baseflow Sample
QAQC 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)

NA - Not Analyzed

City of Saint Paul
2018 Water Quality and Quantity Summary
Table C.6
WSB Project Number 01610-100

MARYLAND POND TREATMENT SUMMARY

Treatment Event Start	Start	Stop	Treatment Event Duration (hours)	Treatment Volume (cubic feet)	Rainfall (inches)	TP Pre-Treatment (mg/L)	TP Post-Treatment (mg/L)	Removal Efficieny	TP Load Captured (grams)	SRP Pre-Treatment (mg/L)	SRP Post-Treatment (mg/L)	Removal Efficieny	SRP Load Captured (grams)
25-May	5/25/2018 3:30	5/26/2018 11:10	31.7	6334	0.60	0.188	0.158	16%	5.4	0.017	0.069	-306%	-9.3
29-May	5/29/2018 19:30	5/31/2018 23:55	52.4	39104	1.40	0.225	0.108	52%	129.6	0.015	0.022	-47%	-7.8
16-Jun	6/16/2018 7:45	6/17/2018 13:10	29.4	15792	1.26	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
17-Jun	6/17/2018 23:00	6/19/2018 7:55	32.9	19571	0.75	0.099	0.170	-72%	-39.3	0.016	0.044	-175%	-15.5
26-Jun	6/26/2018 2:45	6/27/2018 12:30	33.8	17704	1.01	0.094	0.061	35%	16.5	0.023	0.015	35%	4.0
1-Jul	7/1/2018 10:30	7/2/2018 3:35	17.1	14283	0.93	0.128	0.153	-20%	-10.1	0.017	0.011	35%	2.4
4-Jul	7/4/2018 9:45	7/5/2018 12:15	26.5	32963	1.59	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
12-Jul	7/12/2018 17:45	7/14/2018 8:45	39.0	13248	1.23	0.201	0.175	13%	9.8	0.031	0.013	58%	6.8
3-Aug	8/3/2018 22:00	8/4/2018 23:45	25.8	1843	0.73	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
2-Sep	9/2/2018 9:45	9/2/2018 19:30	9.8	344	0.60	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
4-Sep	9/4/2018 17:30	9/6/2018 6:00	36.5	32422	1.25	0.117	0.130	-11%	-11.9	0.021	0.018	14%	2.8
17-Sep	9/17/2018 16:30	9/19/2018 17:10	48.7	9198	0.86	0.235	0.225	4%	2.6	0.017	0.043	-153%	-6.8
20-Sep	9/20/2018 8:30	9/21/2018 23:55	39.4	89061	3.18	0.116	0.150	-29%	-85.7	0.013	0.032	-146%	-47.9
3-Oct	10/3/2018 17:45	10/4/2018 22:00	28.2	8659	0.87	0.264	0.131	50%	32.6	*NA*	*NA*	*NA*	*NA*
9-Oct	10/9/2018 15:40	10/11/2018 0:40	33.0	44930	1.22	0.073	0.105	-44%	-40.7	0.031	0.037	-19%	-7.6
Totals:			**484.1**	**345457**	**17.5**				**8.6**				**-79.0**

NA - Not Analyzed
Bold - Sampled Event
Negative Load Reduction
TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

Mass TP in	1130.8
Mass TP out	1122.2
Mass TP Retained	8.6
% P Retained	1%

Mass SRP in	154.5
Mass SRP out	233.5
Mass SRP Retained	-79.0
% SRP Retained	-51%

City of Saint Paul
2018 Water Quality and Quantity Report
Table C.7
WSB Project number 01610-100

MAGNOLIA POND WATER QUALITY SUMMARY

Date Composite Sampling Start	Date Composite Sampling End/ Grab Sample	Soluble Reactive Phosphorus (mg/L)			Total Phosphorus (mg/L)			Dissolved Phosphorus (mg/L)			Iron (mg/L)			Hardness (mg/L)			TSS (mg/L)		
		Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction
5/29/2018 21:01	5/31/2018 0:51	0.153	0.148	3	0.376	0.195	48	0.196	0.152	22	0.72 J	0.27 J	63	10 J	77	-675	37	NA	
6/16/2018 8:12	6/17/2018 5:02	0.054	0.094	-74	0.235	0.231	2	0.086	0.131	-52	0.36 J	0.41 J	-14	30	53	-75	9	6	33
	6/18/2018 10:40	0.083	0.084	-1	0.278	0.183	34	0.102	0.112	-10	0.49 J	0.27 J	45	26	43	-66	11	3 J	71
	6/18/2018 10:45	0.093	0.100	-8	0.263	0.189	28	0.143	0.137	4	0.53	0.28	47	29	53	-83	11	3	74
6/17/2018 23:59	6/18/2018 19:34	0.078	0.093	-19	0.190	0.179	6	0.126	0.129	-2	0.23 J	0.27 J	-17	20 J	35	-74	6 J	4	33
6/26/2018 4:43	6/26/2018 6:13	0.030	0.074	-147	0.252	0.153	39	0.112	0.075	33	0.91 J	0.72 J	21	28	46	-62	13	5 J	62
7/1/2018 12:12	7/2/2018 6:47	0.061	0.066	-8	0.284	0.206	27	0.093	0.090	3	0.81 J	0.71 J	12	20 J	41	-104	14	5	64
7/4/2018 10:12	7/5/2018 2:42	0.099	0.089	10	0.353	0.202	43	0.127	0.109	14	1.80	0.77 J	57	19 J	28	-48	67	9	87
7/12/2018 18:27	7/13/2018 10:27	0.145	0.117	19	0.372	0.276	26	0.218	0.172	21	1.30	0.99 J	24	17 J	33	-92	21	9	57
8/24/2018 11:42	8/25/2018 16:47	0.085	0.088	-4	0.256	0.339	-32	0.113	0.136	-20	1.10	1.80	-64	35	25 J	29	9	25	-178
9/4/2018 17:24	9/5/2018 6:34	0.095	0.097	-2	0.186	0.236	-27	0.132	0.144	-9	0.68 J	0.98 J	-44	34	17 J	50	3	9	-200
9/20/2018 11:49	9/20/2018 18:20	0.089	0.093	-4	0.158	0.269	-70	0.088	0.103	-17	0.56 J	1.00	-79	20 J	22 J	-10	6	60	-900
10/3/2018 18:14	10/4/2018 2:45	0.061	0.058	5	0.115	0.299	-160	0.080	0.096	-20	0.32 J	1.20	-275	40	20 J	50	4	64	-1500
10/9/2018 19:04	10/10/2018 9:04	0.088	0.103	-17	0.138	0.185	-34	0.117	0.127	-9	0.52 J	0.81 J	-56	24 J	42	-74	4	12	-200
AVERAGE		0.087	0.093	-18	0.247	0.224	-5	0.124	0.122	-3	0.74	0.75	-20	25	38	-88	15	16	-192
MEDIAN		0.087	0.093	-4	0.254	0.204	16	0.115	0.128	-5	0.62	0.75	-1	25	38	-70	10	9	33
MININUM		0.030	0.058	-147	0.115	0.153	-160	0.080	0.075	-52	0.23	0.27	-275	10	17	-675	3	3	-1500
MAXIMUM		0.153	0.148	19	0.376	0.339	48	0.218	0.172	33	1.80	1.80	63	40	77	50	67	64	87
ST. DEV>		0.031	0.021	41	0.080	0.051	55	0.039	0.025	21	0.41	0.42	84	8	16	170	17	20	458

Laboratory analysis was completed by Metropolian Council Environmental Services

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 drain tile outlet to 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

QAQC 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)

NA - Not Analyzed

City of Saint Paul
2018 Water Quality and Quantity Summary
Table C.8
WSB Project Number 01610-100

MAGNOLIA POND TREATMENT SUMMARY

Treatment Event Start	Start	Stop	Treatment Event Duration (hours)	Treatment Volume (cubic feet)	Rainfall (inches)	TP Pre-Treatment (mg/L)	TP Post-Treatment (mg/L)	Removal Efficiency	TP Load Captured (grams)	SRP Pre-Treatment (mg/L)	SRP Post-Treatment (mg/L)	Removal Efficieny	SRP Load Captured (grams)
25-May	5/25/2018 5:20	5/26/2018 5:00	23.7	399	0.65	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
29-May	5/29/2018 21:00	6/1/2018 4:00	55.0	12803	1.35	0.376	0.195	48%	65.6	0.153	0.148	3%	1.8
16-Jun	6/16/2018 8:15	6/17/2018 5:00	20.8	4683	1.25	0.235	0.231	2%	0.5	0.054	0.094	-74%	-5.3
18-Jun	6/18/2018 0:00	6/18/2018 19:10	19.2	4205	0.95	0.190	0.179	6%	1.3	0.078	0.093	-19%	-1.8
26-Jun	6/26/2018 3:05	6/27/2018 1:40	22.6	5099	1.01	0.252	0.153	39%	14.3	0.030	0.074	-147%	-6.4
1-Jul	7/1/2018 11:30	7/2/2018 6:20	18.8	5142	0.93	0.284	0.206	27%	11.4	0.061	0.066	-8%	-0.7
4-Jul	7/4/2018 10:15	7/5/2018 7:10	20.9	14443	1.59	0.353	0.202	43%	61.8	0.099	0.089	10%	4.1
12-Jul	7/12/2018 18:30	7/14/2018 22:35	52.1	8833	1.23	0.372	0.276	26%	24.0	0.145	0.117	19%	7.0
3-Aug	8/3/2018 23:00	8/5/2018 6:30	31.5	797	0.71	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
24-Aug	8/24/2018 11:45	8/25/2018 17:30	29.7	6000	1.19	0.256	0.339	-32%	-14.1	0.085	0.088	-4%	-0.5
2-Sep	9/2/2018 11:30	9/3/2018 5:00	17.5	621	0.36	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
4-Sep	9/4/2018 15:00	9/5/2018 23:30	32.5	7615	1.15	0.186	0.236	-27%	-10.8	0.095	0.097	-2%	-0.4
18-Sep	9/18/2018 4:00	9/19/2018 23:00	43.0	1050	0.51	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
20-Sep	9/20/2018 8:30	9/21/2018 20:00	35.5	41901	3.07	0.158	0.269	-70%	-131.7	0.089	0.093	-4%	-4.7
25-Sep	9/25/2018 2:00	9/26/2018 1:20	23.3	67	0.30	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
3-Oct	10/3/2018 18:20	10/4/2018 13:30	19.2	1666	0.55	0.115	0.299	-160%	-8.7	0.061	0.058	5%	0.1
9-Oct	10/9/2018 1:00	10/10/2018 23:30	46.5	9625	1.17	0.138	0.185	-34%	-12.8	0.088	0.103	-17%	-4.1
Totals:			**511.8**	**124948**	**18.0**				**0.8**				**-10.9**

NA - Not Analyzed
Bold - Sampled Event
Negative Load Reduction
TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

Mass TP in	819.3
Mass TP out	818.5
Mass TP Retained	0.8
% P Retained	0%

Mass SRP in	329.3
Mass SRP out	340.2
Mass SRP Retained	-10.9
% SRP Retained	-3%

City of Saint Paul
2018 Water Quality and Quantity Report
Table C.9
WSB Project number 01610-100

JENKS POND WATER QUALITY SUMMARY

Date Composite Sampling Start	Date Composite Sampling End/ Grab Sample	Soluble Reactive Phosphorus (mg/L)			Total Phosphorus (mg/L)			Dissolved Phosphorus (mg/L)			Iron (mg/L)			Hardness (mg/L)			TSS (mg/L)		
		Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction	Pre	Post	% Reduction
	4/13/2018 13:20	0.021	0.027	-29	0.285	0.205	28	0.034 J	0.050	-47	0.77 J	0.19 J	75	21 J	77	-267	21	12	43
	5/30/2018 8:21	0.021	0.030	-43	0.253	0.166	34	0.056	0.046 J	18	0.68 J	0.39 J	43	18 J	37	-103	9	6	33
	6/18/2018 9:33	0.058	0.018	69	0.241	0.068	72	0.085	0.029 J	66	0.86 J	0.24 J	72	13 J	42	-221	11	3	73
	6/18/2018 9:28	0.054	0.018	67	0.253	0.068	73	0.053	0.042	21	0.85	0.23	73	21	46	-113	13	2	82
	6/26/2018 9:42	0.047	0.019	60	0.179	0.096	46	0.094	0.056	40	0.84 J	0.58 J	31	14 J	59	-321	8	3	63
	7/2/2018 10:14	0.012	0.010	17	0.202	0.129	36	0.044 J	0.020 <	55	1.10	1.00	9	11 J	47	-331	10	6 J	40
	7/13/2018 12:58	0.013	0.033	-154	0.156	0.527	-238	0.047 J	0.099	-111	1.30	2.60	-100	48	28	42	7	15	-114
	9/5/2018 10:15	0.016	0.026	-63	0.057	0.119	-109	0.032 J	0.044 J	-38	0.41 J	0.70 J	-71	36	8 <	78	2 J	8 J	-300
	9/18/2018 13:11	0.023	0.089	-287	0.137	0.338	-147	0.048 J	0.132	-175	0.98 J	2.60	-165	73	35	52	6	10	-67
	9/20/2018 10:38	0.047	0.019	60	0.235	0.116	51	0.173	0.139	20	2.20	1.20	45	28	53	-87	8 J	5 J	38
	10/8/2018 10:52	0.086	0.011	87	0.288	0.055	81	0.154	0.022 J	86	1.80	1.10	39	26	63	-144	15	3 J	80
MININUM		0.012	0.010	-287	0.057	0.055	-238	0.032	0.020	-175	0.410	0.190	-165	11	8	-331	2	2	-300
AVERAGE		0.036	0.027	-30	0.208	0.172	-7	0.075	0.062	-6	1.072	0.985	5	28	45	-129	10	7	-3
MEDIAN		0.023	0.019	17	0.235	0.119	36	0.053	0.046	20	0.860	0.700	39	21	46	-113	9	6	40
MAXIMUM		0.086	0.089	87	0.288	0.527	81	0.173	0.139	86	2.200	2.600	75	73	77	78	21	15	82

Laboratory analysis was completed by Metropolian Council Environmental Services

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

Post-treatment samples were collected from the drain tile outlet to the OCS

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

QAQC 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)

NA - Not Analyzed

City of Saint Paul
2018 Water Quality and Quantity Summary
Table C.10
WSB Project Number 01610-100

JENKS POND TREATMENT SUMMARY

Treatment Event Start	Start	Stop	Treatment Event Duration (hours)	Treatment Volume (cubic feet)	Rainfall (inches)	TP Pre-Treatment (mg/L)	TP Post-Treatment (mg/L)	Removal Efficieny	TP Load Captured (grams)	SRP Pre-Treatment (mg/L)	SRP Post-Treatment (mg/L)	Removal Efficieny	SRP Load Captured (grams)
25-May	5/25/2018 4:30	5/27/2018 2:15	45.8	342	0.56	NA	NA	NA	NA	NA	NA	NA	NA
29-May	5/29/2018 19:30	6/1/2018 4:30	57.0	14336	1.53	0.056	0.046	18%	4.06	0.021	0.030	-43%	-3.65
6-Jun	6/6/2018 6:30	6/7/2018 14:00	31.5	237	0.22	NA	NA	NA	NA	NA	NA	NA	NA
9-Jun	6/9/2018 7:30	6/11/2018 14:00	54.5	284	0.18	NA	NA	NA	NA	NA	NA	NA	NA
16-Jun	6/16/2018 8:30	6/19/2018 2:30	66.0	15072	1.25	0.085	0.029	66%	23.90	0.058	0.018	69%	17.07
19-Jun	6/19/2018 4:25	6/21/2018 8:00	51.6	3720	0.18	NA	NA	NA	NA	NA	NA	NA	NA
26-Jun	6/26/2018 2:30	6/30/2018 9:00	102.5	6725	1.01	0.094	0.056	40%	7.24	0.047	0.019	60%	5.33
1-Jul	7/1/2018 4:30	7/4/2018 5:40	73.2	6236	0.93	0.044	0.020	55%	4.24	0.012	0.010	17%	0.35
4-Jul	7/4/2018 10:00	7/8/2018 1:00	87.0	27936	1.62	NA	NA	NA	NA	NA	NA	NA	NA
12-Jul	7/12/2018 18:45	7/13/2018 1:35	6.8	1268	1.34	0.047	0.099	-111%	-1.87	0.013	0.033	-154%	-0.72
Totals:			**575.8**	**76157**	**8.8**				**37.6**				**18.4**

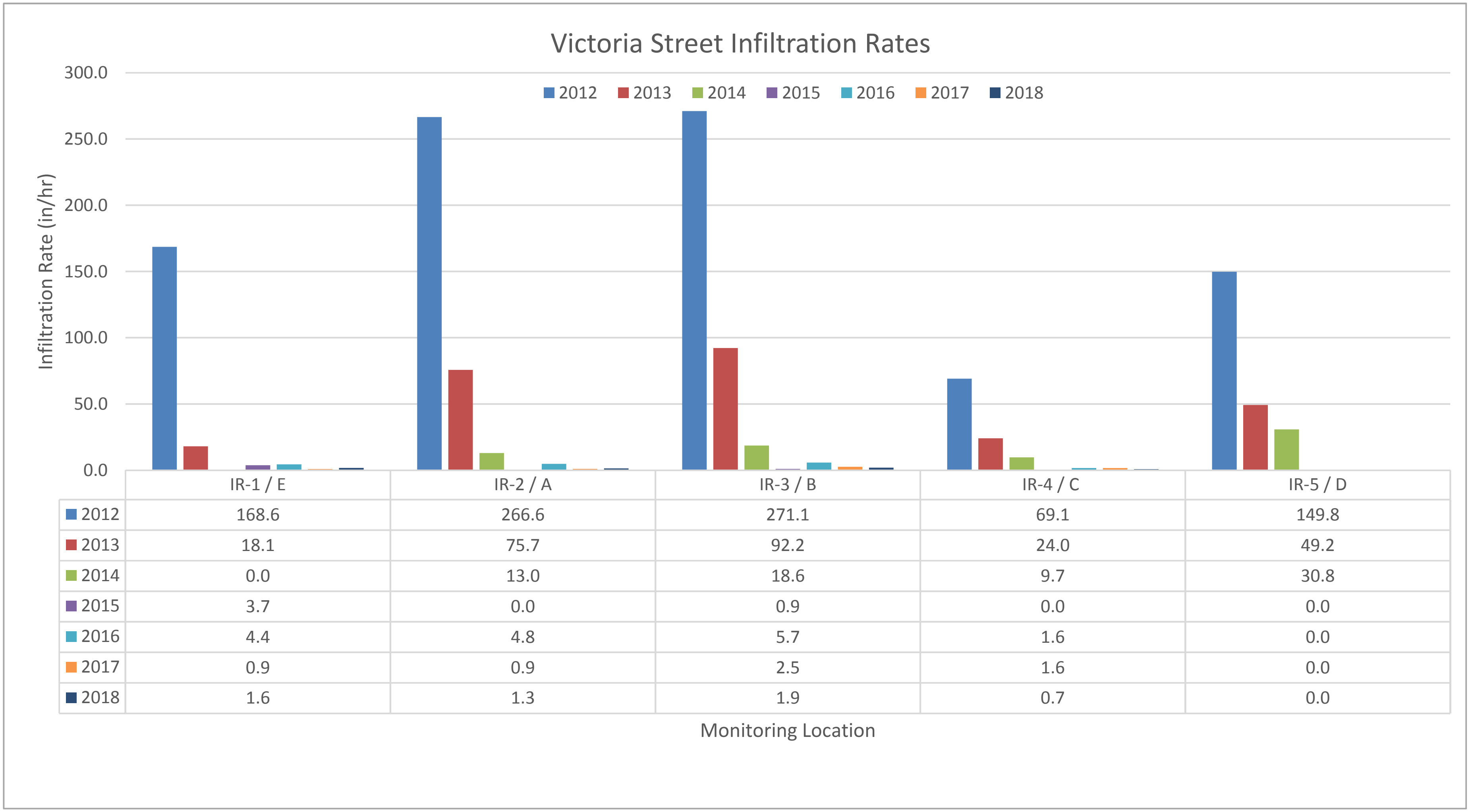
NA - Not Analyzed
Bold - Sampled Event
Negative Load Reduction
TP - Total Phosphorus, SRP - Soluble Reactive Phosphorus

Mass TP in	86.4
Mass TP out	48.8
Mass TP Retained	37.6
% P Retained	43%

Mass SRP in	44.8
Mass SRP out	26.4
Mass SRP Retaine	18.4
% SRP Retained	41%

Appendix D – Pervious Pavement Infiltration Charts

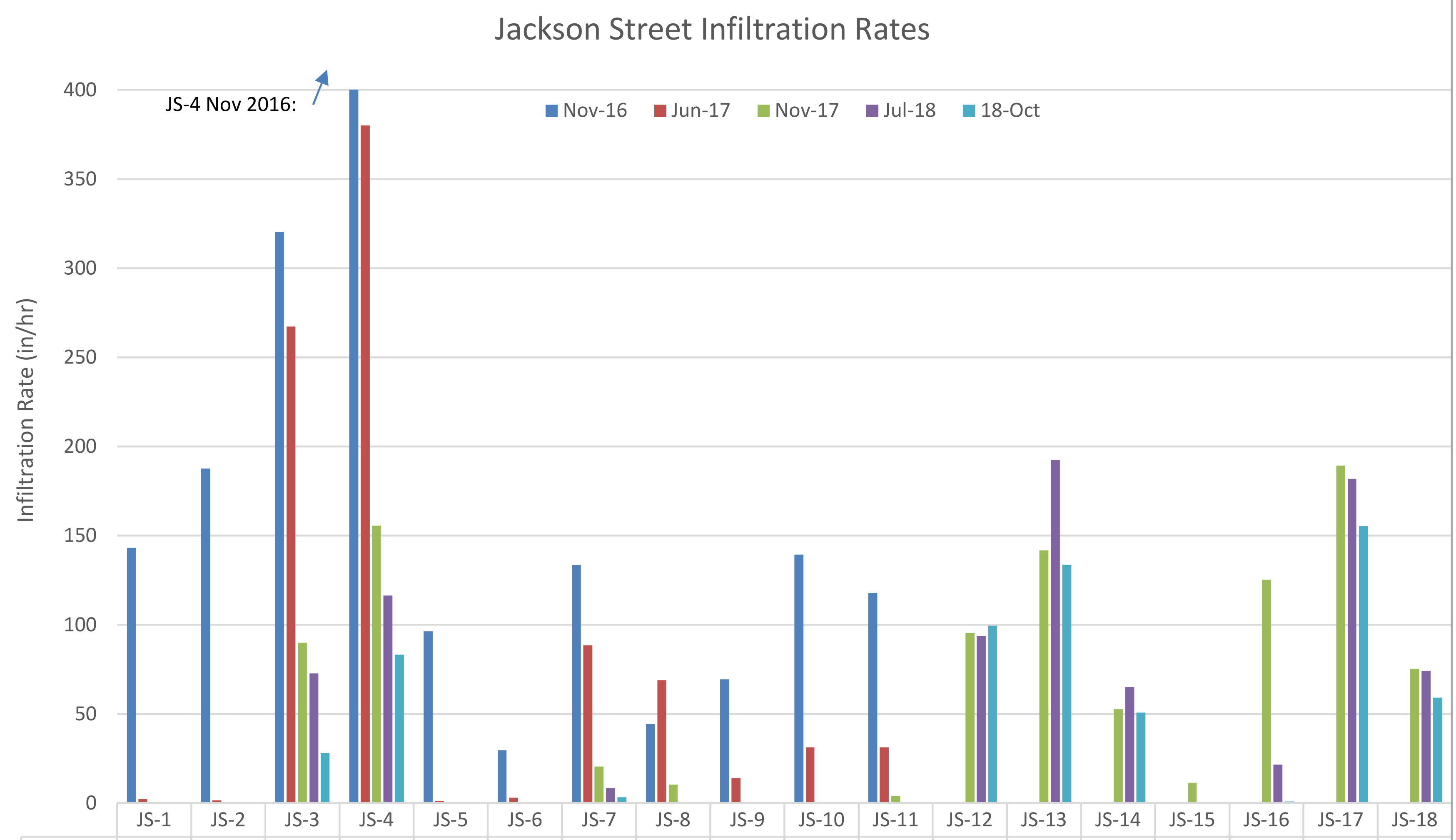
City of Saint Paul
2018 Water Quality and Quantity Report
Chart D.1
WSB Project Number: 01610-100



Victoria Street Infiltration Rates

	IR-1 / E	IR-2 / A	IR-3 / B	IR-4 / C	IR-5 / D
2012	168.6	266.6	271.1	69.1	149.8
2013	18.1	75.7	92.2	24.0	49.2
2014	0.0	13.0	18.6	9.7	30.8
2015	3.7	0.0	0.9	0.0	0.0
2016	4.4	4.8	5.7	1.6	0.0
2017	0.9	0.9	2.5	1.6	0.0
2018	1.6	1.3	1.9	0.7	0.0

City of Saint Paul
2018 Water Quality and Quantity Report
Chart D.2
WSB Project Number: 01610-100



	JS-1	JS-2	JS-3	JS-4	JS-5	JS-6	JS-7	JS-8	JS-9	JS-10	JS-11	JS-12	JS-13	JS-14	JS-15	JS-16	JS-17	JS-18
Nov-16	143.2	187.6	320.5	530.6	96.5	29.7	133.4	44.4	69.5	139.5	117.9							
Jun-17	2.3	1.6	267.3	380.0	1.1	3.0	88.5	68.8	14.0	31.4	31.4							
Nov-17	0.7	0.0	90.0	155.6	0.0	0.0	20.6	10.3	0.3	0.2	4.0	95.6	141.8	52.7	11.3	125.2	189.4	75.4
Jul-18	0.0	0.0	72.8	116.4	0.0	0.0	8.4	0.0	0.0	0.0	0.0	93.8	192.4	65.2	0.0	21.6	182.0	74.3
18-Oct	0.0	0.0	28.0	83.2	0.0	0.0	3.3	0.0	0.0	0.0	0.0	99.5	133.7	50.7	0.0	1.0	155.3	59.1

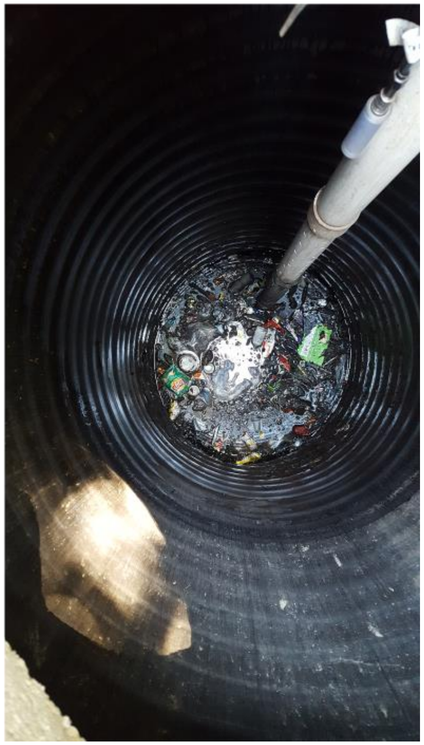
Appendix E – Photolog

2018 St. Paul Storm Water Monitoring Program

Appendix E

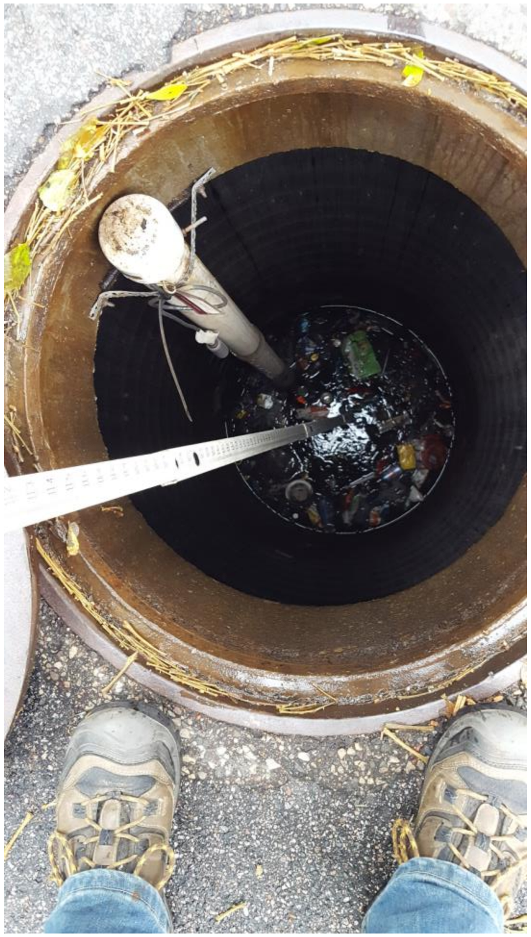
Arundel 4/26/18

Arundel 7/6/18



Arundel 7/31/18

Arundel 8/31/18



Arundel 10/5/18

Arundel 11/8/18

Beacon Bluff 4/10/18

Arundel 4/10/18

Beacon Bluff 5/9/18

Beacon Bluff 6/27/19

Beacon Bluff
10/5/18

Hillcrest Knoll 4/10/18

Hillcrest Knoll 7/6/18

Hillcrest Knoll 7/31/18

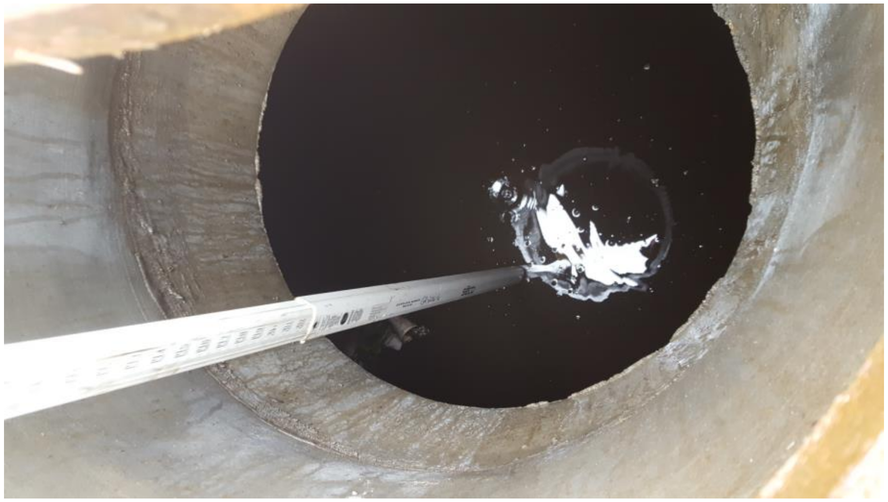


Hillcrest Knoll 10/5/18

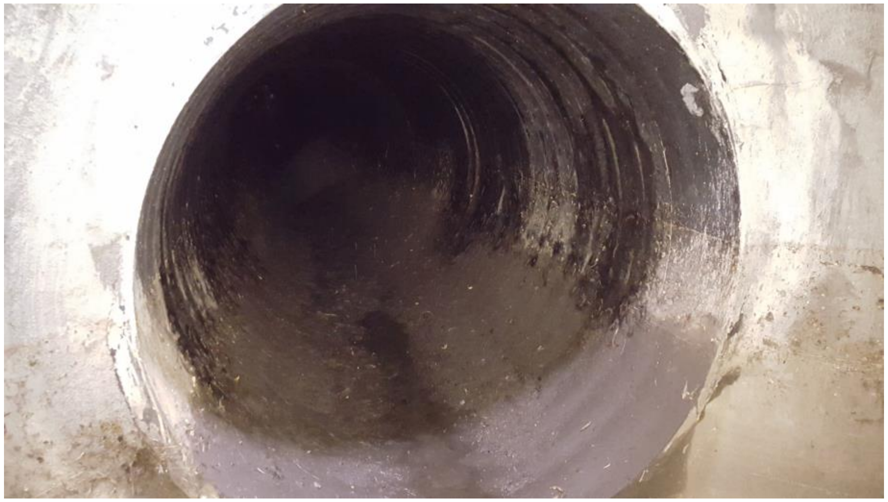
Hillcrest Knoll 11/8/18

Hampden Park 4/10/18

Hampden Park 4/10/18



Hampden Park 7/3/18



Hampden Park 7/3/18

Hampden Park 7/3/18

Hampden Park 7/31/18

Hampden Park 10/5/18

Hampden Park 11/7/18

Hampden Park 11/7/18

Robie 4/24/18

Saint Albans 4/10/18

Saint Albans 7/31/18

Saint Albans 10/5/18

Saint Albans 11/8/18

TBNS – Jenks Pond 5/16/18

TBNS – Magnolia Pond 5/16/18

TBNS – Maryland Pond 5/17/18

Appendix F – 2018 Monitoring Protocols

STORMWATER MONITORING PROTOCOL

2018 Stormwater Monitoring Program
Field Standard Operating Procedures

FOR THE CITY OF
ST. PAUL, MINNESOTA

SAINT PAUL

The Most Livable
City in America

wsb

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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 staff with OSHA 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. 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)
5 – System Level Loggers
    BMP Pipe
    OCS
    IR-31(Rain Garden - west)
    IR-32 (In-rock east)
    BaroTroll (atmospheric logger)
2 – Rugged Troll 100
    GW-50
    GW-53
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)
2 – Level Troll 500
    BMP Pipe
    HK-GW
1 – Rugged Troll 100
    IR-1

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 2150 Area velocity sensor (Upstream)
1 – Level Troll 500
    P-2
1 – Rugged Troll 100
    BMP

Monitoring Parameters:

- Rainfall
- Water level/Infiltration rate
- Flow Rate

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 (8” drain tile)
2 – ISCO 6712 portable water quality sampler (pond, 8” drain tile)
1 – Rugged Troll 100

Monitoring Parameters:

☐ Rainfall
☐ Water Level
☐ Flow Rate
☐ Water Quality **(Total Phosphorus, Dissolved Phosphorus, Soluble Reactive Phospohrus, Total Iron, Total Suspended Solids, Hardness)**

III.7 Robie Street Outfall

The Robie Street Outfall is located on Saint Paul’s West Side neighborhood within the Lower Mississippi River Watershed. The outfall consists of a 54-inch RCP pipe that receives runoff from a 118-acre drainage area, which then outfalls to the Mississippi. The drainage area consists of predominately residential land use and 42% imperious surface. Continuous flow measurements and water quality sampling will be monitored here.

Equipment:

1 – ISCO 2150 Area velocity sensor
1 – ISCO 6712 Portable Water Quality Sampler

Monitoring Parameters:

☐ Flow Rate/volume
☐ Water Quality **(NPDES Permit Required Parameters)**

III.8 Level Logger Only Sites

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

<u>Level Only sites:</u>

- Montreal Trench
- Wordsworth Trench
- Sackett Park Pond
- Flandrau-Hoyt Pond
- St. Kate’s (6 groundwater piezometers)

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 VI**)

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.)	Robie Street Outfall	Beacon Bluff
	Runoff Volume (cu-ft)	Runoff Volume (cu-ft)
0.10-0.15”	**30,840**	**4,500**
0.25”	**51,400**	**20,986**
0.5”	**102,800**	**63,000**
1.0”	**205,600**	**156,756**
2.0”	**411,200**	**373,550**
3.0”	**616,800**	**657,879**

<u>Program Automated Sampling Parameters:</u>

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
    - Robie Street: 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
    - ▪ Robie Street: 5,140 cu-ft
- ☐ **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 Robie Street Outfall. 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 Robie Street Outfall 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, Soluble Reactive Phosphorus, Total Suspended Solids, Total Iron, and Hardness.

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

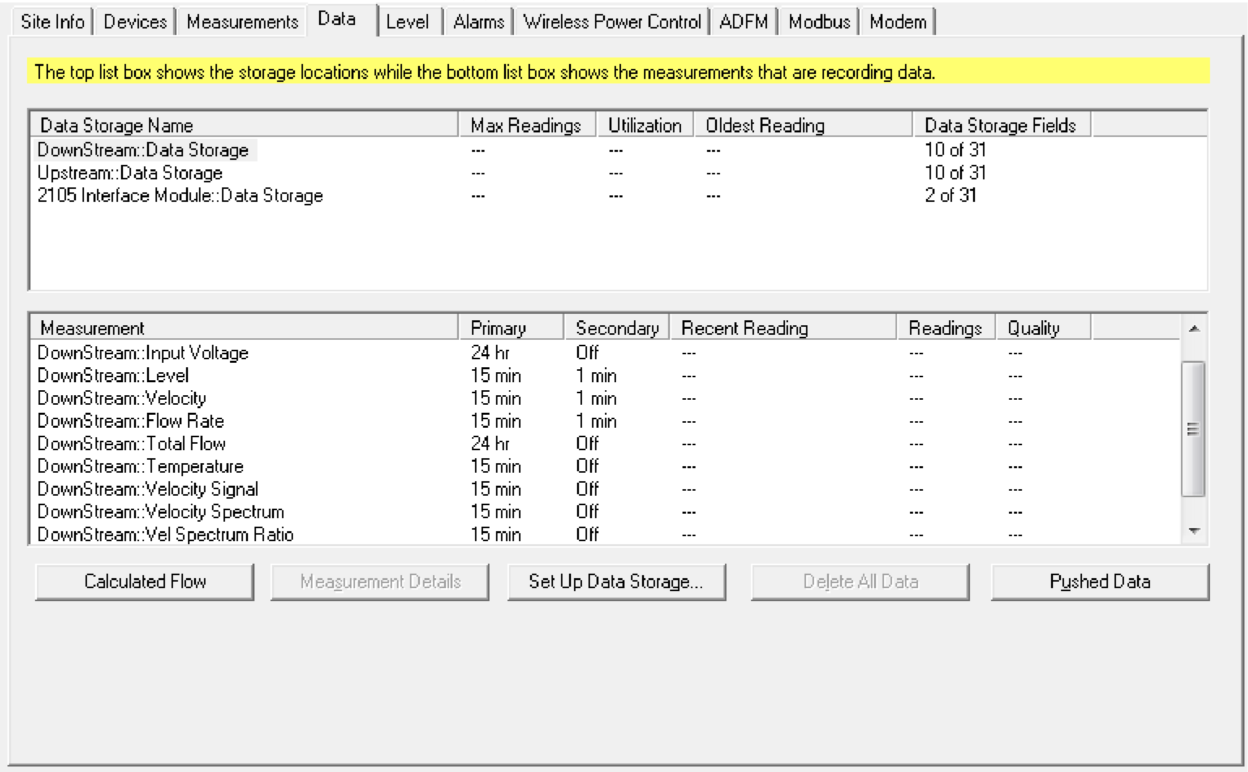
VII. Operation and Maintenance of Monitoring Equipment

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



The top list box shows the storage locations while the bottom list box shows the measurements that are recording data.

Data Storage Name	Max Readings	Utilization	Oldest Reading	Data Storage Fields
DownStream::Data Storage	---	---	---	10 of 31
Upstream::Data Storage	---	---	---	10 of 31
2105 Interface Module::Data Storage	---	---	---	2 of 31

Measurement	Primary	Secondary	Recent Reading	Readings	Quality
DownStream::Input Voltage	24 hr	Off	---	---	---
DownStream::Level	15 min	1 min	---	---	---
DownStream::Velocity	15 min	1 min	---	---	---
DownStream::Flow Rate	15 min	1 min	---	---	---
DownStream::Total Flow	24 hr	Off	---	---	---
DownStream::Temperature	15 min	Off	---	---	---
DownStream::Velocity Signal	15 min	Off	---	---	---
DownStream::Velocity Spectrum	15 min	Off	---	---	---
DownStream::Vel Spectrum Ratio	15 min	Off	---	---	---

- ☐ **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*

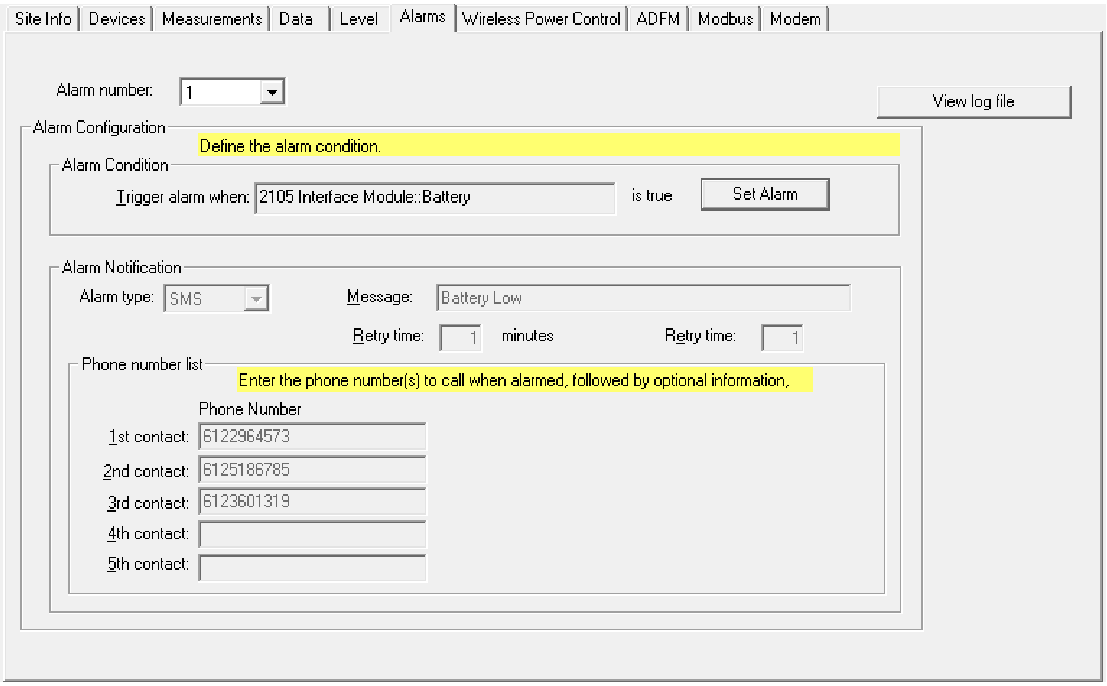
---

[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



Alarm number: 1

Define the alarm condition.

Trigger alarm when: 2105 Interface Module::Battery is true

Alarm type: SMS

Message: Battery Low

Retry time: 1 minutes

Retry time: 1

Enter the phone number(s) to call when alarmed, followed by optional information.

1st contact: 6122964573
2nd contact: 6125186785
3rd contact: 6123601319
4th contact:
5th contact:

- ☐ **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. Robie Street, 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:

---

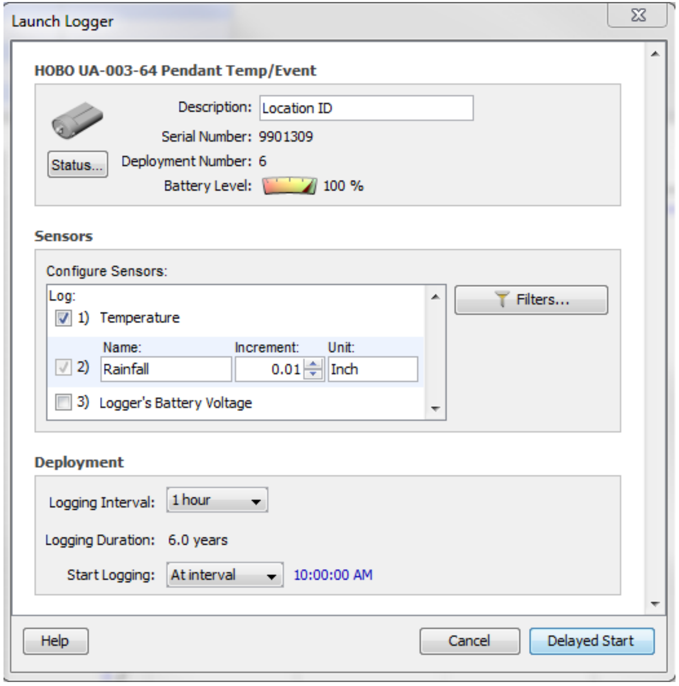
[5] See 6712 Portable Samplers – Installation and Operation Guide, Teledyne ISCO, Rev. April 11, 2011.

☐ **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**



Launch Logger

HOBO UA-003-64 Pendant Temp/Event

Description: Location ID
Serial Number: 9901309
Deployment Number: 6
Battery Level: 100 %

Sensors

Configure Sensors:
Log:
☑ 1) Temperature
☑ 2) Name: Rainfall Increment: 0.01 Unit: Inch
☐ 3) Logger's Battery Voltage

Deployment

Logging Interval: 1 hour
Logging Duration: 6.0 years
Start Logging: At interval 10:00:00 AM

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_2017
    - **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 (sites with standing water in the BMP should utilize a threshold that will prevent the "event" setting from being continuously triggered)
        - Default record data every 60 measurements
    - **Schedule Start time:** on Next Hour
    - **Output:** Depth (BMP Sites) Depth to water (Groundwater Sites)

---

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

        - 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: ____

Retain completed form – Submit copy to WSB & Associates Inc. - Safety

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:	

Retain completed form – Submit copy to WSB & Associates Inc. - 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: _______

Retain completed form – Submit copy to WSB & Associates Inc. - Safety

City of Saint Paul/ WSB and Associates

Date Submitted:

Sampler: Dan O'Neill

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

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

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Location ID:	**BEACON_BL**	**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:	**MH7**	[X] CL-AV (3)	[X] CU-MSV	[X] BOD5C_IS
Sample Name:	[ ] Grab [X] Comp	[X] N_N-AV2 (2)	[X] HARD-HL	[X] NH3N-AV
Start Date/Time:		[X] NUT-AV (1) [X] TSSVSS-GF (4)	[X] PB-MSV [X] ZN-MSV	[X]TDS-180 [X] Oil and Grease [X] ECOLI-MPNT**
End Date/Time:			**FILT (Monthly)** [X] ORTHO-AV	**FILT (2x/yr)** [ ] SO4-ICV
Location ID:	**BEACON_BL**	**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:	**MH7**	[ ] CL-AV (3)	[ ] CU-MSV	[ ] BOD5C_IS
Sample Name:	[ ] Grab [ ] Comp	[ ] N_N-AV2 (2)	[ ] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[ ] NUT-AV (1) [ ] TSSVSS-GF (4)	[ ] PB-MSV [ ] ZN-MSV [ ] Oil and Grease	[ ]TDS-180
End Date/Time:			**FILT (Monthly)** [ ] ORTHO-AV	[ ] ECOLI-MPNT** **FILT (2x/yr)** [ ] SO4-ICV
Location ID:	**ROBIE_ST**	**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:	**OUTFALL**	[**X**] CL-AV (3)	[X] CU-MSV	[] BOD5C_IS
Sample Name:	[X] Grab [ ] Comp	[**X**] N_N-AV2 (2)	[X] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[**X**] NUT-AV (1) [**X**] TSSVSS-GF (4)	[X] PB-MSV [X] ZN-MSV	[ ]TDS-180 [ ] Oil and Grease [ ] ECOLI-MPNT**
End Date/Time:			**FILT (Monthly)** [X] ORTHO-AV	**FILT (2x/yr)** [ ] SO4-ICV
Location ID:	**ROBIE_ST**	**LIQ (Loading)**	**LIQ (Monthly)**	**LIQ (Quarterly)**
Sample PT:	**OUTFALL**	[ ] CL-AV (3)	[ ] CU-MSV	[ ] BOD5C_IS
Sample Name:	[ ] Grab [ ] Comp	[ ] N_N-AV2 (2)	[ ] HARD-HL	[ ] NH3N-AV
Start Date/Time:		[ ] NUT-AV (1) [ ] TSSVSS-GF (4)	[ ] PB-MSV [ ] ZN-MSV [ ] Oil and Grease	[ ] pH [ ]TDS-180
End Date/Time:			**FILT (Monthly)** [ ] ORTHO-AV	[ ] ECOLI-MPNT** **FILT (2x/yr)** [ ] SO4-ICV

Comments:

BLUE: Analysis Priority List

** Dilution needed – High concentrations anticipated

Proceed with ORTHO-AV & N_N-AV2 if outside of hold time

City of Saint Paul/ WSB and Associates

Date Submitted: ____________________

Sampler: Dan O.

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

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

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Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MRLPON**	[**X**] P-AV (1)	[**X**] P-AV (3)
Sample Name:	[ ] Grab [X] Comp	[X] TSSVSS-GF(6)	[**X**] ORTHO_P (2)
Start Date/Time:		[**X**] HARD-HL(4)	
End Date/Time:		[**X**] Fe-MSV(5)	

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MRLOCS**	[**X**] P-AV (1)	[**X**] P-AV (3)
Sample Name:	[ ] Grab [X] Comp	[X] TSSVSS-GF(6)	[**X**] ORTHO_P (2)
Start Date/Time:		[**X**] HARD-HL(4)	
End Date/Time:		[**X**] Fe-MSV(5)	

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MAGPON**	[**X**] P-AV (1)	[**X**] P-AV (3)
Sample Name:	[ ] Grab [X] Comp	[X] TSSVSS-GF(6)	[**X**] ORTHO_P (2)
Start Date/Time:		[**X**] HARD-HL(4)	
End Date/Time:		[**X**] Fe-MSV(5)	

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**MAGOCS**	[**X**] P-AV (1)	[**X**] P-AV (3)
Sample Name:	[ ] Grab [X] Comp	[X] TSSVSS-GF(6)	[**X**] ORTHO_P (2)
Start Date/Time:		[**X**] HARD-HL(4)	
End Date/Time:		[**X**] Fe-MSV(5)	

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**JENPON**	[**X**] P-AV (1)	[**X**] P-AV (3)
Sample Name:	[X] Grab [ ] Comp	[X] TSSVSS-GF(6)	[**X**] ORTHO_P (2)
Start Date/Time:		[**X**] HARD-HL(4)	
End Date/Time:		[**X**] Fe-MSV(5)	

Location ID:	**TBNS**	**LIQ**	**FILT**
Sample PT:	**JENOCS**	[**X**] P-AV (1)	[**X**] P-AV (3)
Sample Name:	[X] Grab [ ] Comp	[X] TSSVSS-GF(6)	[**X**] ORTHO_P (2)
Start Date/Time:		[**X**] HARD-HL(4)	
End Date/Time:		[**X**] Fe-MSV(5)	

Comments:

BLUE: Analysis priority list

Proceed with Ortho_P if out of hold

Appendix G – ASTM C1701 Procedures

Designation: C1701/C1701M – 09

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.

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[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

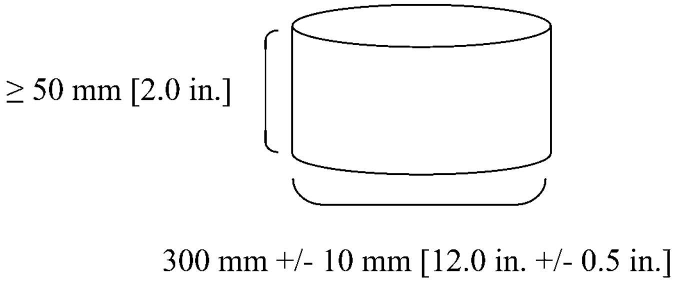

FIG. 1 Dimensions of Infiltration Ring

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

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