Vancouver Green Infrastructure

# PERFORMANCE MONITORING REPORT 2023-2025

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Published: December 2025

# Executive Summary

This report is the City of Vancouver's Green Infrastructure Implementation Branch's third performance monitoring report, covering the period from **July 1, 2023 to June 30, 2025**. This report evaluates the effectiveness of over 400 green rainwater infrastructure (GRI) assets—including bioretention systems, rainwater tree trenches (RTTs), permeable pavements, and subsurface infiltration systems—against their performance objectives and compliance requirements. We are carrying out this work to understand the performance and benefits of green infrastructure and to improve our implementation going forward.

Key Findings from this report include:

- **GRI systems drain down quickly**: Monitoring shows that surface water typically drains within 24 hours and subsurface water within 72 hours for nearly all assets, meeting design criteria. Many assets with low native soil infiltration rates are showing drawdown rates quick enough that we could cap more underdrains to prioritize infiltration over filtration.

- **GRI systems retain soil moisture**: Soil moisture monitoring at nine sites indicates that systems maintain adequate moisture levels for plant health, even during summer droughts. RTTs under pavement show less seasonal variation, suggesting reduced evaporation.

- **GRI reduces runoff to sewer systems**: Catchment-level flow monitoring at Richards Street revealed a statistically significant reduction in sewer flow volumes post-GRI installation, with similar rainfall amounts. This suggests GRI is partially contributing to runoff reduction.

- **Permeable pavements require frequent maintenance**: Annual power washing is essential to maintain infiltration capacity. Infiltration capacity could not be restored at older assets that received no maintenance over several years, while newer assets show improved performance post-cleaning.

- **Healthy soils improve GRI performance**: Soil inoculation and matrix planting experiments are underway, with the goal of improving plant survival, soil structure and biodiversity in soils, especially during drought conditions. Ongoing trials will further inform best practices.

- **GRI may improve biodiversity**: Pre-construction biodiversity monitoring at the St. George Rainway has been completed. Post-construction monitoring in 2026 and 2027 is planned to assess ecological benefits.

- **Routine maintenance sustains GRI condition**: Condition assessments from 2022 and 2024 show mixed trends, with some assets improving and others deteriorating. 76% of assets are in good to fair condition, requiring only routine maintenance.

Next Steps for the Green Infrastructure Branch at City of Vancouver include:

- Continue monitoring drawdown rates and durations to assess long-term performance.
- Maintain annual cleaning of permeable pavements.
- Advance soil health initiatives through inoculation trials and plant matrix studies.
- Include data from community science inspections.
- Conduct post-construction biodiversity assessments.
- Refine maintenance strategies according to condition assessment data.
- Continue to advance catchment level flow monitoring studies for evaluating flow mitigation with GRI.

# Contents

***Figures***

***Tables***

# 1 Introduction

## 1.1 About Green Rainwater Infrastructure

As cities around the world continue to be impacted by climate change, rapid urbanization and environmental degradation, green rainwater infrastructure (GRI) is emerging as a key tool that mimics natural water processes in our urban environments to help build resilient and sustainable communities.

The Rain City Strategy and the Integrated Rainwater Management Plan target improving water quality using green rainwater infrastructure (GRI). GRI provides many benefits to cities such as:

- Improving water and air quality
- Sustainably managing rainwater and reducing flooding
- Enhancing resiliency to climate change
- Helping to reduce sewer infrastructure costs
- Increasing green space for our communities and urban wildlife

GRI uses a suite of typologies that retain and filter runoff close to where it falls, decreasing the volume of runoff directed to the sewer system, reducing combined sewer overflow, and removing pollutants from rainwater runoff before it is discharged to receiving waters. The City of Vancouver Green Infrastructure Implementation Branch currently operates more than four hundred GRI assets that include:

**Bioretention or bioswales:** shallow depression with layers of rock, engineered soils and resilient vegetation. Rainwater runoff enters the system where it soaks into the soils and filters pollutants.

**Subsurface infiltration:** uses gray infrastructure to collect and convey rainwater runoff to areas where it can be stored and infiltrate back into soils. Includes infiltration trenches and dry wells.

**Permeable pavement:** they come in a variety of forms, but they all allow rainwater runoff to soak into the underlying base where it can infiltrate back into the ground

**Rainwater tree trench:** rainwater runoff is collected into a catchbasin and distributed underground through piping and soil to the tree trench. This provides additional rainwater storage, and the increased soil moisture and pore space that supports tree health.

**Stormwater Wetland:** designed to use the same process as a natural wetland to manage rainwater runoff: rainwater detention, sediment settling, filtering through vegetation and soil, and biological treatment.

## 1.2 Report Overview

### 1.2.1 Purpose

This is the third monitoring report that has been published from the City of Vancouver green infrastructure team. Our previous monitoring reports concluded that the systems are performing as expected to manage rainwater runoff. Continued monitoring provides vital information to understand long-term performance and benefits, as well as asset life cycle costs and maintenance activities.

The goals of this report are to understand:

- the performance of our GRI systems compared to their design objectives,
- track and verify progress toward City's environmental goals and regulatory requirements,
- understand how plants influence our systems, and
- understand how our projects affect local-area biodiversity.

Monitoring our systems helps our staff to:

- identify asset-specific issues,
- refine our designs for improved performance, and
- inform maintenance and rehabilitation decisions.

### 1.2.2 Scope

This report includes water level monitoring that was conducted at thirteen GRI assets, soil moisture monitoring that was conducted at nine GRI assets, sewer flow monitoring at a catchment level scale, permeable pavement monitoring at eight sites, plant health monitoring, and systems tracking over time. The time period covered is July 1, 2023 to June 30, 2025. This report builds on two previous monitoring report from *July 1, 2021 to June 30, 2023* and *2018 to June 30, 2021*. Some longitudinal data referenced in this report is prior to July 1, 2023, due to the need to reference a longer data set for discussion.

### 1.2.3 Structure

This report is organized into seven sections. Each section corresponds to a key finding that relates to our monitoring objectives. Within each section, a description of the objectives addressed, the data collection process, the data analysis methods and results are presented. The seven sections are:

- GRI systems drain down quickly
- GRI retains moisture in soils
- GRI systems reduce amount of runoff entering the storm sewer system
- Permeable pavements require significant routine maintenance
- GRI systems do better when we take care of the soil
- Does GRI improve local biodiversity?
- Routine maintenance sustains GRI condition

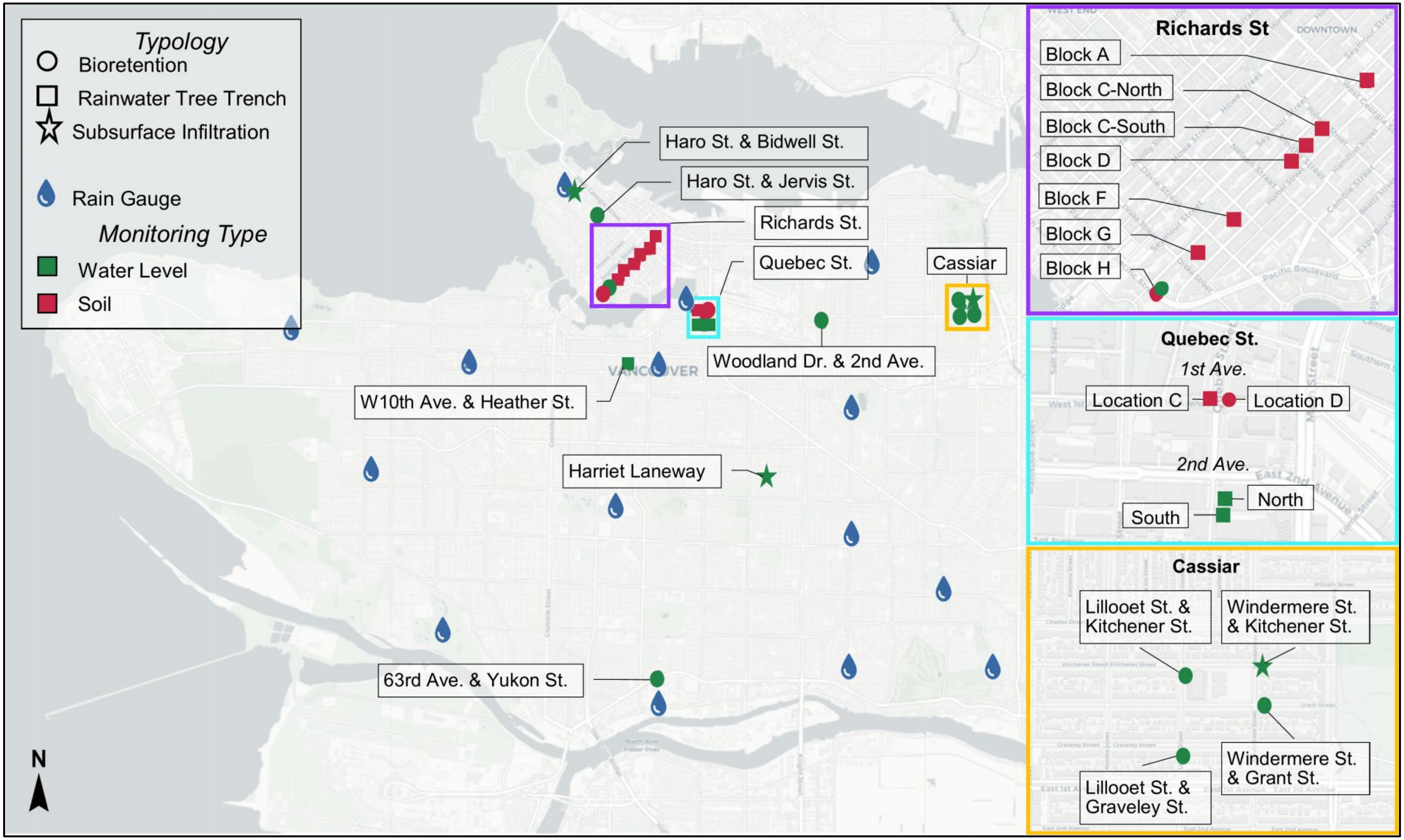



*Figure 1: Map of rain gauges, water level and soil monitoring across the City of Vancouver*

### 1.2.4 Methods

The information in this report was compiled using a series of loggers and sensors for water level, soil and sewer flow monitoring, on-site testing and visual inspections. Water level, soil and rain gauge locations around the city are shown in Figure 1. All GRI monitoring requires some knowledge of rainfall, and the same rainfall data source, City of Vancouver's managed rain gauge network, was used across the report. The rain gauge network consists of tipping bucket rain gauges located throughout the city with data being collected at 5-minute intervals and stored on a cloud server. GRI uses this rainfall data to separate out rainfall events to be used in combination with other monitoring data for analysis. A rainfall event is defined as having a minimum cumulative rainfall of 2.0-mm and a minimum 6-hour antecedent dry period. Rainfall events are separated for analysis into three categories:

- Typical Event: ≤24 mm;
- Large Event >24 mm & ≤ 48 mm; and
- Extreme Event >48 mm

# 2 GRI systems drain down quickly

## 2.1 Introduction

GRI systems are designed to meet two criteria:

1. Surface water drawdown within 24 hours – this standard addresses a public perception that ponding beyond 24 hours is generally unacceptable. While mosquito hatching is a commonly raised concern, mosquitoes need at least seven days of standing water to develop and hatch.
2. Subsurface water drawdown within 72 hours – this is to ensure that the system has capacity to accept more rainwater runoff by the next rainfall event.

We also evaluate the expected infiltration capacity of a GRI system during design by conducting infiltration rate testing. By monitoring the infiltration capacity of the constructed systems, we can determine if our methods for estimating infiltration capacity are reasonable.

The goal of this section is to determine:

1. Do GRI systems drawdown at the surface within 24 hours?
2. Do GRI systems drawdown at the subsurface within 72 hours?
3. Does the drawdown rate of built systems match the design infiltration rates?

## 2.2 Methods

Monitoring wells are incorporated into the design of each GRI practice. The monitoring wells consist of a 150-mm diameter perforated pipe that extends the vertical depth of the practice (Figure 2). The wells are wrapped in a geotextile to prevent sediment from entering. The monitoring well pipe is capped and protected by a valve box with a bolted lid to deter theft or vandalism. Design changes have occurred to the monitoring wells, and newer assets are also capped on the bottom of the well to keep a small volume of standing water for the logger to remain submerged.

There are two types of water level loggers that are currently in use for water level measurements. The first type are Onset HOBO U20-001-01 pressure transducers that are set to record pressure measurements at 5-minute intervals. These loggers are non-vented and need to be adjusted for atmospheric pressure. Two methods can be used for this barometric compensation. The first is to use a central barometric sensor. However, if the site is located at too great a distance from the central sensor, or if the design does not allow for proper venting to the atmosphere, then a secondary sensor is installed inside the well. Data is offloaded from the loggers manually using an optic USB Base station and coupler every 4-6 weeks. Data is offloaded using HOBOware Pro software, which also performs the barometric compensation. Manual water level measurements are taken at the time of data downloading to compare to the data logger readings to ensure the quality of the downloaded data and make any corrections if required.

The second type of water level loggers used are Seametrics PT12 pressure transducers. These sensors are vented and do not require the need for additional barometric compensation. They are set to record a measurement every 5-minutes. These loggers are connected to Novion® data loggers and data is sent to a cloud platform every three hours. Data is downloaded from the platform to Excel for analysis purposes.

All loggers are installed in the monitoring well post-construction by suspending the logger in the well with a non-stretch rope above the bottom of the well to prevent any sediment accumulation from blocking the sensor (Figure 2). Well depth, level logger depth and standing water depth (if applicable) measurements are taken at time of deployment.

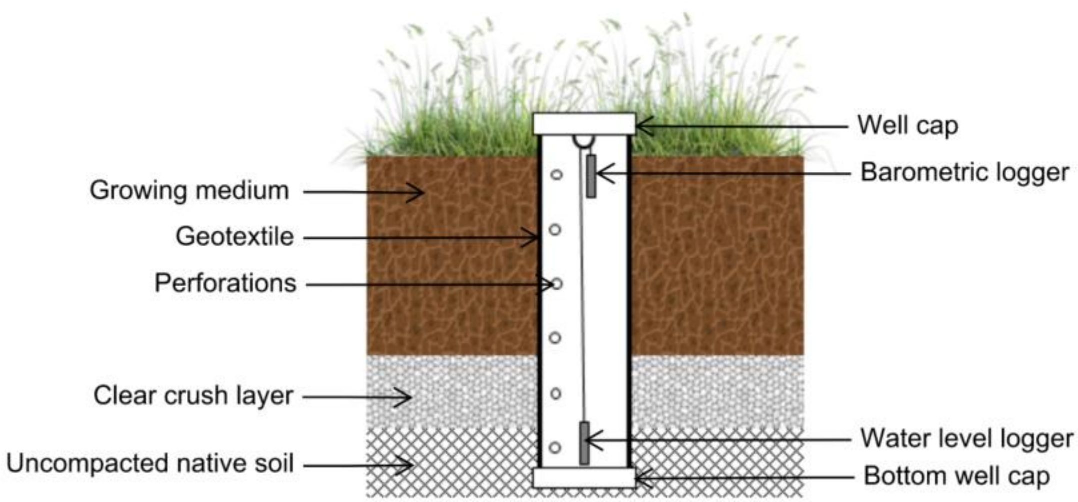



*Figure 2: Schematic of HOBO water level logger installation inside a monitoring well in a bioretention system*

The water level and rainfall data were plotted in Python to check for any inconsistencies or invalid data, any outliers or missing values. Using the *find_peaks* function in Python, the water level data was analyzed to determine drawdown rate and drawdown duration for each rainfall event. Drawdown rate is defined as the rate at which water exits the GRI system during and following a rainfall event and is calculated by dividing the drawdown level (from peak water level to water level before rainfall) by the drawdown duration (Figure 3). Drawdown rate is compared to the design infiltration rate. The design infiltration rate is determined by infiltration rate testing of native soils beneath the GRI system prior to construction and installation and is a conservative estimate of the real drawdown rate.

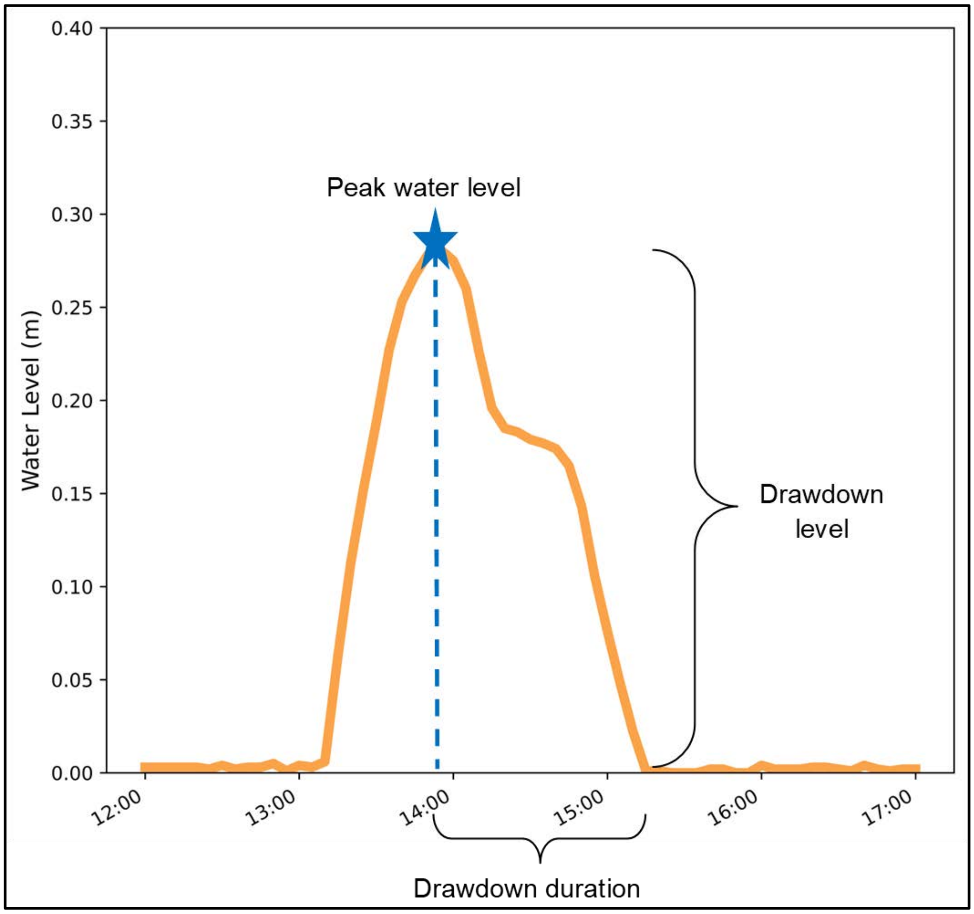



*Figure 3: Example of water level response to show calculation of drawdown duration and drawdown rate*

During extreme rainfall events (>48 mm in 24 hours), and 24 hours after these rainfall events, members of the Green Infrastructure Implementation team conducted visual inspections of primarily bioretention assets around the city. During this time, we inspected the sites for any water bypassing the inlet, the amount of water that was ponded in the system, whether the system was using the overflow, any issues that might be apparent in the contributing drainage area and any other issues that might be visible.

Twenty-four hours after a large rainfall event, visual inspections were conducted at select assets to assess whether there was any ponded water in the system and the amount of sediment build-up in the pre-treatment.

## 2.3 Results

### 2.3.1 63rd Ave. and Yukon St. Bioretention

The bioretention practice located at 63rd Ave. and Yukon St. was constructed in 2018 (*see fact sheet here*). The location was highlighted in the Marpole Community Plan and features a bioretention practice to manage rainwater runoff, as well as seating areas, a drinking fountain, and interpretative signage.

The bioretention practice is located along two boulevards of residential streets and manages rainwater runoff from a drainage area of 1170 $m^2$ from adjacent sidewalks and roads. In addition, this system is on a major overland flow path. During moderate to high intensity rainfall events, bypass of upstream catchbasins is frequently observed; thereby increasing flows to the 63rd Ave. and Yukon St. practice beyond the 1170 $m^2$ contributing drainage area. Infiltration testing was performed prior to construction using the double ring infiltrometer method. After a factor of safety was applied to the infiltration results, the practice was sized using a design infiltration rate of 39 mm/h.

This site exhibited water level changes for rainfall events larger than 5 mm/h, with most of the responses occurring over the wet weather season. Throughout the years, this site has maintained a very quick drawdown rate. Compared to previous monitoring periods, the drawdown rate has decreased slightly from 736 mm/h in 2021-2023, to 412 mm/h in 2023-2025, however the overall average (2018-2025) drawdown rate is still well above the design infiltration rate (Table 1).

*Table 1: 63rd Ave. and Yukon St. bioretention drawdown rate comparison over the years*

| Monitoring Time Period | Average drawdown rate (mm/h) |
|---|---|
| 2018-2021 | 367 |
| 2021-2023 | 736 |
| 2023-2025 | 412 |
| Overall Average 2018-2025 | 474 |

The monitoring well generally demonstrated a drawdown time of a few hours. Between 2018 and 2025, 110 events produced a water level change for which the drawdown time and drawdown rate were calculated, as shown in Table 2. Water level and rainfall response from July 2023 to June 2025 are shown in Figure 4. Visual inspections of this site during a rainfall event in 2023 indicated only 20% of the area was ponded and not using the overflow (Figure 5).

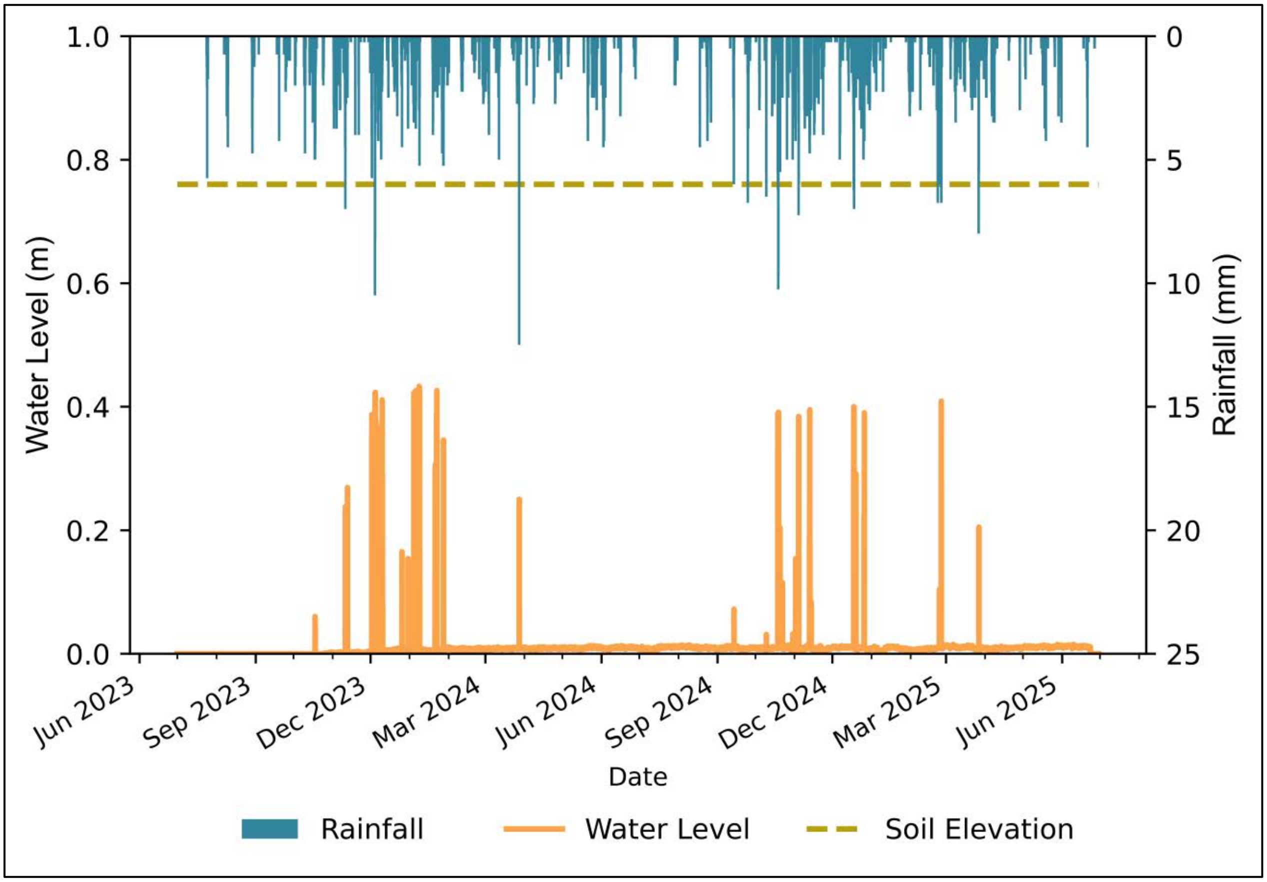



*Figure 4: Average hourly water level response at 63rd Ave. and Yukon St. bioretention and total hourly rainfall at Manitoba rain gauge from July 1, 2023 to June 30, 2025*

*Table 2: 63rd Ave. and Yukon St. bioretention water level analysis*

| Rainfall Event Category | Typical (<24mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 61 | 29 | 20 | 110 |
| Average Drawdown Duration (h) | 1.7 | 1.6 | 2.5 | 1.8 |
| Average Drawdown Rate (mm/h) | 430 | 550 | 490 | 470 |
| Design Infiltration Rate (mm/h) | 39 | | | |
| % change in rate | 1000% | 1300% | 1100% | 1100% |

*Figure 5: 63rd Ave. and Yukon St. bioretention during fall 2023 rainfall event. Only 20% of ponding area contained standing water*

## 2.3.2 Quebec St. and 2nd Ave. Rainwater Tree Trench

The Quebec St and 2nd Ave. rainwater tree trenches are a half block system that was constructed in 2019 as part of upgrades along Quebec St. These RTT use soil cells that manage a drainage area of 610 $m^2$ and was sized using a design infiltration rate of 10 mm/h. There are two monitoring wells, one in the north end of the system and one in the south end of the system. Water level monitoring has been ongoing since November 2020. Both the north and south system have separate catchbasin inlets and use a rainwater distribution pipe to distribute the water into the soil cell system. The distribution pipes are perforated at 10 and 2 o'clock and feature 10-mm-diameter holes every 3m along the bottom (Figure 6). The system is fully infiltrating and does not connect to sewer. The system was inspected in summer 2025 and both the catchbasins and distribution pipes were found to be full of sediment and have since been flushed out.

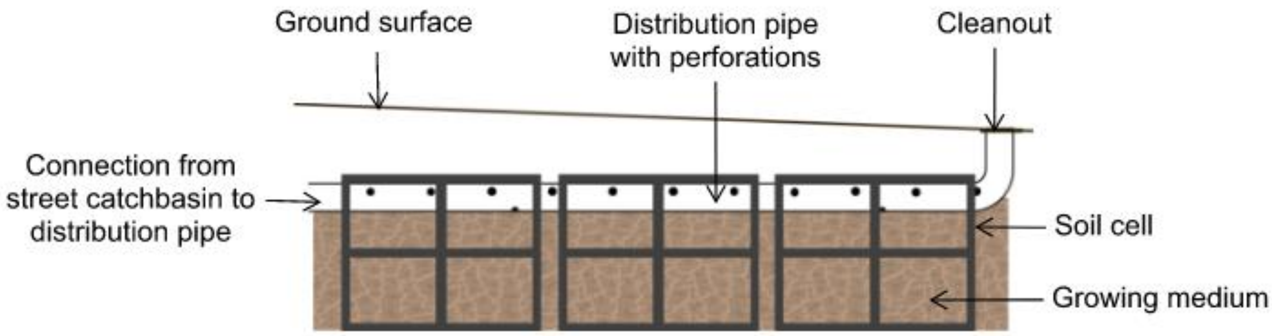



*Figure 6: Soil cell rainwater tree trench schematic*

#### 2.3.2.1 North Monitoring Well

The north well displayed water level changes for 245 rainfall events over the 2020-2025 monitoring period. The average drawdown rate has slightly decreased since the previous monitoring report from 8.7 mm/h to 7.8 mm/h, but still very similar. This well almost never fully drained down and often during the wet weather season had an elevated standing water level between rainfall events (Figure 7). The amount of sediment in the catchbasins and distribution pipes might have caused clogging of the system slowing down infiltration. Water level analysis showing drawdown duration and drawdown rate from 2020-2025 is shown in Table 3.

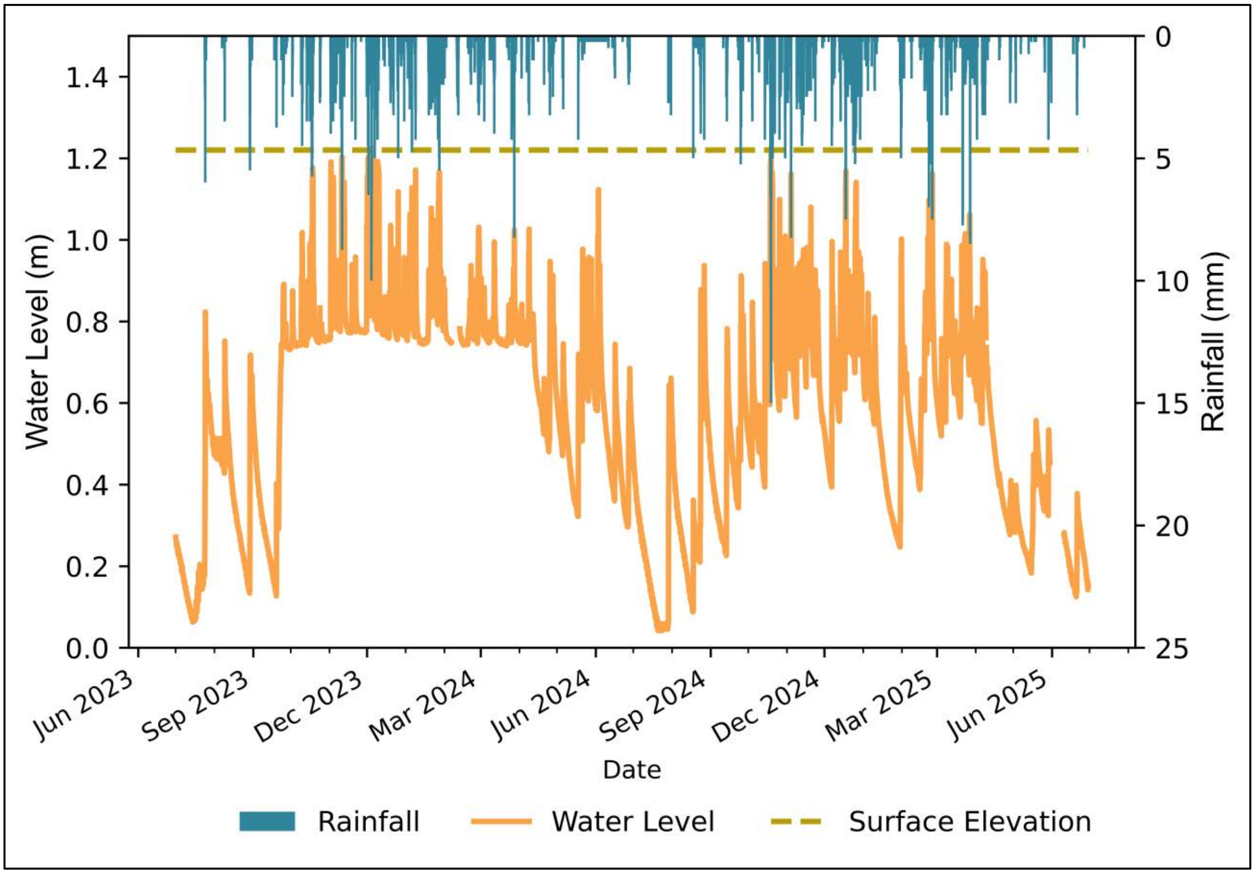



*Figure 7: Average hourly water level response at Quebec St. and 2nd Ave. North RTT and total hourly rainfall at Creekside rain gauge from July 1, 2023 to June 30, 2025*

*Table 3: Quebec St. and 2nd Ave. North rainwater tree trench water level analysis*

| Rainfall Event Category | Typical (<24mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 165 | 53 | 27 | 245 |
| Average Drawdown Duration (h) | 53 | 52 | 47 | 52 |
| Average Drawdown Rate (mm/h) | 6.5 | 9.9 | 11 | 7.8 |
| Design Infiltration Rate | 10 | | | |
| % change in rate | -35% | -1.0% | 10% | -22% |

#### 2.3.2.2 South

The south monitoring well at Quebec St. and 2nd Ave. had a water level response for 257 rainfall events since monitoring began in 2020. The water level in this well drained down all the way in the dry summer months. During the wet weather season, on occasion the water level had not return to its pre-rainfall level before another rainfall event occurred (Figure 8). The average drawdown rate has not changed significantly over time and remained around 9-10 mm/h. Rainfall events, drawdown duration and drawdown rates are shown in Table 4.

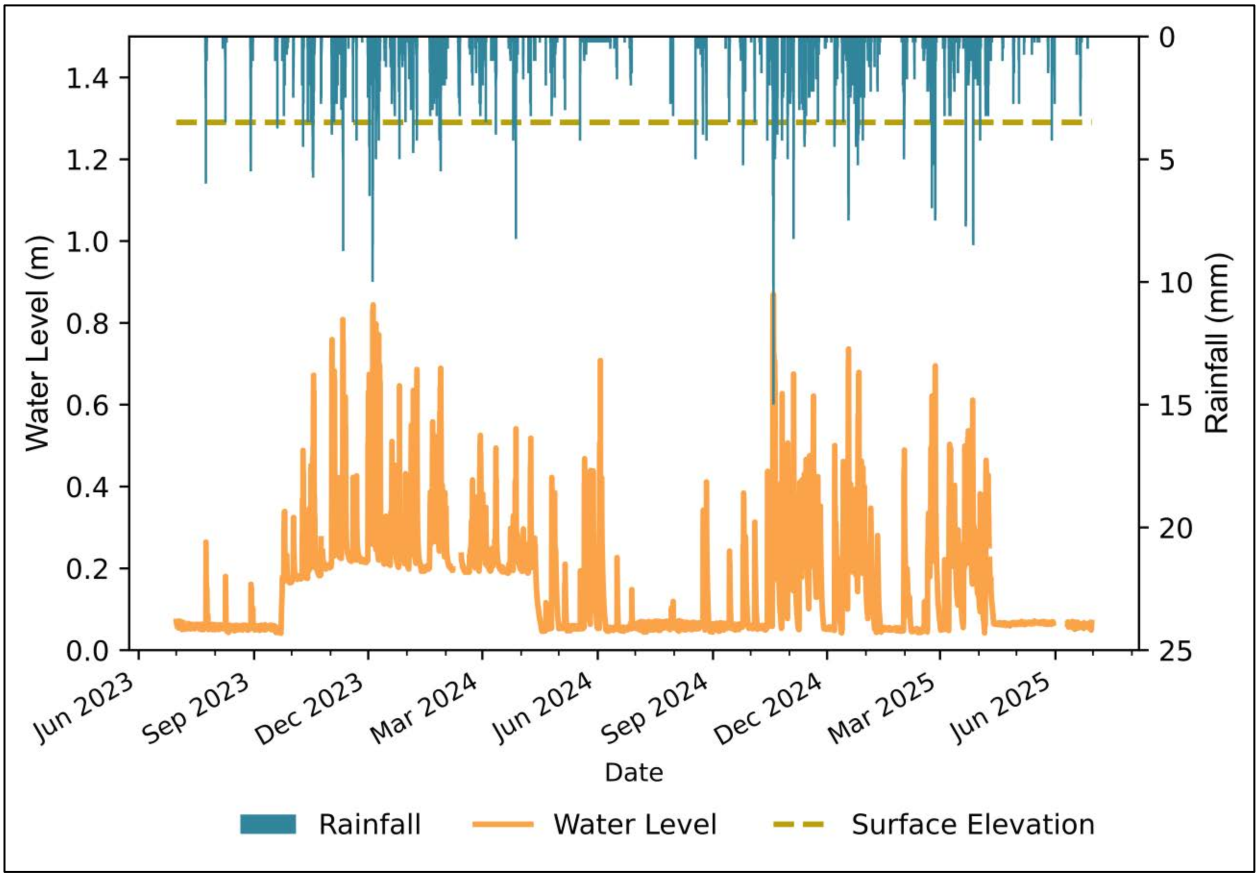



*Figure 8: Average hourly water level response at Quebec St. and 2nd Ave. South RTT and total hourly rainfall at Creekside rain gauge from July 1, 2023 to June 30, 2025*

*Table 4: Quebec St. and 2nd Ave. South rainwater tree trench water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| **Number of Rainfall Events** | 176 | 53 | 28 | 257 |
| **Average Drawdown Duration (h)** | 31 | 41 | 46 | 35 |
| **Average Drawdown Rate (mm/h)** | 7.7 | 12 | 12 | 9.0 |
| **Design Infiltration Rate** | | 10 | | |
| **% change in rate** | -23% | 16% | 23% | -10% |

## 2.3.3 Richards St. Block H Bioretention

The Richards St. project consists of 8-blocks of GRI along with a AAA (all ages and abilities) bike lane and over 100 new trees located in the downtown core (*see fact sheet here*). All the blocks contain rainwater tree trenches that use either structural soils or soil cells. Due to utility conflicts in the last block (Block H), the end of the block was not able to be completed with a tree trench system. Instead, a bioretention system using Permavoid cells was installed. Block H bioretention manages a drainage area of 251 $m^2$ and was designed with an infiltration rate of 5 mm/h. The monitoring well is in the structural soil adjacent to the bioretention area and has been monitoring water level since November 2021.

Drawdown times increased slightly since the last monitoring report from 14 hours in 2021-2023 to 18 hours in 2021-2025. The average drawdown rate has slightly decreased since the last report from 40 mm/h to 34 mm/h. The drawdown rate for typical and large rainfall events has decreased slightly, however the drawdown rate for extreme rainfall events has increased. Overall, the drawdown times and rates have still exceeded the design infiltration rate. Since the start of monitoring to June 2025, there have been 163 water level responses to rainfall events, with an average drawdown time of 18 h and an average drawdown rate of 34 mm/h. See Table 5 for the water level analysis and Figure 9 for the water level and rainfall response from July 2023 to June 2025.

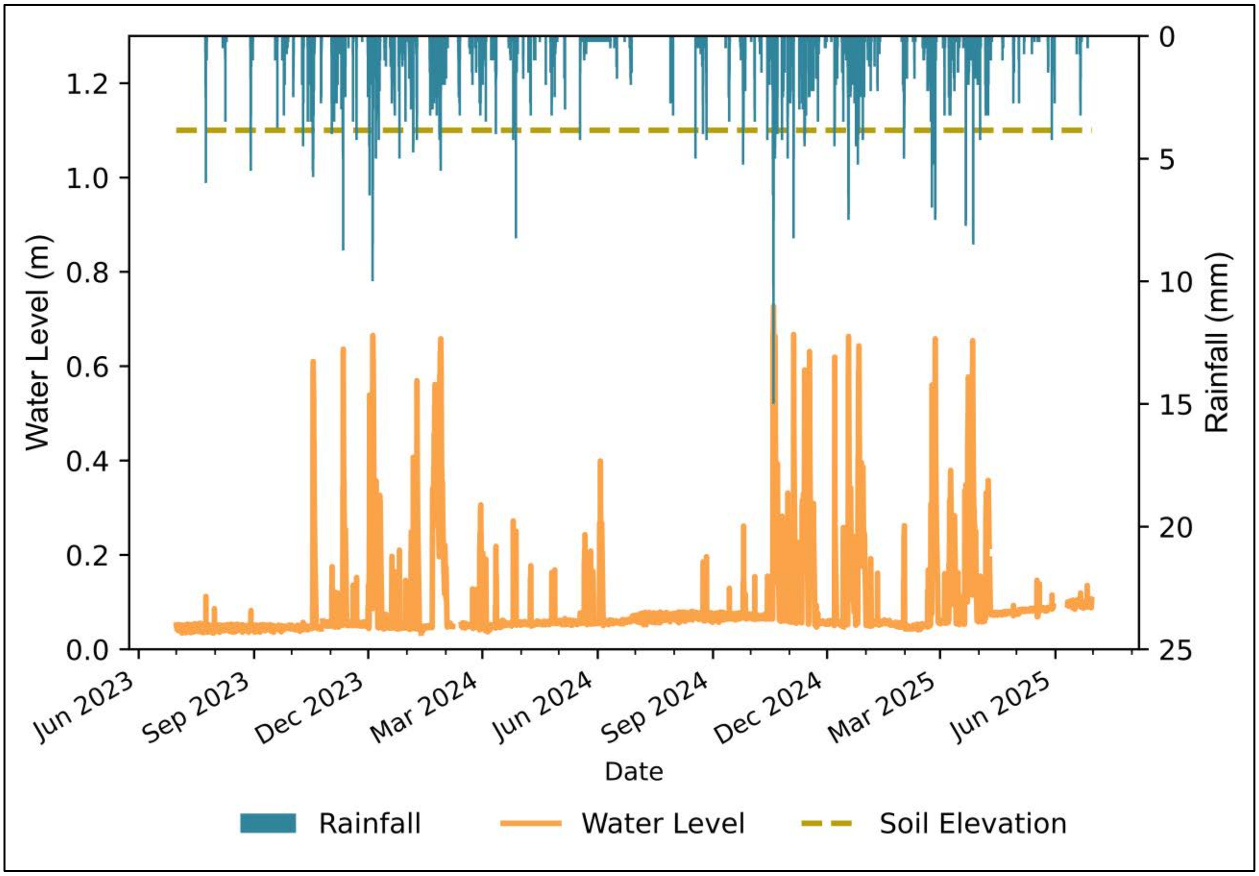



*Figure 9: Average hourly water level response at Richards St. Block H bioretention and total hourly rainfall at Creekside rain gauge from July 1, 2023 to June 30, 2025*

*Table 5: Richards St. Block H bioretention water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 114 | 32 | 17 | 163 |
| Average Drawdown Duration (h) | 12 | 28 | 39 | 18 |
| Average Drawdown Rate (mm/h) | 41 | 17 | 15 | 34 |
| Design Infiltration Rate (mm/h) | | | 5 | |
| % change in rate | 720% | 250% | 200% | 570% |

## 2.3.4 Haro St. and Bidwell St. Dry Well

The dry well was constructed in June 2021 and consists of a 600-mm diameter, 1.5-m deep PVC chamber with perforations every 15-cm. Yearly sediment accumulation measurements have been taken since construction to help determine maintenance frequency. Measurements were taken in the springtime and there has never been any water noted in the dry well at these times. After the first year, the dry well contained minimal sediment, and every year after that accumulated approximately 10-cm of sediment and debris. In June 2025, there was approximately 30-cm of sediment in the dry well sump, taking up much of the sump space. The dry well, the catchbasin and the connection between them was hydro-vacuumed and flushed to restore the sump space and allow the dry well to continue performing as intended.

A Novion water level logger was installed in February 2022. The dry well has filled up and occasionally overflowed to sewer during rainfall events of all magnitudes. The dry well has drawn down completely in the 2023 to 2025 monitoring period – indicating the holes at the bottom of the dry well were allowing water to freely drain into the surrounding clear crush and native soil (Figure 10).

The dry well was very responsive to rainfall events and has had a water level response for 233 rainfall events since monitoring began. Since the 2023 monitoring report, the drawdown time has increased slightly from 12.3 h to 14 h on average. The drawdown rate has also decreased slightly to 79 mm/h from 92 mm/h. However, large and extreme rainfall events seemed to have increased in drawdown rate. The sediment accumulation may have caused some of the lower perforations to become clogged resulting in a slightly lower drawdown rate. Overall, the system was still outperforming its design infiltration rate. Water level analysis for the entire monitoring period can be found in Table 6. Water level and rainfall response for July 2023 to June 2025 can be found in Figure 11.

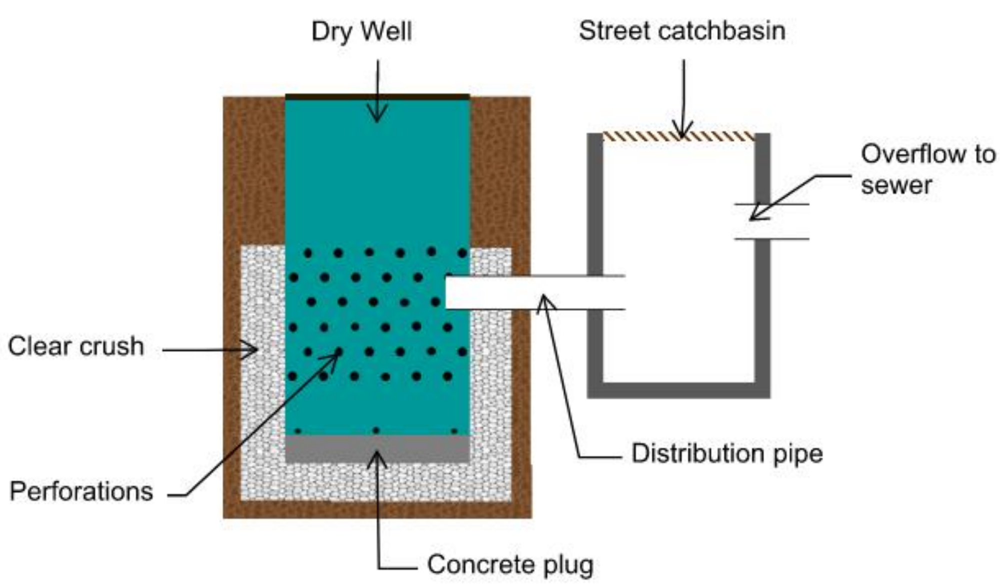



*Figure 10: Dry well cross section schematic*

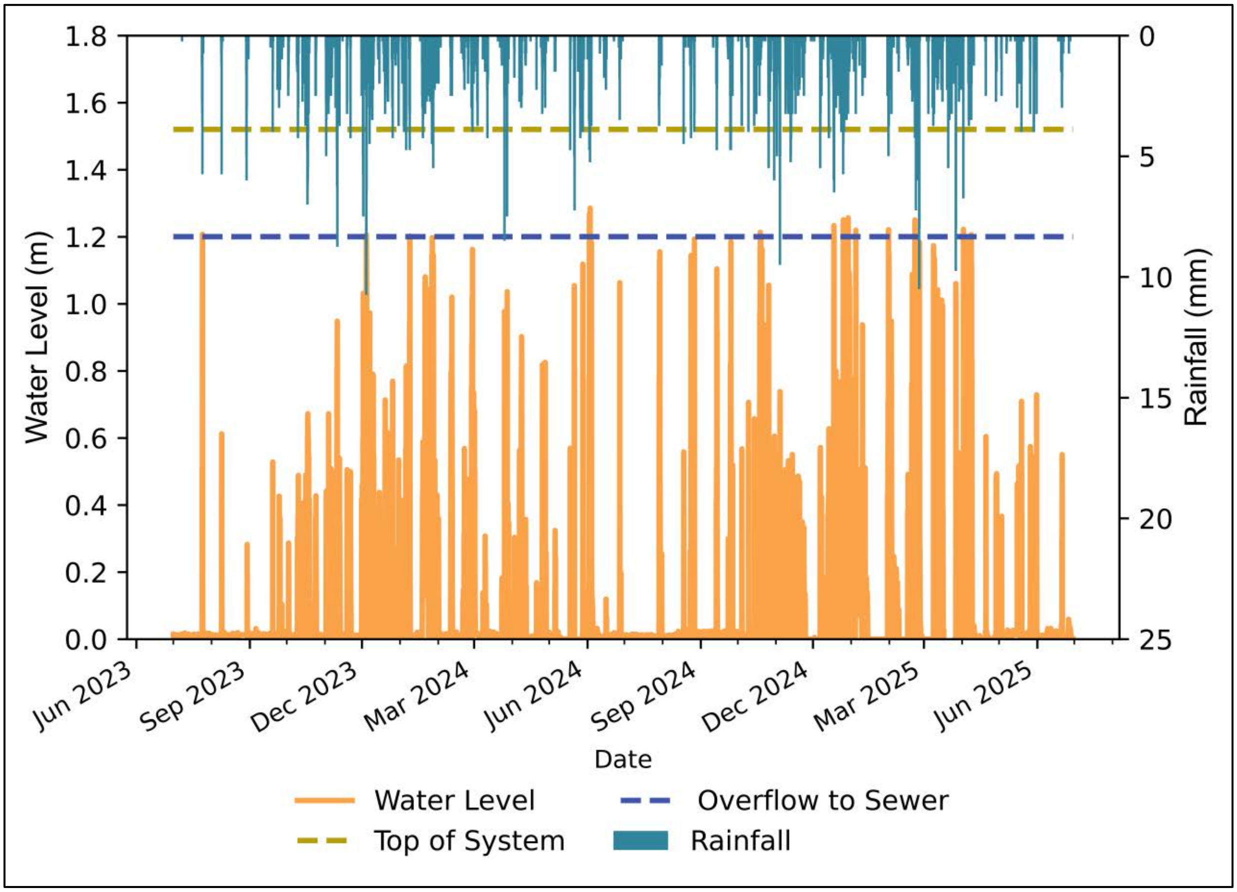



*Figure 11: Average hourly water level response at Haro St. and Bidwell St. dry well and total hourly rainfall response at West End rain gauge from July 1, 2023 to June 30, 2025*

*Table 6: Haro St. and Bidwell St. dry well water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of rainfall Events | 168 | 49 | 16 | 233 |
| Average Drawdown Duration (h) | 12 | 15 | 26 | 14 |
| Average Drawdown Rate (mm/h) | 82 | 78 | 50 | 79 |
| Design Infiltration Rate (mm/h) | 47 | | | |
| % change in rate | 75% | 67% | 7.0% | 68% |

### 2.3.5 Haro St. and Jervis St. Bioretention

The Haro St. and Jervis St. bioretention was constructed in June 2021 and receives runoff from a drainage area of 530 $m^2$. The system features an inlet with a sediment pad as well as an additional curb cut inlet downstream to capture any additional bypass. The system has 30-cm of clear crush at the bottom along with an underdrain (Figure 12). Water level has been monitored since February 2022 using a Novion logger.

The water level from 2023-2025 indicated that the subsurface water level rarely reached above 30-cm, implying water may only be filling the clear crush layer and then exiting the underdrain to the sewer. The first year of monitoring from February 2022 – February 2023 had water levels filling the entire subsurface (soil and underdrain), but since then, the water levels rarely reached over 30-cm from the base of the system. Possibly as plants established, more subsurface flow pathways have been formed, resulting in short-circuiting to the clear crush layer and underdrain faster than previously measured, thus not filling the system (Figure 13). The drawdown time and rates have slowed slightly since the previous monitoring period, but overall have still outperformed the design objectives. A water level response was triggered by 223 rainfall events since monitoring began, with an average drawdown rate of 15 mm/h. Water level analysis for the entire monitoring period can be found in Table 7.

During wet weather inspections of this system, only 30% of the area was ponded and the system was not draining to the overflow. This might be a good candidate to cap the underdrain as it seems it can handle more surface and subsurface water.

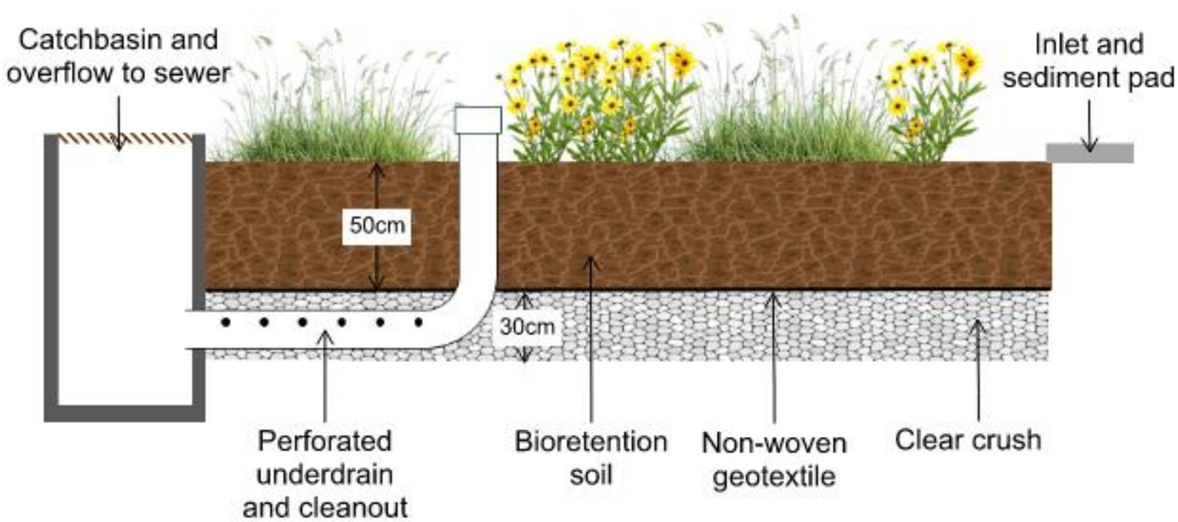



*Figure 12: Schematic cross section of the bioretention system at Haro St. and Jervis St.*

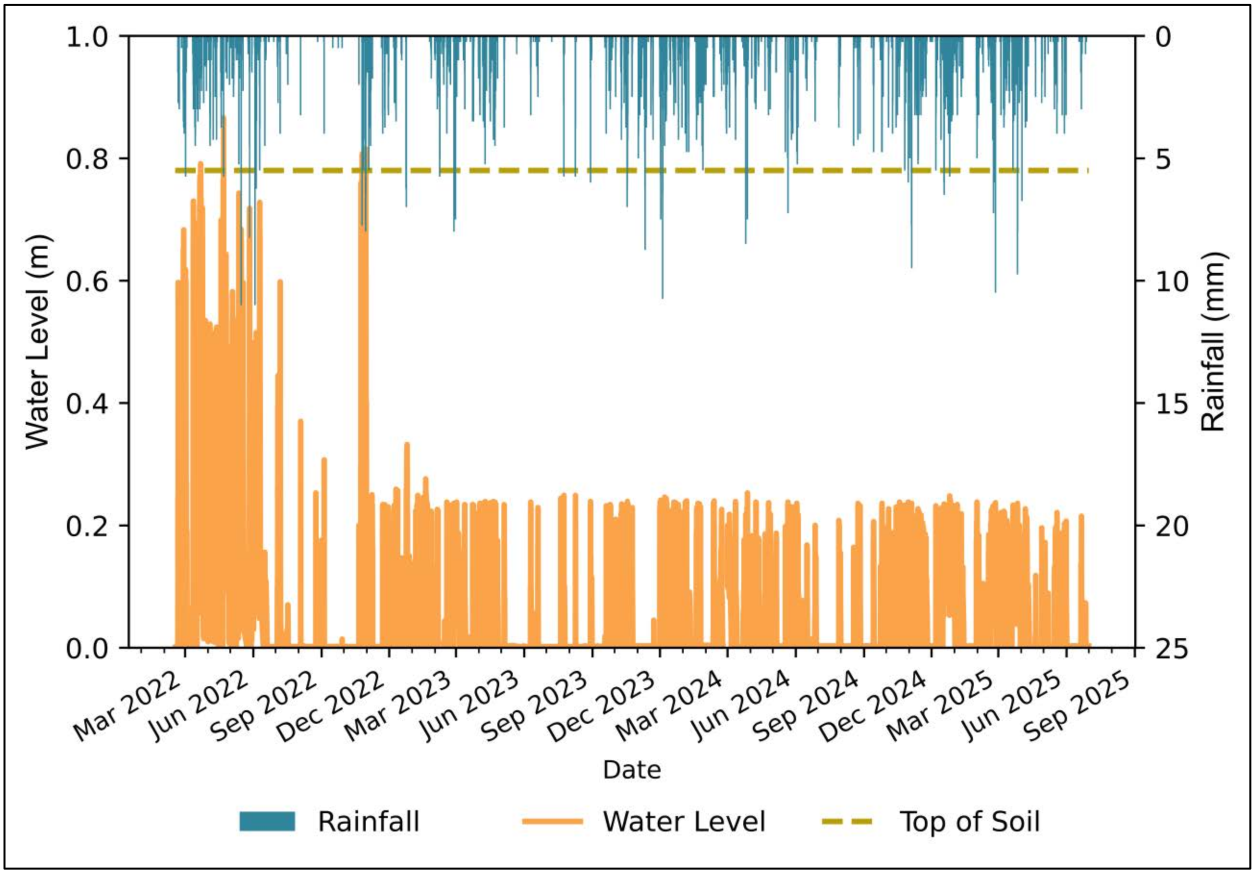



*Figure 13: Average hourly water level response at Haro St. and Jervis St. bioretention and total hourly rainfall response at West End rain gauge from February 2022 to June 30, 2025*

*Table 7: Haro St. and Jervis St. bioretention water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 160 | 49 | 14 | 223 |
| Average Drawdown Duration (h) | 23 | 27 | 32 | 25 |
| Average Drawdown Rate (mm/h) | 15 | 13 | 11 | 15 |
| Design Infiltration Rate (mm/h) | 5 | | | |
| % change in rate | 210% | 160% | 110% | 190% |

### 2.3.6 W10th Ave. and Heather St. Rainwater Tree Trench

A rainwater tree trench was constructed along W10th Ave. at Heather St. in 2021. It features an improved bike lane, new tree planting and landing area for vehicles. It treats a drainage area of 2,475 $m^2$ and has 88 $m^2$ of structural soil for tree soil volume and water management. The entire tree trench area is overlain by permeable pavers to increase the stormwater management function. The system has steep slope of 2.5% so to create a flat area and encourage infiltration, two impermeable gravel check dams were installed (Figure 14). The system is fully infiltrating and does not connect to sewer.

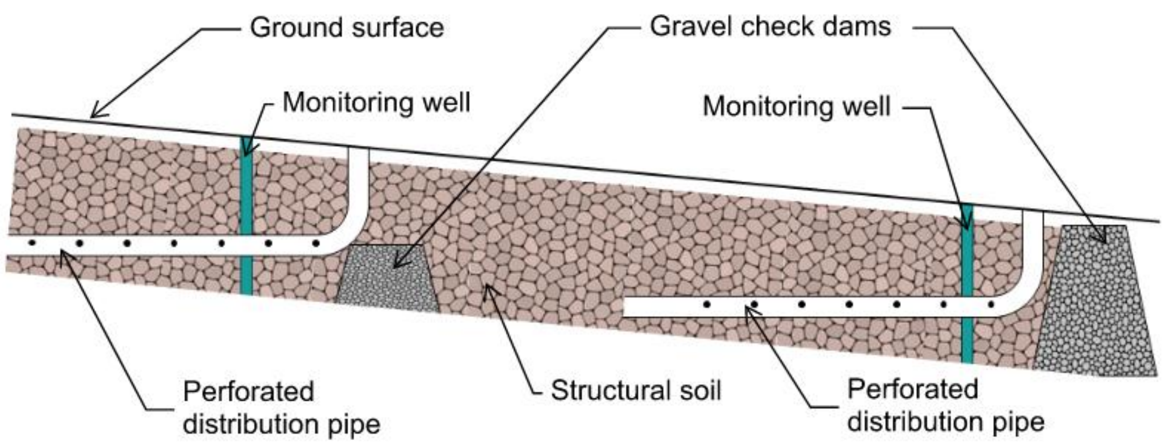



*Figure 14: W10th Ave. and Heather St. RTT schematic cross section*

Two monitoring wells were installed, one on the west side of the system, and one on the east side of the system, however only the east well has continued to be monitored since March 2022. The system was very responsive to rainfall events, and for the entire monitoring period 160 rainfall events demonstrated a water level response. The average drawdown rate was 20 mm/h, which is lower than the 50 mm/h that the system was designed for and has decreased slightly from average drawdown rate of 30 mm/h from 2022-2023. The average drawdown duration was 39 hours which was still well below the design objective. The system did occasionally exceed the check dam in the wet season, but overall, the design worked well to encourage infiltration (Figure 15). Rainfall events, drawdown durations and drawdown rate summary are found in Table 8.

The system had not been flushed since it was constructed and during 2025 condition assessments, the east cleanout and the inlet catchbasins contained significant amount of sediment and debris. The distribution pipes have since been flushed/cleaned in summer 2025. We do not think that the sediment accumulation is affecting the drawdown rate, as the native soil is the likely limit on the drawdown rate, so the slower drawdown rate may be more representative of the true conditions at this site.

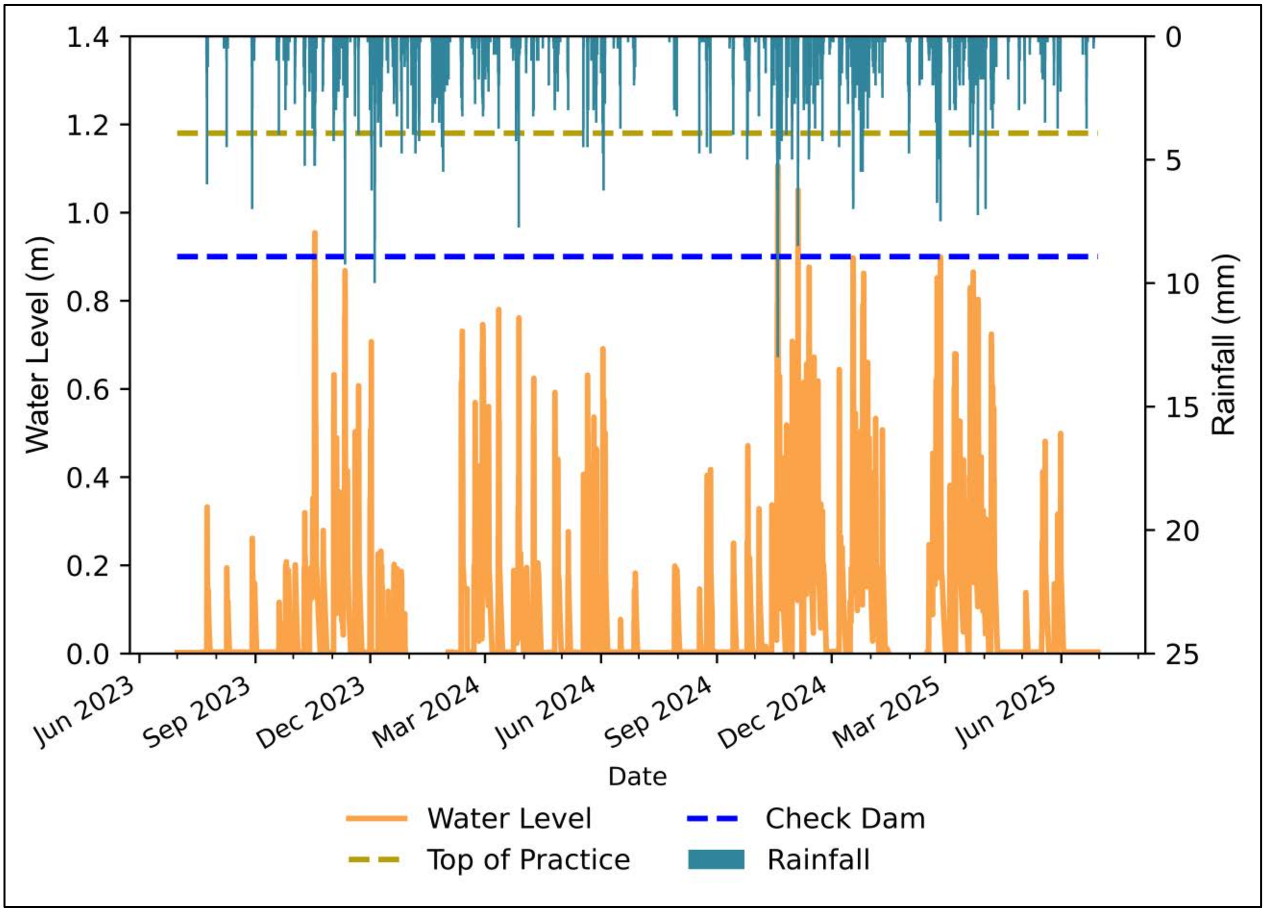



*Figure 15: Average hourly water level response at W10th Ave. and Heather St. RTT and total hourly rainfall at Vancity rain gauge from July 1, 2023 to June 30, 2025*

*Table 8: W10th Ave. and Heather St. rainwater tree trench water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 112 | 39 | 9 | 160 |
| Average Drawdown Duration (h) | 39 | 34 | 51 | 39 |
| Average Drawdown Rate (mm/h) | 15 | 32 | 24 | 20 |
| Design Infiltration Rate (mm/h) | | 50 | | |
| % change in rate | -70% | -36% | -52% | -61% |

### 2.3.7 Woodland Dr. and 2nd Ave. Bioretention

A bioretention located at Woodland Drive and East 2nd Avenue was constructed between March and September 2022 (*see fact sheet here*). What was previously a bike lane with a gravel parking shoulder was transformed into a permanent two-way bike lane with a 140 $m^2$ bioretention system on one side, and a bee-friendly sod install on the other. The site also features education signage, sediment pad artist-designed stamps and painting by the local school along the bike path. The bioretention features recycled granite blocks and fallen tree logs as weir walls to help slow the flow of water through the bioswale and encourage infiltration. The system manages runoff from 2,600 $m^2$ of impervious area and receives sheet flow at the surface as well as runoff through pipes connected to catchbasins in the laneway and opposing side of the street. The entire bioswale is connected at the subsurface with a clear crush layer and underdrain. The system was designed with an infiltration rate of 1 mm/h, as geotechnical investigations conducted prior to construction indicated a low native soil infiltration rate of less than 1 mm/h. Previous monitoring results from 2022-2023 indicated an average drawdown rate of 13.1 mm/h. This lead the GII team to cap the underdrain in November 2023 to help encourage infiltration in the system. Monitoring from 2022-2025 showed an increased drawdown rate to an average of 21 mm/h, and a slightly decreased drawdown duration to 18h from 18.5h previously. Water level response is shown in Figure 16 and water level analysis in Table 9.

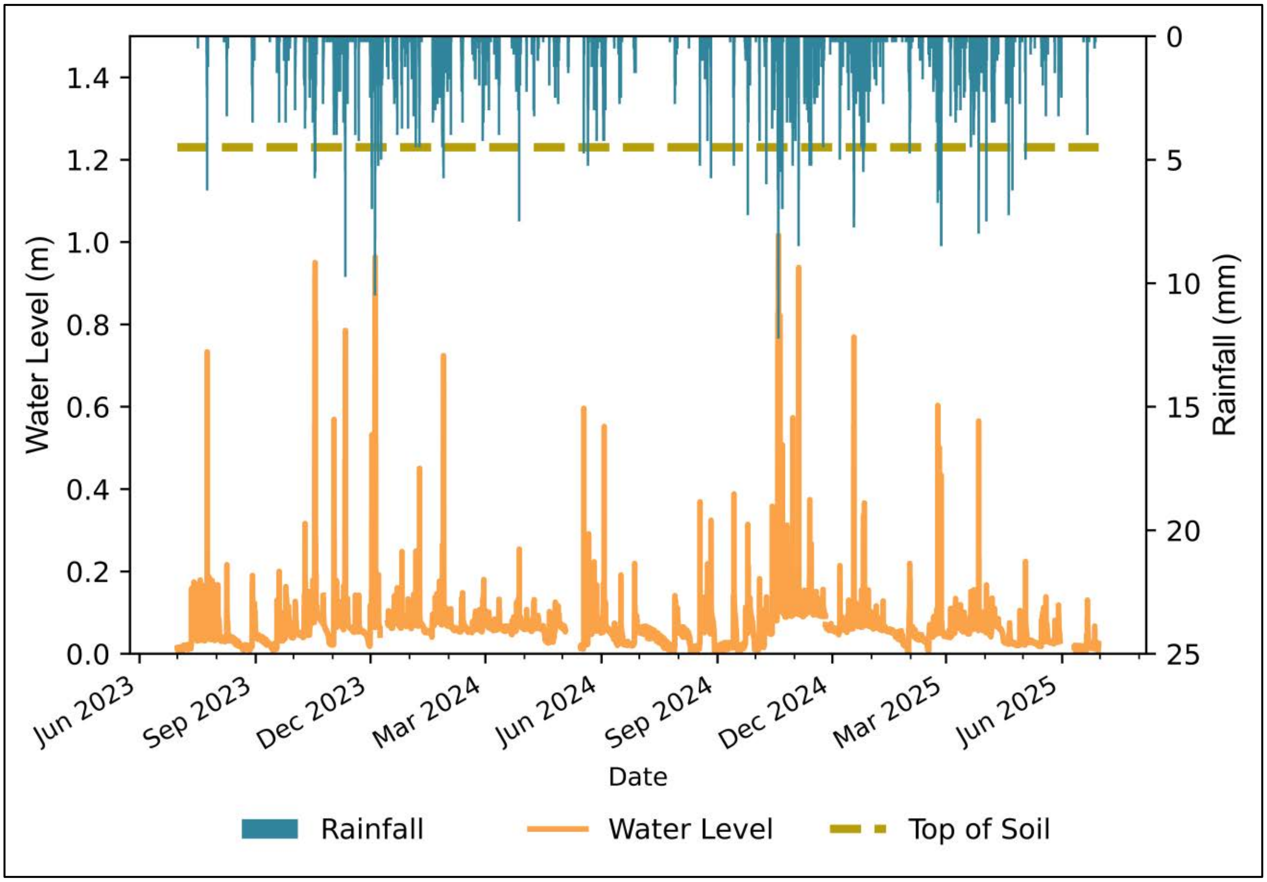



*Figure 16: Average hourly water level response at Woodland Dr. and 2nd Ave. bioretention and total hourly rainfall response at Trout Lake rain gauge from July 1, 2023 to June 30, 2025*

*Table 9: Woodland Dr. and 2nd Ave. bioretention water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 88 | 31 | 15 | 134 |
| Average Drawdown Duration (h) | 18 | 15 | 26 | 18 |
| Average Drawdown Rate (mm/h) | 17 | 32 | 24 | 21 |
| Design Infiltration Rate (mm/h) | 1 | | | |
| % change in rate | 1600% | 3100% | 2300% | 2000% |

During wet weather inspections in January 2023 and October 2023, the system was only 20% ponded and was not using the overflow (Figure 17). After 24 hours the system did not have any ponding.

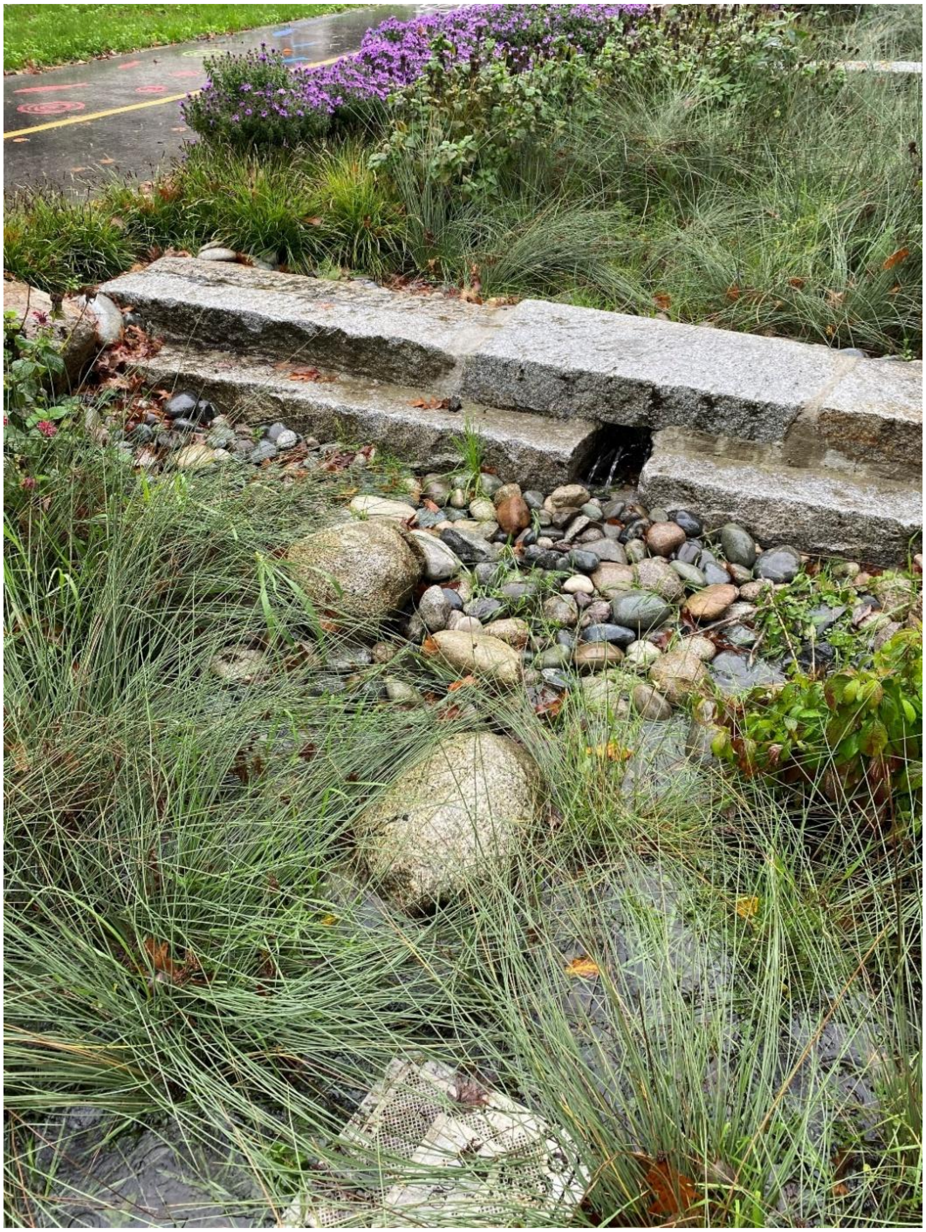


*Figure 17: Woodland Dr. and 2nd. Ave. bioretention during October 2023 rainfall event. The system was only 20% ponded.*

### 2.3.8 Harriet Laneway Infiltration Trench

A laneway infiltration trench was constructed in summer 2022 with a catchment area of 924 $m^2$ that collects runoff from the full laneway width, some adjacent driveways, some structure rooftops that drain onto the laneway, and an additional extension added in Fall 2023 to take runoff from private property rear-yard drainage. The system captures water through two catchbasins and eliminates the need for a storm sewer connection at the south end of the laneway by storing and infiltrating storms up to the 5-year return period design storm event. During events that exceed the capacity of the trench, overflow will occur overland to another catchbasin located at the north end of the laneway that is connected to sewer. This is to prevent any flow from travelling laterally on the surface to private property. Geotechnical investigations indicated a low native soil infiltration rate, so the system was designed with an infiltration rate of 1 mm/h.

The monitoring well only responded to rainfall events over 24 mm. Standing water was always observed in the well, and the drawdown above the distribution pipe in the clear crush was quick but slowed below the distribution pipe as it infiltrated into the native soil. The new extension for the private property rear-yard drainage did not seem to have reduced the infiltration capacity of the system. During extreme rainfall events the water level did fill the depth of the trench and had a slow drawdown time exceeding 72 hours. However, the average drawdown rate exceeded the design infiltration rate, and has increased to 8.9 mm/h from 6.9 mm/h from the previous monitoring report. Water level response can be seen in Figure 18. Due to logger battery issues, data is missing between March 2024 and May 2024. Rainfall events, drawdown rates and drawdown durations are shown in Table 10.

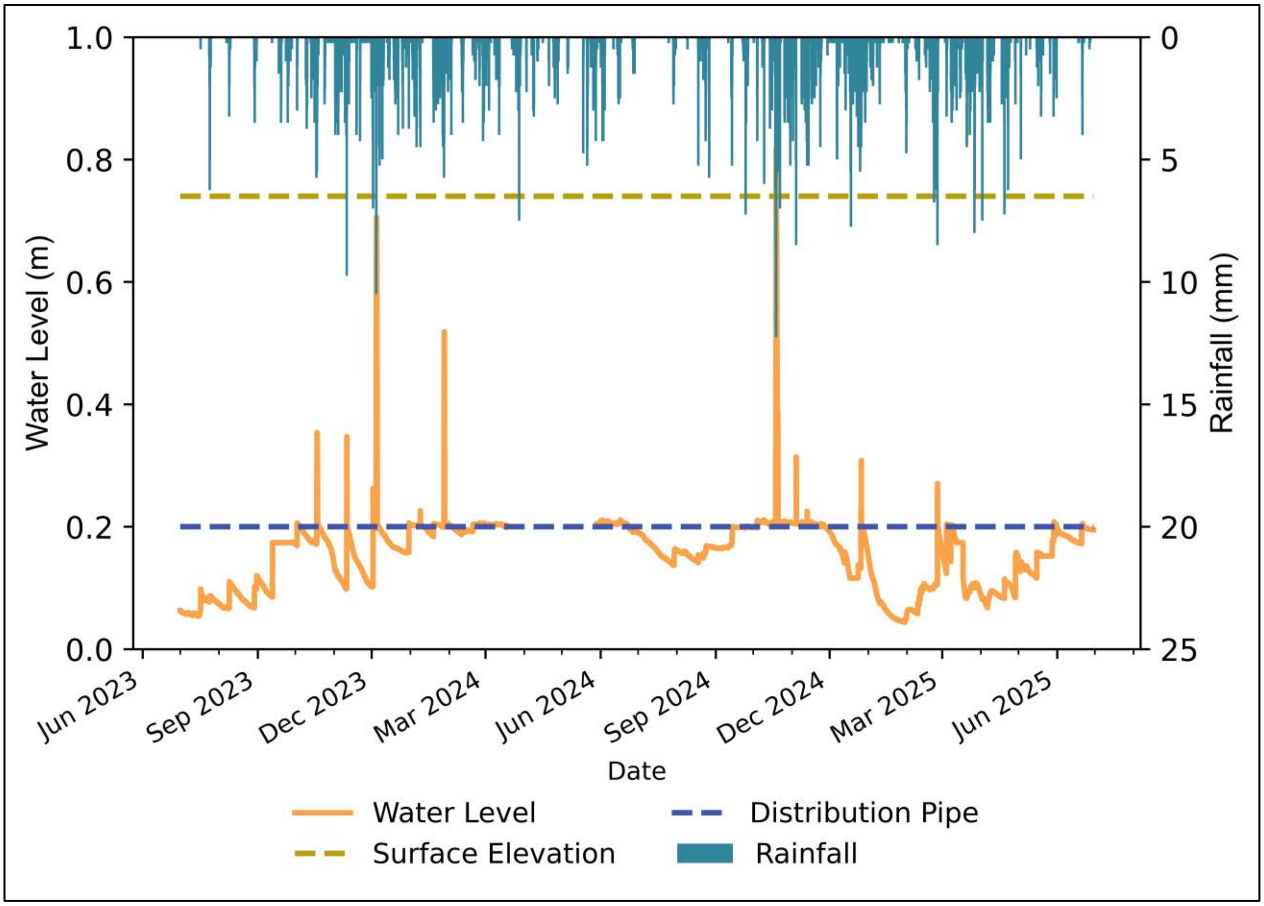



*Figure 18: Average hourly water level response at Harriet Laneway infiltration trench and total hourly rainfall at Trout Lake rain gauge from July 1, 2023 to June 30, 2025*

*Table 10: Harriet Laneway infiltration trench water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 0 | 8 | 10 | 18 |
| Average Drawdown Duration (h) | - | 44 | 110 | 82 |
| Average Drawdown Rate (mm/h) | - | 7.3 | 10 | 8.9 |
| Design Infiltration Rate (mm/h) | | 1.0 | | |
| % change in rate | - | 630% | 920% | 790% |

## 2.3.9 Cassiar GRI

As part of the first phase of a larger sewer renewal project in the Cassiar Sewershed in the Hastings Sunrise neighbourhood, 26 new GRI practices were constructed. The practices are further broken down into 16 dry wells and 10 corner bioretention bulges. Construction of the systems took place between March 2023 and September 2023. The geotechnical investigations found very high native soil infiltration rates in this area, and the bioretention systems were designed with an infiltration rate of 70 mm/h and they do not contain an underdrain. The dry wells were designed with infiltration rates ranging from 150-270 mm/h. Water level monitoring of one dry well and three bioretention systems has been ongoing since September 2023.

### *2.3.9.1 Windermere St. and Kitchener St. Dry Well*

The dry well at Windemere St. and Kitchener St. has a drainage area of 430 $m^2$ and collects runoff from the residential street into a catchbasin that is then conveyed to the dry well (see Figure 10). The dry well uses a recycled granite product as the surrounding clear crush layer. The dry well had always maintained water within the dry well sump below the perforations. The dry well did fill during rainfall events, but did not overflow to sewer (Figure 19). The average drawdown rate was 48 mm/h which is lower than the design infiltration rate. See Table 11 for rainfall events, drawdown durations and drawdown times.

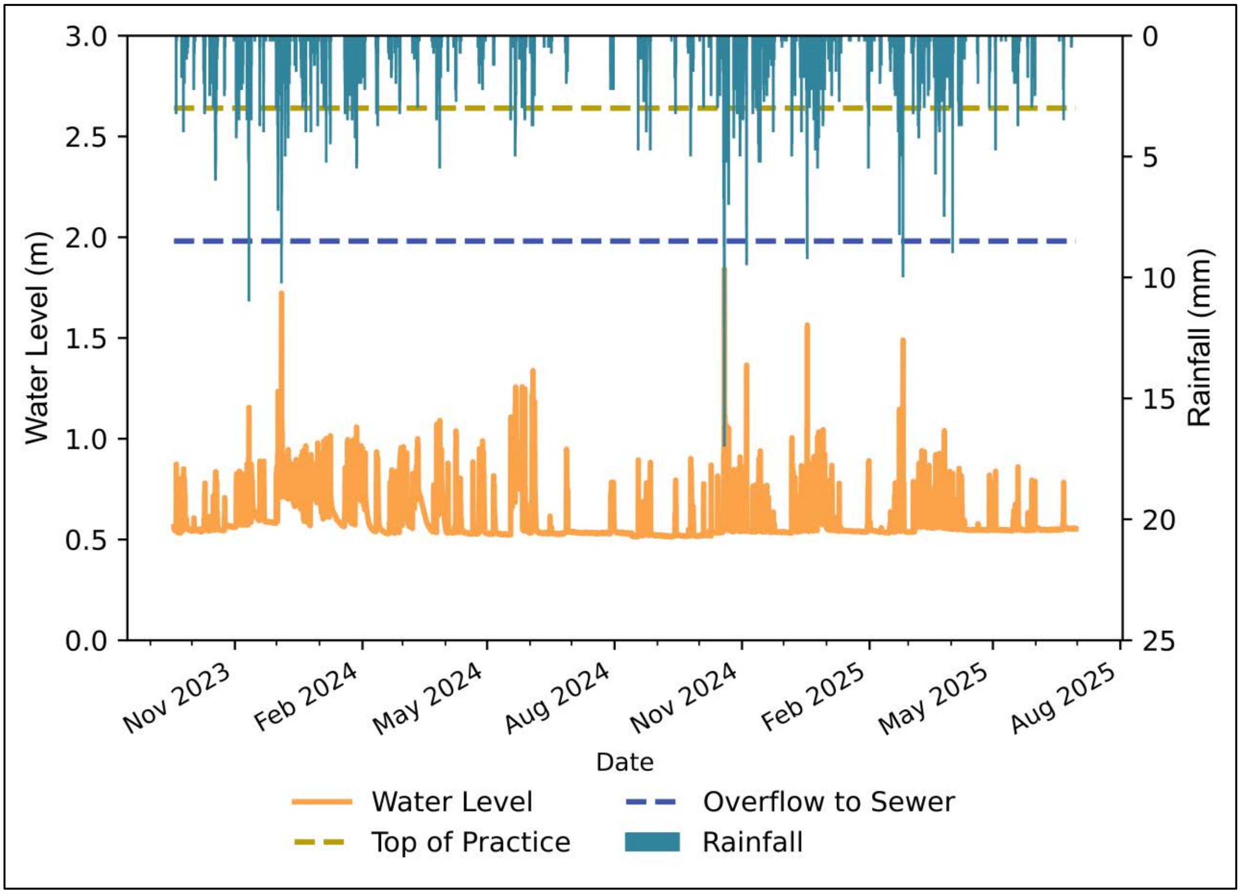



*Figure 19: Average hourly water level response at Windermere St. and Kitchener St. dry well and total hourly rainfall at Templeton Secondary School rain gauge from September 2023 to June 30, 2025*

*Table 11: Windermere St. and Kitchener St. dry well water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| **Number of Rainfall Events** | 103 | 24 | 14 | 141 |
| **Average Drawdown Duration (h)** | 14 | 22 | 17 | 16 |
| **Average Drawdown Rate (mm/h)** | 48 | 50 | 50 | 48 |
| **Design Infiltration Rate (mm/h)** | | 270 | | |
| **% change in rate** | -82% | -82% | -82% | -82% |

#### 2.3.9.2 Cassiar Bioretention # 1 – Lillooet St. and Kitchener St.

The bioretention at Lillooet St. and Kitchener St. has a drainage area of 200 $m^2$. Since the geotechnical investigation found high native soil infiltration rates here, it was designed with no underdrain, merely 45-cm of growing medium above a 10-cm clear crush layer. It was designed with an infiltration rate of 70 mm/h, and from water level monitoring it had been found to have an average drawdown rate of 41 mm/h, and a very quick average drawdown duration of 6.3 hours. Water level response is shown Figure 20 and water level analysis is shown in Table 12. The system was inspected during a rainfall event after it was newly constructed but not yet planted, and the ponded area was about 90% and was not using the overflow (Figure 21).

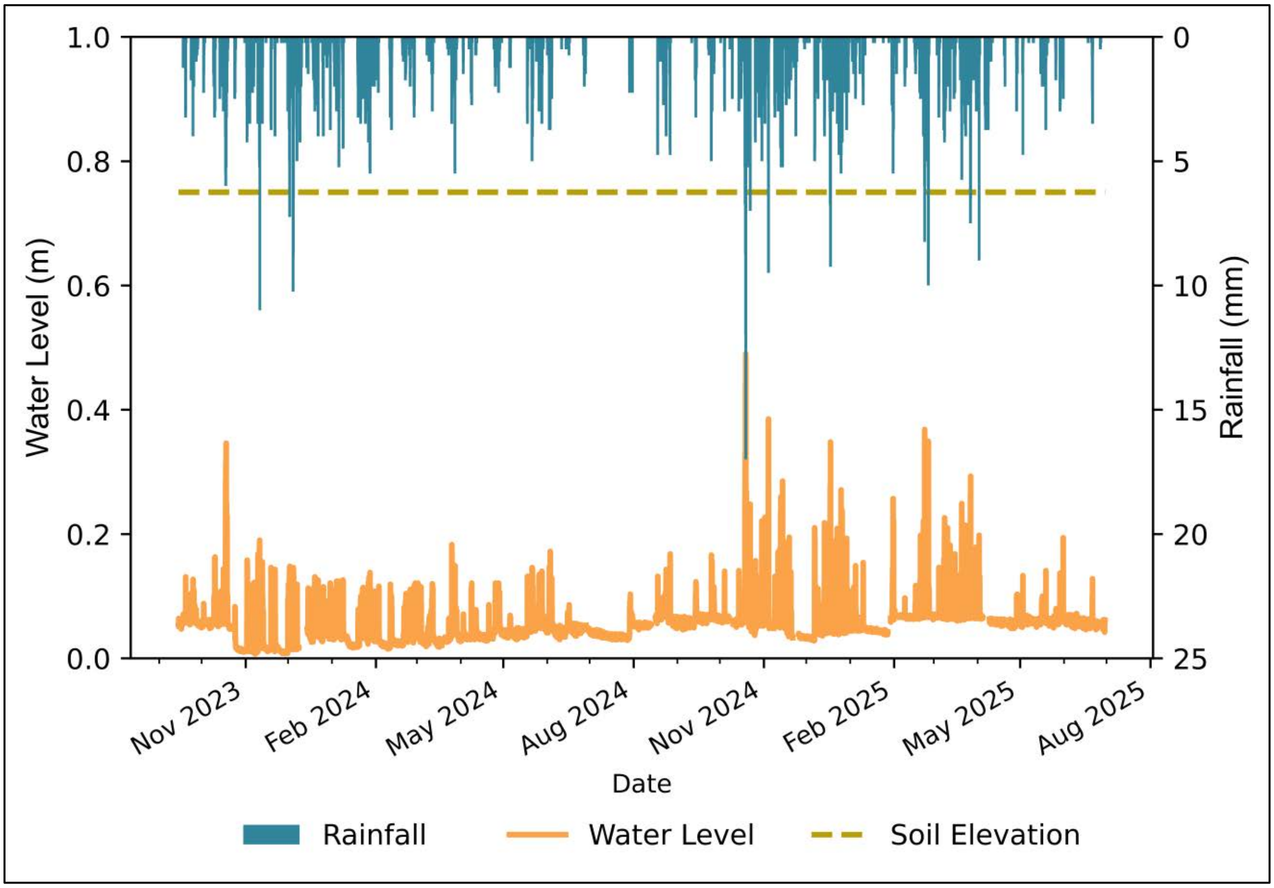



*Figure 20: Average hourly water level response at Lillooet St. and Kitchener St. bioretention and total hourly rainfall at Templeton Secondary School rain gauge from September 2023 to June 30, 2025*

*Table 12: Lillooet St. and Kitchener St. bioretention water level analysis*

| Rainfall Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 81 | 21 | 13 | 115 |
| Average Drawdown Duration (h) | 5.5 | 7.5 | 9.0 | 6.3 |
| Average Drawdown Rate (mm/h) | 42 | 36 | 37 | 41 |
| Design Infiltration Rate (mm/h) | 70 | | | |
| % change in rate | -40% | -49% | -47% | -42% |

*Figure 21: Lillooet St. and Kitchener St. bioretention during October 2023 large rainfall event prior to planting*

### *2.3.9.3 Cassiar Bioretention # 2 – Windermere St. and Grant St.*

The design of this bioretention practice is the same as other bioretention in this area. It contains a 10-cm clear crush drainage layer, overlain by a non-woven geotextile and a 45-cm growing medium layer with no underdrain and an overflow catchbasin. This system has a larger drainage area of 435 $m^2$. The average drawdown rate was slightly higher in this bioretention system at 47 mm/h and it also exhibited a very quick average drawdown duration of 5.5 hours. See Figure 22 for water level response and Table 13 for water level analysis. The system was inspected after it was newly constructed but not yet planted during a large rainfall event in October 2023 and was fully ponded and using the overflow. Observations during large rainfall events since have had it less ponded (60%) but still using the overflow.

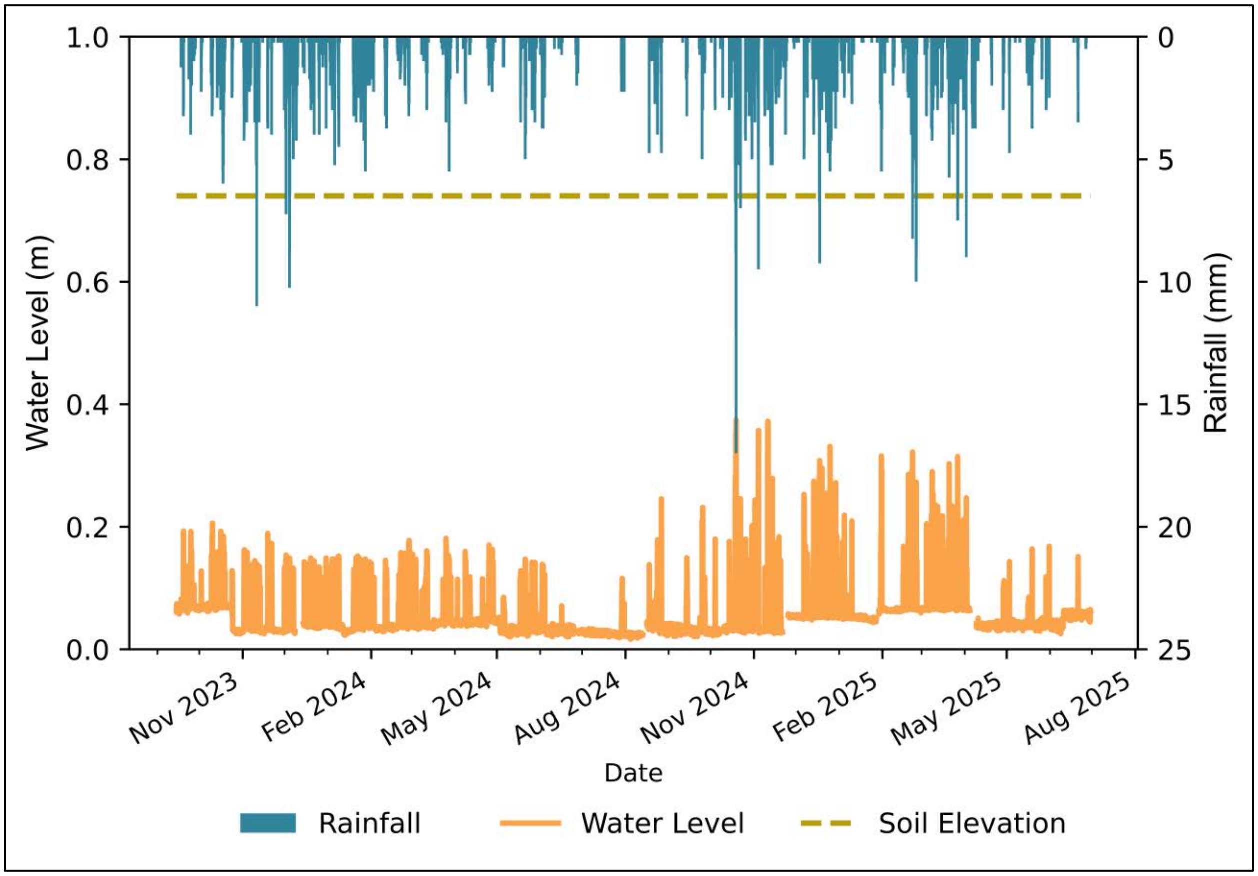



*Figure 22: Average hourly water level response at Windermere St. and Grant St. bioretention and total hourly rainfall at Templeton Secondary School rain gauge from September 2023 to June 30, 2025*

*Table 13: Windermere St. and Grant St. bioretention water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 105 | 23 | 13 | 141 |
| Average Drawdown Duration (h) | 4.4 | 7.1 | 11 | 5.5 |
| Average Drawdown Rate (mm/h) | 51 | 38 | 29 | 47 |
| Design Infiltration Rate (mm/h) | 70 | | | |
| % change in rate | -27% | -45% | -59% | -33% |

#### *2.3.9.4 Cassiar Bioretention # 3 - Lillooet St. and Graveley St.*

This system has the smallest drainage area of the Cassiar sites monitored at 150 $m^2$. This system was very responsive to rainfall events, and the water level response even showed some surface ponding of the system (Figure 23). The inlet of the system had an erosion and sediment control device to stop sediment from upstream construction, which prevented water from entering the system. The inlet was covered from March 2024 to August 2024, which is when we see a gap in water level response in Figure 23. Observations during rainfall events pre and post planting had the system 100% full of ponded water and using the overflow. The average drawdown time was very quick at 8.0 hours, and it had the fastest drawdown rate of the 3 bioretention systems being monitored at Cassiar at 52 mm/h. Water level analysis is shown in Table 14.

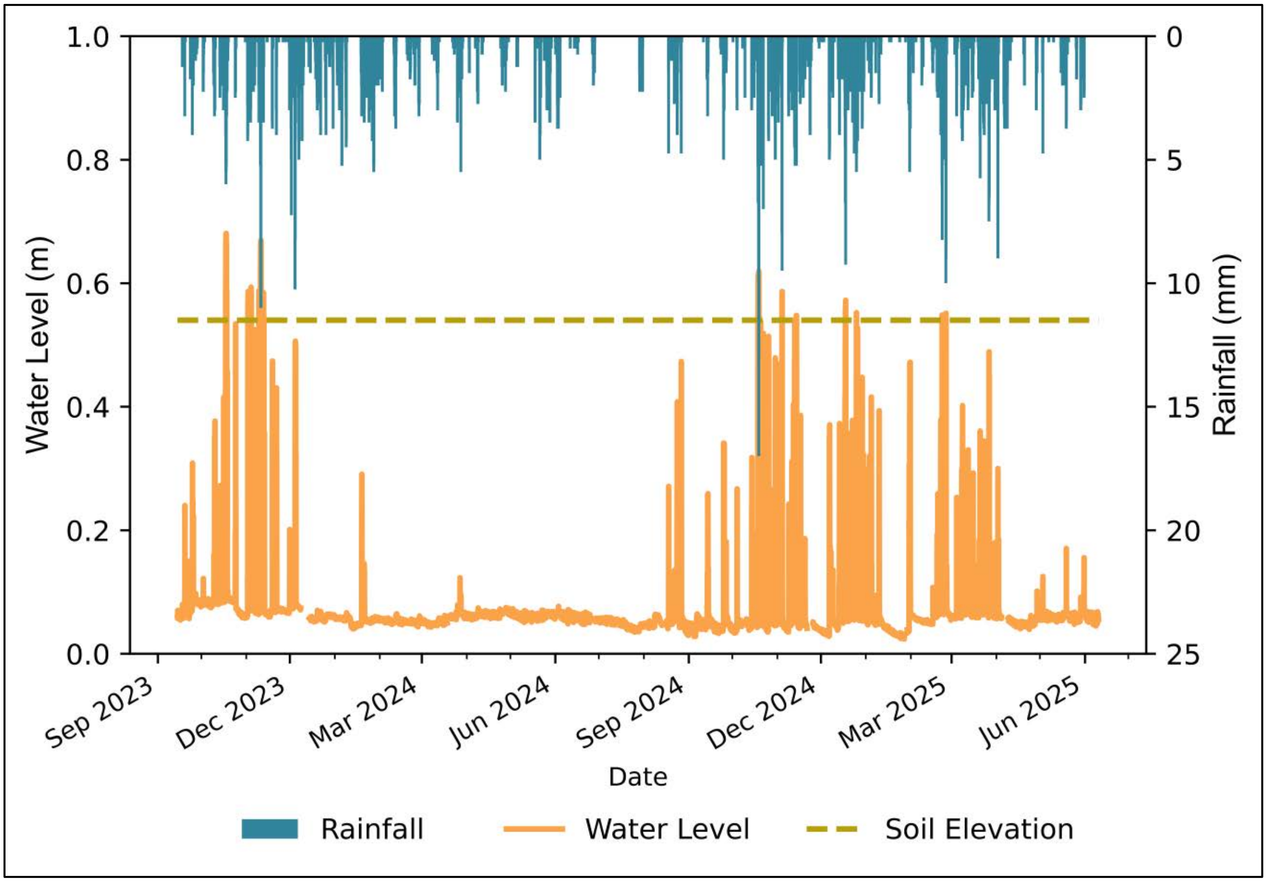



*Figure 23: Average hourly water level response at Lillooet St. and Graveley St. bioretention and total hourly rainfall at Templeton Secondary School rain gauge from September 2023 to June 30, 2025*

*Table 14: Lillooet St. and Graveley St. bioretention water level analysis*

| Rainfall Event Category | Typical (<24 mm) | Large (>24 mm & ≤ 48 mm) | Extreme (>48 mm) | Overall |
|---|---|---|---|---|
| Number of Rainfall Events | 60 | 15 | 11 | 86 |
| Average Drawdown Duration (h) | 6.9 | 9.4 | 12 | 8.0 |
| Average Drawdown Rate (mm/h) | 55 | 45 | 48 | 52 |
| Design Infiltration Rate (mm/h) | | 70 | | |
| % change in rate | -21% | -36% | -32% | -25% |

## 2.3.10 Wet Weather Inspections and Visual Monitoring

In our wet weather inspection program, we aim to conduct annual inspections of our bioretention systems during and after extreme rainfall events. During extreme rainfall events, we are more likely to see bypass and overflow within our systems, since our systems are designed to capture and/or treat 48 mm in 24 hours. Our systems are inspected to determine if rainwater runoff is bypassing at the inlet, which would indicate water not being treated by our GRI system. We also check if the catchbasin within the bioretention system is overflowing, which would indicate that the ponded area in the bioretention cell is full, the soil is saturated, and water is flowing directly into the storm sewer system instead of being treated.

Since starting the wet weather inspection program in 2021, we have conducted 4 wet weather inspections. See Table 15 for rainfall amounts and inspection times.

*Table 15: Wet weather inspection dates and rainfall amounts. Rainfall from Vancity rain gauge*

| Rainfall Period | Wet Weather Inspection Period | Total Event Rainfall (mm) |
|---|---|---|
| September 16, 2021 8:00pm – September 17, 2021 9:00pm | September 17, 2021 12:00pm - 6:00pm | 82 |
| January 11, 2022 6:00am – January 12, 2022 12:00pm | January 12, 2022 9:00 am- 2:00pm | 66.8 |
| January 11, 2023 1:00pm – January 13, 2023 12:00am | January 12, 2023 9:00am-12:00pm | 39.8 |
| October 17, 2023 7:00am – October 19, 2023 6:00am | October 18 2023 9:00am-3:00pm | 82.8 |

Over the four events where visual inspections were performed, we found that 40-50% of assets had no water bypassing the inlet, and 30-40% had some bypass, with only a small portion (10-20%) having all (complete) bypass. The September 2021 event had the most bypass at the inlet, which we attributed to the inspection of several systems constructed prior to the GRI branch forming, requiring upgrades to meet our current design standards (Figure 24). Many have been upgraded since, hence the smaller portion of assets with complete bypass, where updates include increasing the ponding area, increasing ponding depth by increasing the height of the overflow grate, increasing the size of the sediment pad and adding weirs to hold back more sediment.

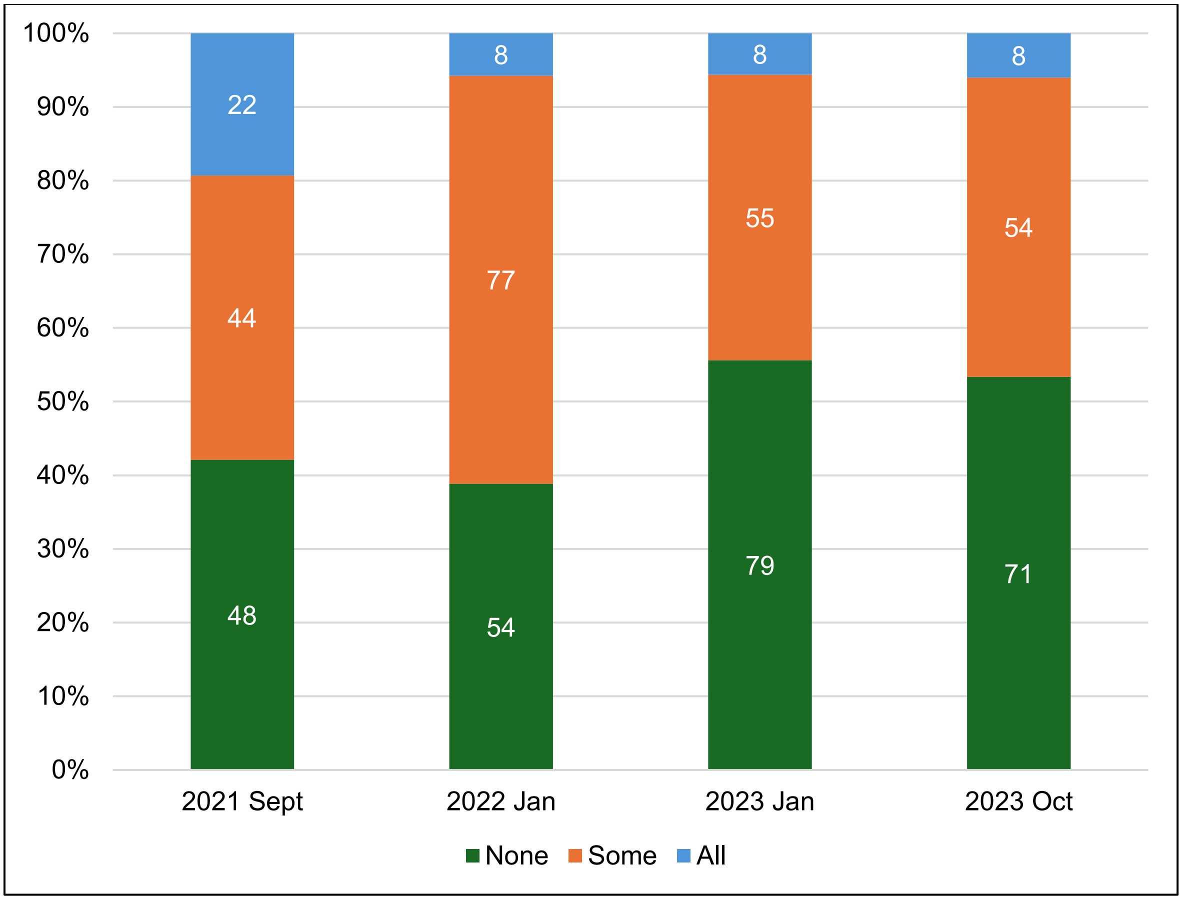



*Figure 24: Rainwater runoff bypassing inlet during wet weather inspections*

We also checked whether the ponded area overflowed into the overflow catchbasin, which is an indicator of the system being full. For these four extreme events, 20-35% of the systems overflowed, whereas the remainder were able to capture all the flow within the bioretention system (Figure 25). A limitation of this observation is that it does not account for the time variability of rainfall intensity within an event. For instance, a site may have been overflowing an hour earlier when the rainfall was more intense, or perhaps it started to overflow in an hour after our observation. In general, wet weather inspection results line up with measured results from water level loggers, showing very good performance even during extreme rainfall events.

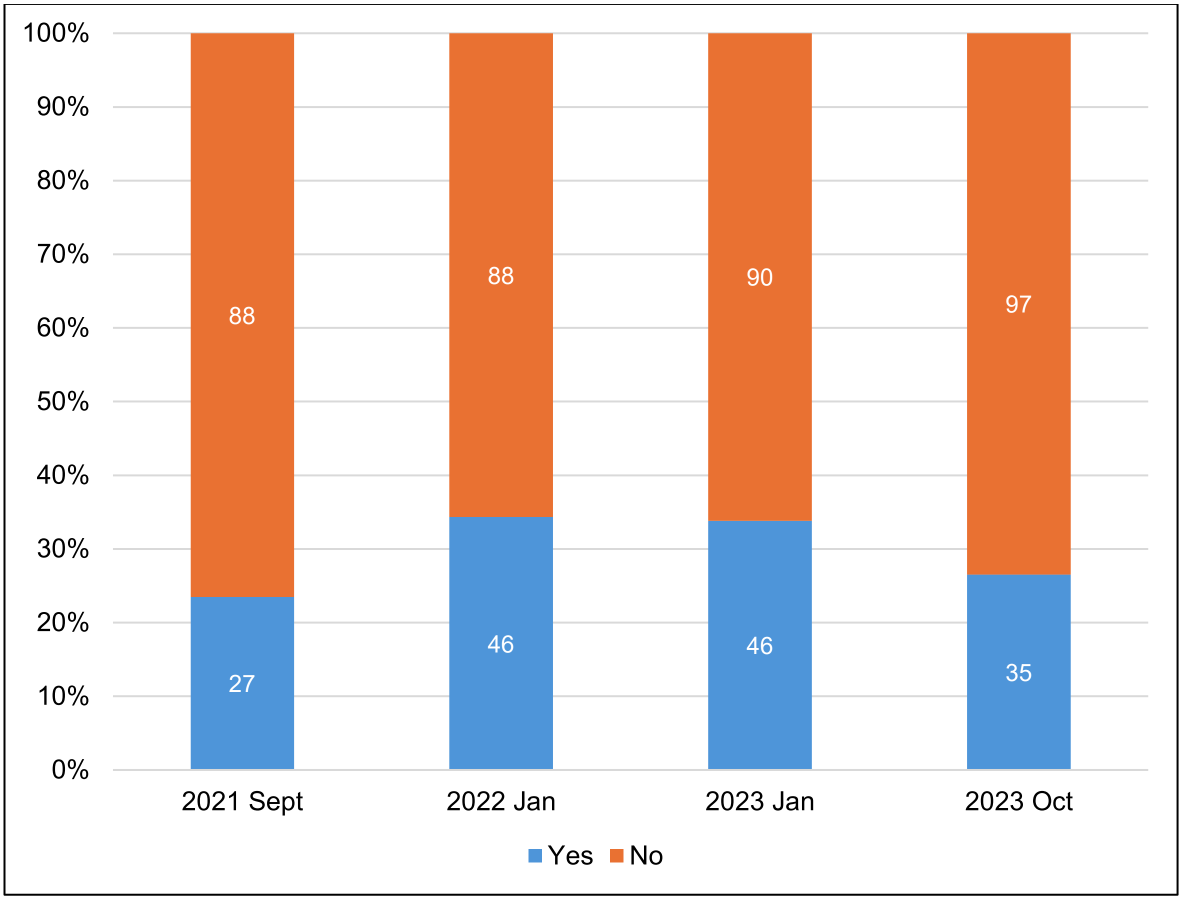



*Figure 25: Rainwater runoff using the overflow catchbasin within the bioretention system during wet weather inspections*

Lastly, we had three events where we monitored the system status 24 hours after an extreme rainfall to determine if the surface of the system had drained. Rainfall amounts and inspection periods are shown in Table 16. We found that only a small minority of systems had any ponding after 24 hours, and that ponding was quite minor (Figure 26). We had no instances where the full ponding area was full with water after 24 hours. This indicates that our systems are draining quite well, which is similarly shown in Sections 2.3.1-2.3.10.

*Table 16: Post wet weather inspection rainfall amounts and inspection period*

| Post Wet Weather Inspection Date | Total rainfall prior to inspection (mm) | Post Wet Weather Inspection Period | # of hours after rainfall event and inspections |
|---|---|---|---|
| November 16, 2021 | 131.3 | November 16, 2021<br>10:00 am - 4:00pm | 24 - 30 |
| October 20, 2023 | 82.8 | October 20, 2023<br>8:30am - 3:30pm | 20 - 27 |
| March 25, 2025 | 17 | March 25, 2025<br>11:00 am - 4:30 pm | 7 - 13 |

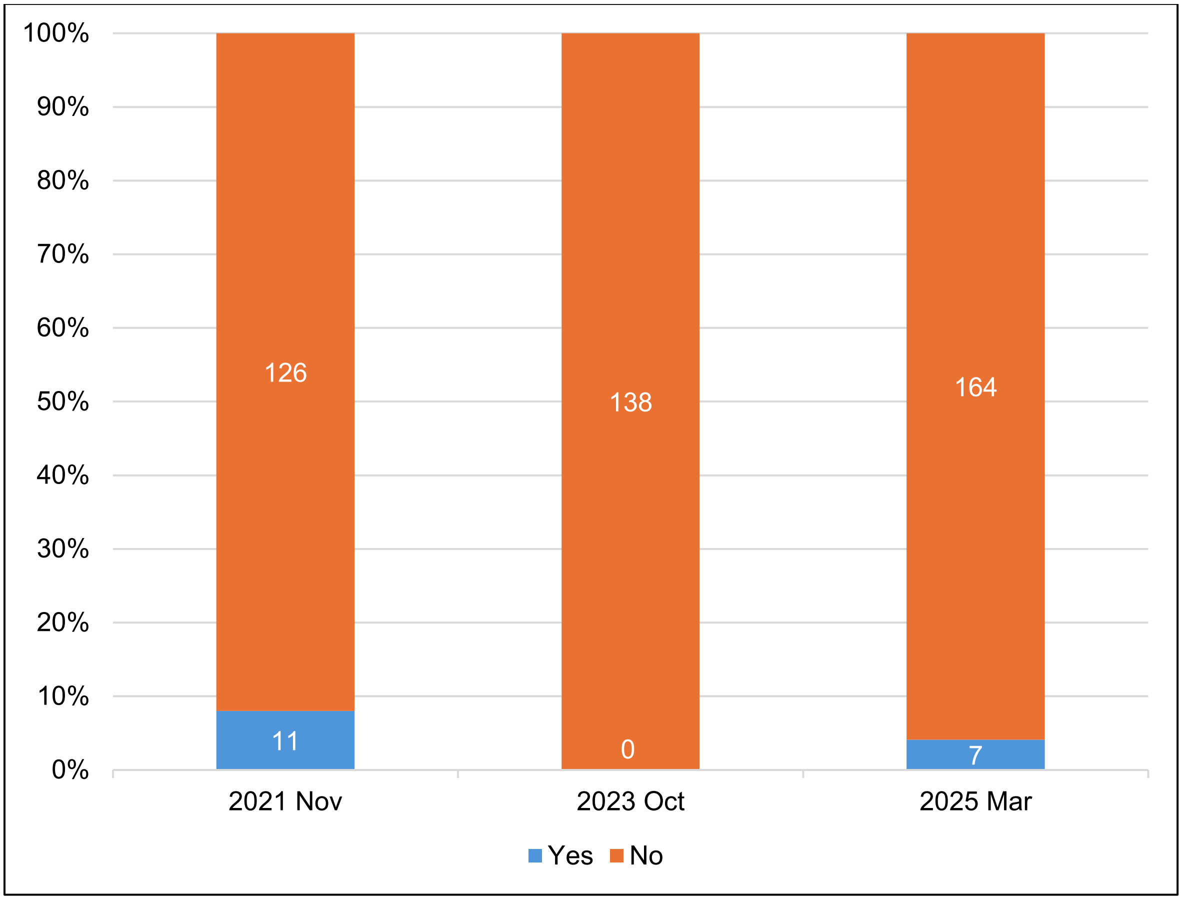



*Figure 26: Ponded water in systems >24 hours after rainfall*

## 2.4 Conclusion

We asked three main questions in the introduction, and answered them with thirteen sites of data:

1. Do GRI systems drawdown at the surface within 24 hours?
    - ➢ Yes – our visual inspections after extreme rainfall events show that all of our systems drain within 24 hours at the surface, with a few exceptions of minor ponding 24 hours after a rainfall event.
2. Do GRI systems drawdown at the subsurface within 72 hours?
    - ➢ Yes – on average all our systems drain within 72 hours. During extreme rainfall events the drawdown duration tends to be longer, but generally still within the 72 hours.
    - ➢ We are so successful with drawdown rates that we could cap more underdrains to prioritize infiltration instead of filtration.
3. Does the drawdown rate of real systems match the design infiltration rates?
    - ➢ Our bioretention systems perform very well and in excess of the design infiltration rate with the exception of the Cassiar sites, which still have a very high drawdown rate. Our RTT systems are below but still close to the design infiltration rate.

The excellent performance of our GRI systems is in no small part due to regular operating procedures adopted by the Green Infrastructure branch. For infiltration trenches, rainwater tree trenches and dry wells, we regular clean inlet catchbasins and distribution pipes, ensuring that filter media within GRI systems remains clear for infiltrating water. In bioretention systems, contractors routinely clean sediment forebays, ensuring that large deposits of sediments are not clogging bioretention filter media.

Even with low native soil infiltration rates, we see excellent GRI performance, with our average drawdown rate considered high. For GRI design, we consider <15 mm/h to be low (and require an underdrain), between 15-50 mm/h is medium or typical, and >50 mm/h is a high drawdown rate. The shading in Table 17 reflects these three categories of drawdown rates. Our sites show a fairly even distribution of drawdown rates, with 4/13 sites having a low average drawdown rate, 6/13 sites have a medium average drawdown rate, and 3/13 sites have a high average drawdown rate.

*Table 17: Summary of water level analysis from all sites: = low drawdown rate, = medium drawdown rate, =high drawdown rate*

| Site | Typology | Monitoring Period | Average Drawdown Time (h) | Average Drawdown Rate (mm/h) | Design Infiltration Rate (mm/h) | Difference between Drawdown Rate and Design Infiltration Rate (%) |
|---|---|---|---|---|---|---|
| **63rd Ave. and Yukon St.** | Bioswale | July 2018 - June 2025 | 1.8 | 470 | 39 | 1100 |
| **Quebec St. and 2nd Ave.** | | | | | | |
| South | Soil Cell RTT | March 2020 - June 2025 | 35 | 9.0 | 10 | -10 |
| North | Soil Cell RTT | March 2020 - June 2025 | 52 | 7.8 | 10 | -22 |
| **Richards St.** | Bioretention | Nov 2021-June 2025 | 17 | 34 | 5.0 | 570 |
| **Haro St. and Bidwell St.** | Dry Well | Feb. 2022 - June 2025 | 14 | 79 | 47 | 68 |
| **Haro St. and Jervis St.** | Bioretention | Feb. 2022 - June 2025 | 25 | 15 | 5.0 | 190 |
| **W 10th Ave. and Heather St.** | RTT | Feb. 2022 - June 2025 | 39 | 20 | 50 | -61 |
| **Harriet Laneway** | Infiltration Trench | Sept. 2022 - June 2025 | 82 | 8.9 | 1.0 | 790 |
| **Woodland Dr. and 2nd Ave.** | Bioretention | Sept. 2022 - June 2025 | 18 | 21 | 1.0 | 2000 |
| **Cassiar** | | | | | | |
| Windermere St. and Kitchener St. | Dry Well | Sept. 2023 - June 2025 | 16 | 48 | 270 | -82 |
| Lillooet St. and Kitchener St. | Bioretention | Sept. 2023 - June 2025 | 6.3 | 41 | 70 | -42 |
| Windemere St. and Grant St. | Bioretention | Sept. 2023 - June 2025 | 5.5 | 47 | 70 | -33 |
| Lillooet St. and Graveley St. | Bioretention | Sept. 2023 - June 2025 | 7.9 | 52 | 70 | -25 |
| **Average** | | | 25 | 66 | | |

# 3 GRI retains moisture in soils

## 3.1 Introduction

One of the advantages of rainwater tree trenches over typical street tree plantings is access to rainwater runoff as additional water for trees. Our goal with monitoring soil moisture in rainwater tree trenches is to determine if rainwater runoff does help with moisture retention for trees, particularly during summer droughts. A secondary goal is verifying construction methods, such as determining if structural soil and soil cells help with soil moisture retention compared to conventional tree pit materials. Seven RTT systems and two bioretention systems were monitored for soil moisture for this report.

## 3.2 Methods

TEROS 12 soil moisture sensors were inserted into the soil or structural soil to measure volumetric water content (VWC), electrical conductivity and temperature. The TEROS 12 sensors were installed in the soil during construction by placing the sensor prongs into the soil at the desired depth. The cables were fed through a narrow PVC pipe that led to a valve box. Once construction was completed, a data logger was connected to the soil sensor. A pelican box was used to house the data logger and the entire system locked inside a valve box. The data logger was set to collect data at 5-minute intervals, allowing for 120 days of data to be stored in the EM50, or 2 years of data in the ZL6. Data was collected and batteries changed approximately every 12-16 weeks. Upon collection, each parameter was plotted with rainfall to determine any trends or locate any outliers in the data set.

The volumetric water content (VWC) was compared to typical values for soils for permanent wilting point. Permanent wilting point (PWP) is the water content in soil when plants can no longer access the moisture and begin to wilt and die. PWP for sandy soils is 5-10%, which is comparable to typical soils used in City and GRI projects.

## 3.3 Results

### 3.3.1 Quebec St. and 1st Ave. Location C RTT

Location C RTT manages rainwater runoff from a drainage area of 415 $m^2$ and has three soil sensors measuring volumetric water content, electrical conductivity and temperature that were installed during construction at depths of 20-cm, 40-cm and 60-cm. The 40-cm sensor displayed erratic readings and is believed to have been damaged during construction. For this reason, data from the 40-cm sensor has been omitted from the analysis. A data logger was connected post-construction to continuously log the data. Soil monitoring has been occurring since September 2018.

The soil moisture in the Quebec St. and 1st Ave. Location C RTT displayed very little seasonal variation throughout the monitoring period. The location of the sensors under the bike lane may explain how little variation there is, as soil moisture is not lost through evaporation. The 60-cm depth soil moisture levels varied between 21-49%. The lowest moisture content occurred in October 2022, after a dry summer season. In 2024 there were some very high soil moisture readings. Some corresponded to rainfall, but the highest soil moisture occurred in June 2024. The reason was unknown for this spike. Possible reasons include the sensor aging and starting to malfunction, the sensor tip moving within the structural soil or nearby trees being watered causing a spike in moisture levels. However we did not see the same response in the 20-cm depth sensor. The 20-cm depth sensor had little variation and the soil moisture ranged from 22-34%. Rainfall and VWC monthly maximums, minimums and means for the 60-cm and 20-cm depth sensors are shown in Figure 27.

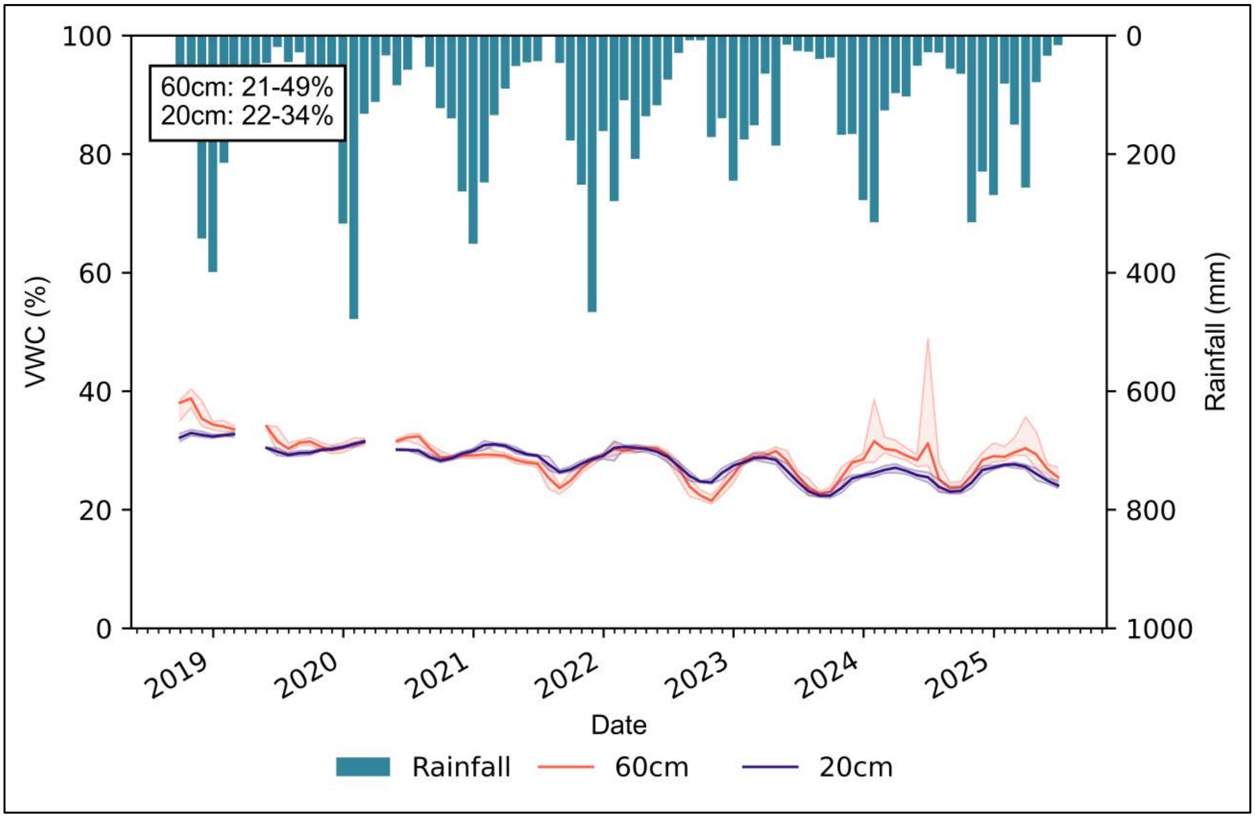



*Figure 27: Monthly VWC maximums, minimums and means at 60-cm and 20-cm depth at Quebec St. and 1st Ave. RTT and total monthly rainfall at Creekside rain gauge from 2018 to 2025*

## 3.3.2 Quebec St. and 1st Ave. Location D Bioswale

Location D bioswale manages rainwater runoff from a drainage area of 630 $m^2$. Two soil sensors were installed during construction at depths of 20-cm and 40-cm to measure volumetric water content, electrical conductivity and temperature. A data logger was connected post-construction to continuously log the data. Soil monitoring has been ongoing since September 2018.

Both soil sensors installed in the bioswale were functional and provided data on volumetric water content, electrical conductivity and temperature since September 2018, however there are some intermittent data gaps where sensors disconnected from the logger. Seasonal variation in moisture levels was very apparent, with moisture levels being at the highest during the wet seasons when there was the greatest amount of rainfall, and the lowest occurring in early fall after the hot dry summer months The moisture level at the 40-cm depth ranged from 6.5-51%, and the 20-cm depth ranged from 5-47%. The 20-cm depth sensor showed very little response during 2023, but had begun to show variation in VWC in 2024. The soil moisture at the 40-cm depth were generally higher than at 20-cm. The pronounced seasonal variation compared to the other sites is likely influenced by the GRI typology. The soils in a bioswale are more exposed to evaporation and transpiration that can cause moisture loss. Rainfall and VWC monthly maximums, minimums and means for the 40-cm and 20-cm depth are shown in Figure 28.

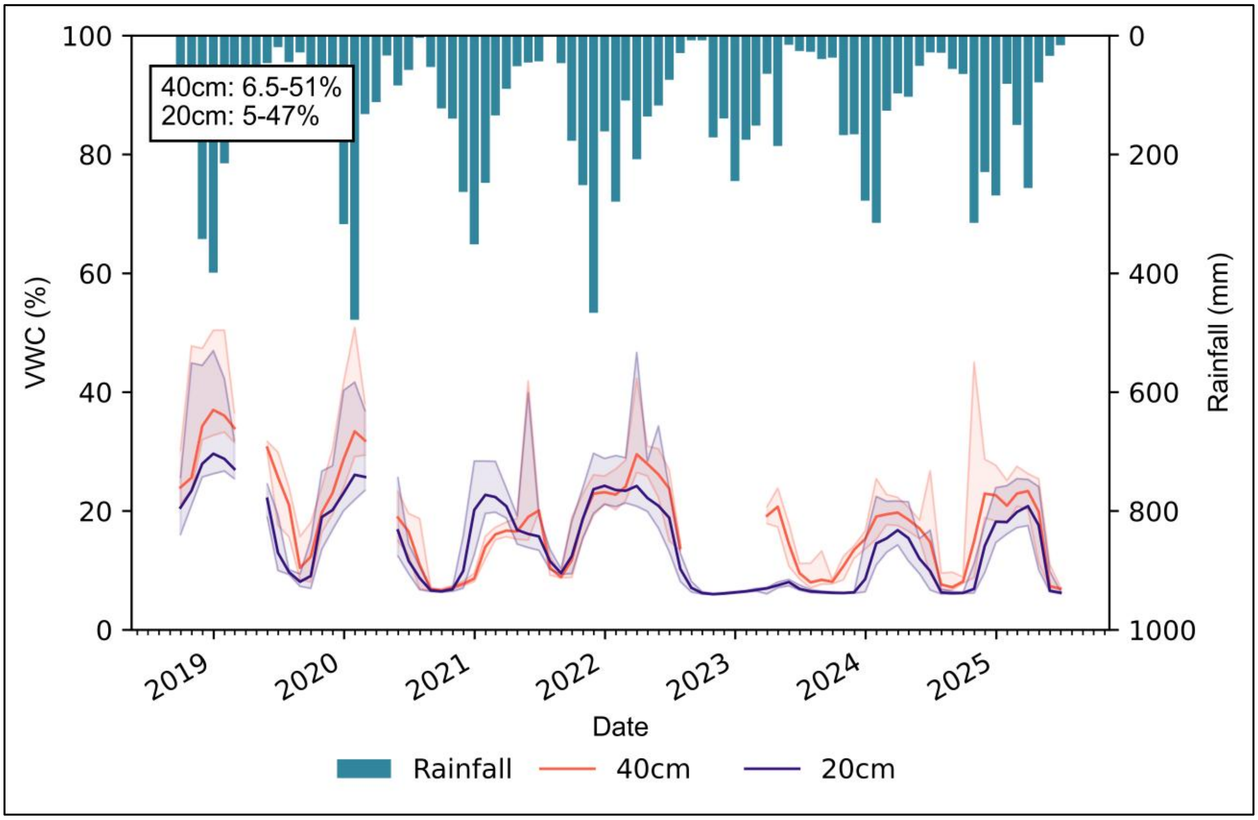



*Figure 28: Monthly VWC maximums, minimums and means at 40-cm and 20-cm depth at Quebec St. and 1st Ave. bioswale and total monthly rainfall at Creekside rain gauge from 2018 to 2025*

## 3.3.3 Richards St. RTT and Bioretention

The Richards Street project is an eight-block (between Dunsmuir and Pacific) bike lane upgrade project where rainwater tree trenches were incorporated into the design to collect rainwater runoff from the bikeway and roadway. The project also features permeable pavers that allow water to infiltrate through the surface. The project consists of 100 new street trees planted in the median – a mixture of Brandon Elms, American Hornbeams and River Birches, as well as a bioswale with Permavoid drainage units. Construction took place from May 2020 to November 2021, with Blocks A-D completed in mid-2021, and Blocks E-H completed in November 2022 (see Figure 1 for Block labels). All blocks had soil moisture sensors installed, but the soil moisture sensor at Block B was not functional from early on and has been removed from analysis.

Soil moisture levels across all blocks were highly variable, with some blocks very responsive to rainfall conditions (A, C-South, G), and other blocks with fairly consistent moisture content despite lack of rainfall in the summer (C-North, D, F). This is likely due to the placement of the soil moisture sensor, in terms of proximity to distribution pipes or permeable pavers or the tree pit opening, though during construction every attempt was made to keep installation location consistent. Monthly maximum, minimum, and mean VWC results across 2021-2025 and Blocks A-H are shown in Figure 29.

A trend among the soil moisture monitoring at all blocks was that the lowest soil moisture occurred in September, which was after months of very low rainfall, and before higher rainfalls in October. The exception to this was summer 2021 for Blocks A-D, though the moisture likely stayed high in these months since the trees were new and were receiving regular watering. Establishment period watering stopped in summer 2023 for Blocks A-D, and November 2023 for Blocks E-G, and so summer 2024 was the first summer without external watering, and the low moisture levels were not significantly lower than in 2023 and 2022.

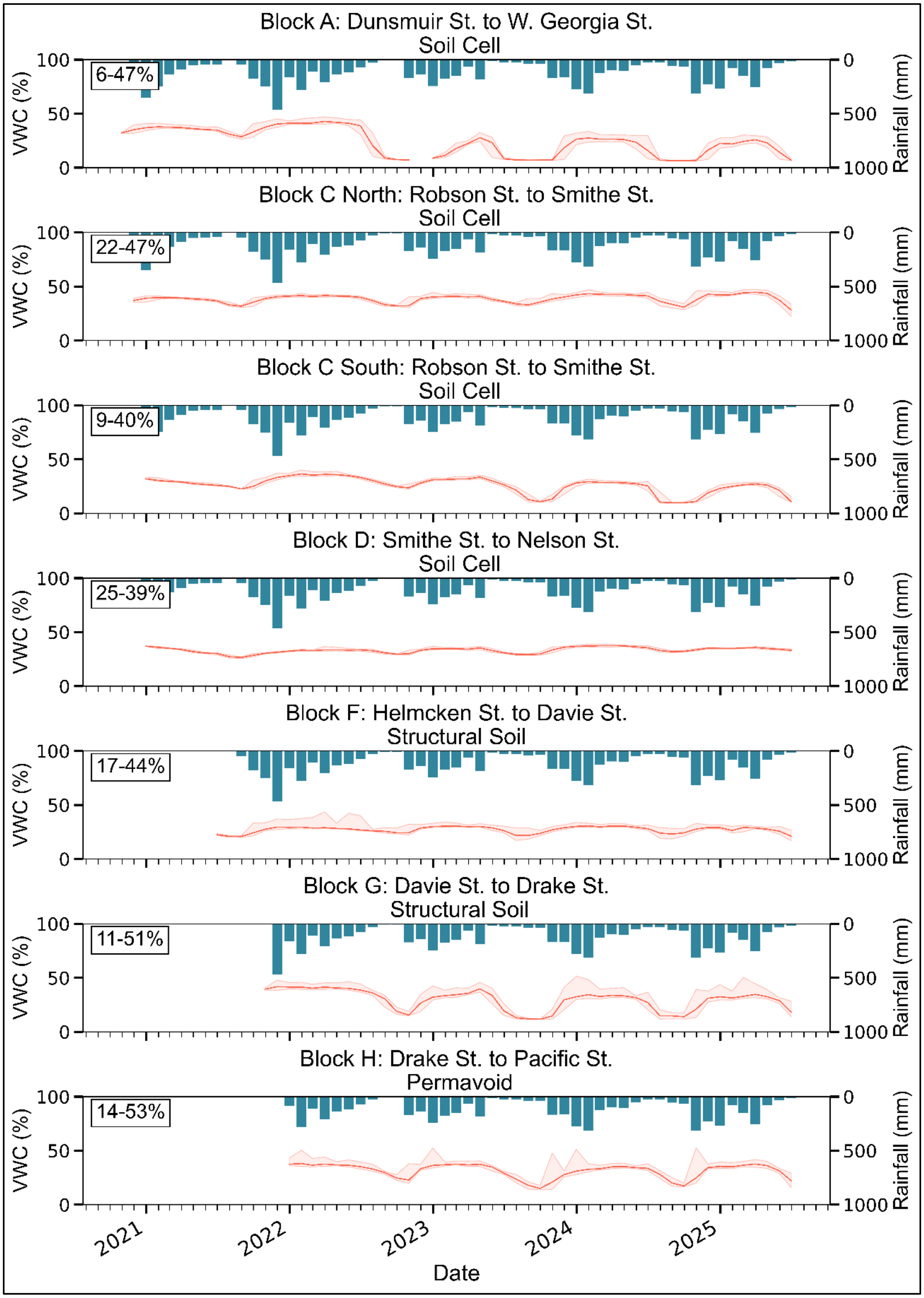



*Figure 29: Monthly VWC maximums, minimums and means for Richards St. Block A-H and total monthly rainfall at Creekside rain gauge from 2021 to June 30, 2025*

## 3.4 Conclusion

Summer 2023 and Summer 2024 were the first real test of soil moisture in RTTs and bioretention without any external watering, and all systems continued to perform well. All systems had moisture content above 5%, which is a typical value of permanent wilting point in sandy soils. Also, all systems had healthy trees, with none dying, as well as healthy understory plants. Plant growth, plant die-off and soil moisture will continue to be monitored as we move forward, particularly as it relates to type of soil and soil structure, topics discussed further in Section 5.

As can be seen throughout this section, there are several issues with reliability of sensors as they age within subsurface systems, and we cannot change or update the sensor without removing paved surfaces and a significant construction effort. It is difficult to know when a large drop is due to loss of soil moisture, or an issue with the sensor or the location of the sensor in soil.

# 4 GRI systems reduce amount of runoff entering the sewer system

## 4.1 Introduction

GRI is effective at keeping water out of the sewer system, thereby reducing combined sewer overflows, and improving water quality by reducing the mass of pollutants released to surface water via stormwater outfalls.

It is very difficult to understand the exact runoff reduction of GRI sites. Several attempts at monitoring individual sites has been described in the past two monitoring reports (*2021-2023*, *2018-2021*), where we saw that the volume reduction of individual systems was 70-90% on average. This is consistent with many literature values, e.g. 60-90% volume reduction found across a literature review of bioretention systems (Huang, Sage, Técher, & Gromaire, 2025).

A new addition to the scope of this monitoring report is catchment-level monitoring of GRI systems.

Richards St. GRI consists mostly of rainwater tree trenches constructed in 2021-2022, on Richards Street in the boulevard between bike lanes and the roadway, between West Cordova and Pacific St (8 blocks). The GRI systems captures rainwater runoff from the roadway, bike lane, median and sidewalks, and distributes the runoff through structural soil, tree pits and soil cells. Any water in excess of what the system could handle overflows to the storm sewer system. We conducted flow monitoring in a storm sewer before, during and after construction of rainwater tree trenches on Richards St. and analyzed the impact of the new GRI on the flow in the storm sewer.

## 4.2 Methods

An area-velocity meter (FloWav AV meter with Telog ultrasonic level meter) was installed in a sewer maintenance hole (MH FID 423502) on Richards St. south of Drake Street from June 2020 to February 2023 to measure the flow in the storm sewer. On February 12, 2023, due to sensor failures, the installation was replaced with a Flow-Tronic Raven-Eye until the end of the monitoring period in May 2023. Figure 30 shows the location of the flow sensor in MH, the catchment area for the flow sensor, and the GRI systems within the catchment area. The sensor was field validated during maintenance visits, and data reviewed regularly to ensure flow measurements conformed to Manning's flow conditions.

The catchment area for the MH is approximately 5-ha, which includes 5 blocks of GRI, from Robson St. to Drake St. Within this 5-ha catchment area to the sewer maintenance hole, 0.78 hectares or 16% of the catchment drains to GRI. Based on land cover analysis, the estimated imperviousness is 63%, which would indicate a rainfall runoff coefficient (unit of runoff generated per unit of rainfall for a given land surface) of around 0.6.

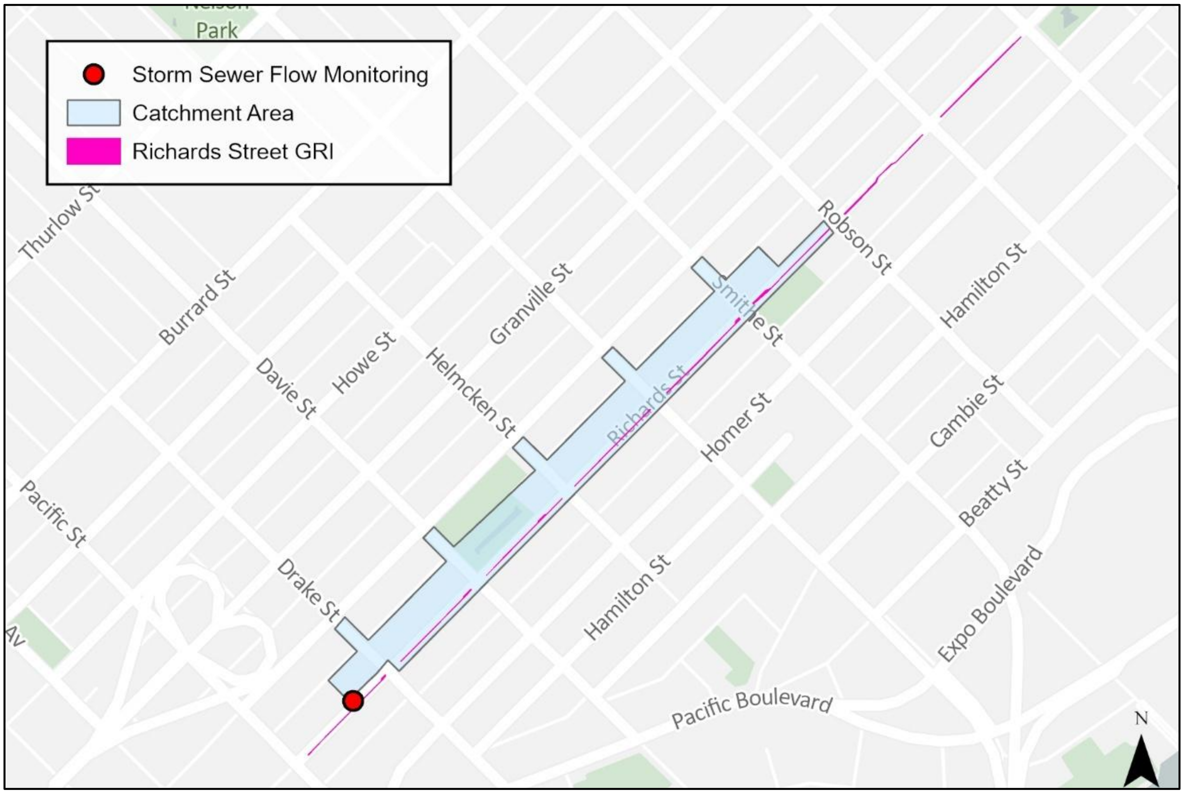



*Figure 30: Richards St. RTT, catchment area and flow sensor location*

Since this is a separated catchment, and we know from our building inventories that the buildings are also separated, the sources of flow to this sewer manhole consist of the following:

- Runoff from private sites (includes roofs and outside landscaped and paved areas)
- Groundwater from foundation drains (buildings with deep foundations often have drains and pumps that connect to the storm sewer, but building-level information on these systems is difficult to obtain)
- Runoff from streets not captured by GRI (goes directly into catchbasins then the storm sewer)
- Runoff from streets captured by GRI (partial catchment during mid-construction and full 0.78-ha captured during the post-construction period)
- Inflow/infiltration into storm sewers, due to groundwater mounding which may or may not be present at the depth of the storm sewer. The amount of inflow/infiltration in this sewer is not known, and so it is difficult to know whether there were any changes over time to these values.

We observed constant flow in the storm sewer across all dry periods and the whole period of analysis. It was assumed that there was baseflow into the storm sewer from building foundation drains and/or inflow/infiltration from groundwater. From observing the full data set, during all seasons, we assumed that the baseflow was 2 L/s, and this value was subtracted from all flow values before other analyses were started, to the point where the baseflow (non-event flow) was consistently 0 L/s. Flow was then converted to volume by multiplying by the inter-measurement time period (5 minutes). Rainfall data from the Creekside Community Centre rain gauge station was used in the analysis. Rainfall events for the 2020-2023 time period were determined per method outlined in Section 1.13. Associated flow events were created that correspond to 3 hours before and after the rainfall event, which was selected after reviewing hydrographs for multiple rainfall events.

The following calculations were made and summarized for each rainfall event:

$$\text{Rainfall (mm)} = \sum_{t_{initial}}^{t_{end}} \text{Rainfall (t)}$$

$$\text{Volume (L)} = \sum_{t_{initial}}^{t_{end}} \text{Flow} \left(\frac{L}{s}\right) \times 5 \text{ minutes (t)}$$

$$\text{Rainfall runoff coefficient} = \frac{\text{Volume}}{\text{Rainfall} \times \text{Drainage area}}$$

The rainfall events and associated flow events were categorized as pre-construction (July 2020 – July 2021), mid-construction (July 2021 – July 2022) and post-construction (July 2022 – May 2023), and also categorized as either typical (≤24 mm), large (24 mm-48 mm) or extreme (>48 mm). A total of 263 rainfall and flow events were analyzed, with 86 events categorized as pre-construction, 105 as mid-construction and 72 as post-construction. One event was removed from analysis because it was a snowfall event, and the City rain gauges do not differentiate between rainfall and snowfall. Data by construction period was summarized statistically and a Mann-Whitney U-test was performed to determine if there were statistically significant differences between categories. Mann-Whitney U-Test was chosen since the data was not normally distributed, observations are independent (since each rainfall event is independent), and the observations are ordinal (one observation is different than another). All calculations and statistical tests were performed in Python.

## 4.3 Results

Flow volumes decreased between pre-construction and post-construction, which may be attributable to the addition of GRI, as rainfall totals were not significantly different between pre-construction and post-construction. Boxplots showing the results for rainfall, volume and rainfall runoff coefficient are shown in Figure 31, with an asterisk denoting statistically significant difference between time periods. A p-value of less than 0.05 indicates a statistically significant difference. The only statistically significant results were flow volume from pre-construction to post-construction. The decrease in median flow volume from pre- to post-construction was 133 $m^3$ or 48% and was statistically significant (see Table 18).

Since rainfall events are also quite variable, we also examined the difference in flow for different event categories (typical ≤24 mm, large 24-48 mm, extreme >48 mm). Similar to all events, the sub-categories of typical, large and extreme rainfall events were not significantly different between time periods. Flow volume for typical events was significantly different from pre- to mid-construction, and pre- to post-construction. However, flow volume for large events pre- to post-construction was not significantly different, though pre- to mid-construction was. Some difference from pre- to mid-construction is likely, given that the GRI systems would have been partially constructed during this time.

There were no statistically significant differences between flow volumes for extreme events, which is expected as GRI systems are designed for typical and large events. Large and extreme events were less frequent (see count of events on the left side of Figure 31 and on Table 18), and therefore the statistical comparisons are not as reliable. For both large and extreme events, the spread in flow volumes (the difference between minimum and maximum volumes) was much wider for post-construction events than pre- and mid-construction events. This means there were some large and extreme events in the post-construction period which had very low flows relative to the rainfall amounts, so even large and extreme events had some reductions due to GRI.

Rainfall runoff coefficients were variable, and generally lower than the expected coefficient (based on imperviousness) of 0.6. Since the coefficient depends on the rainfall amount, the dataset is not fully independent, so we did not conduct statistical tests on these results. The median rainfall runoff coefficient decreased from pre-construction through to post-construction, and for all event types. Large and extreme events were the most variable in the post-construction period, with coefficients varying from 0.2 to 0.8, but this is likely due to the very small number of events during the large (n=9) and extreme events (n=4).

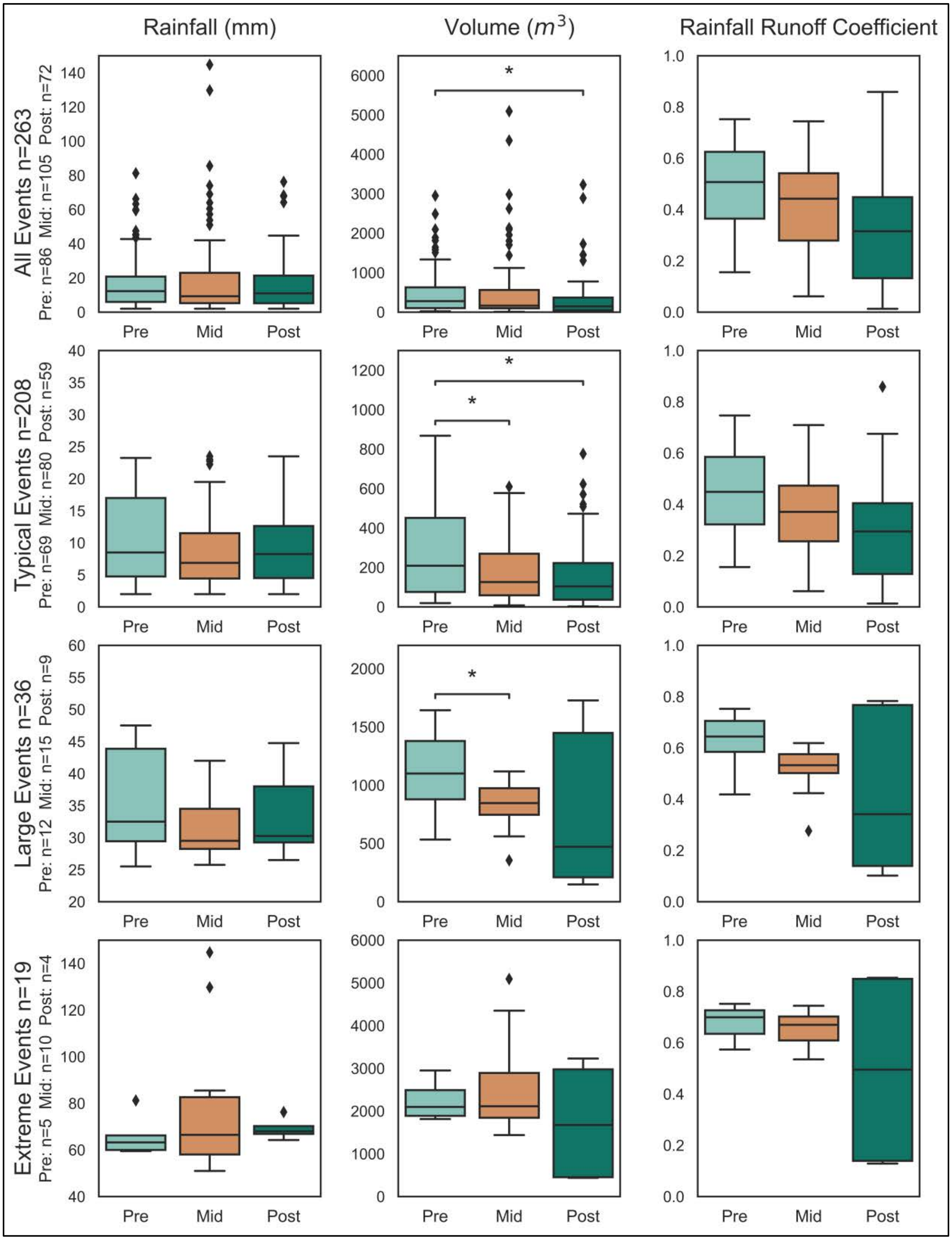



*Figure 31: Boxplots comparing rainfall, volume and rainfall runoff coefficient during different construction periods and for different rainfall types. The * represents a p-value less than 0.05, between the periods denoted by brackets. Statistical tests were not conducted for rainfall runoff coefficients.*

*Table 18: Rainfall event category and construction period analysis*

| Rainfall Event Category | Construction Period | Count | Median Rainfall (mm) | Median Volume ($m^3$) | Median Rainfall Runoff Coefficient |
|---|---|---|---|---|---|
| All Rainfall Events | pre-construction | 86 | 12.25 | 279 | 0.51 |
| | mid-construction | 105 | 9.25 | 164 | 0.44 |
| | post-construction | 72 | 11 | 146 | 0.32 |
| Typical | pre-construction | 69 | 8.5 | 209 | 0.45 |
| Typical | mid-construction | 80 | 6.9 | 126 | 0.37 |
| Typical | post-construction | 59 | 8.3 | 104 | 0.29 |
| Large | pre-construction | 12 | 33 | 1101 | 0.64 |
| Large | mid-construction | 15 | 30 | 847 | 0.53 |
| Large | post-construction | 9 | 30 | 471 | 0.34 |
| Extreme | pre-construction | 5 | 63 | 2098 | 0.70 |
| Extreme | mid-construction | 10 | 67 | 2114 | 0.67 |
| Extreme | post-construction | 4 | 68 | 1675 | 0.49 |

The hydrographs of individual rainfall events tell the same story as above – that GRI has a had a significant impact on reducing the amount of water entering the storm sewer system. As there is large variability among individual rainfall events, we selected events that had a similar rainfall volume and duration to compare pre- and post-construction. Figure 32 compares the hydrographs of a large rainfall event pre-construction in November 2020 of 25.5mm that lasted for 26.7 hours to a post-construction rainfall event in April 2023 of 25.6mm that lasted 28 hours. This is equal to a 43% decrease in volume from pre- to post-construction between these rainfall events.

Figure 33 compares the hydrographs from an extreme rainfall event pre-construction in December 2020 of 59.5 mm that lasted 36 hours to a post construction rainfall event in November 2022 of 64.25mm that lasted 35 hours. This is equal to a 76% volume reduction from pre- to post-construction between these similar rainfall events.

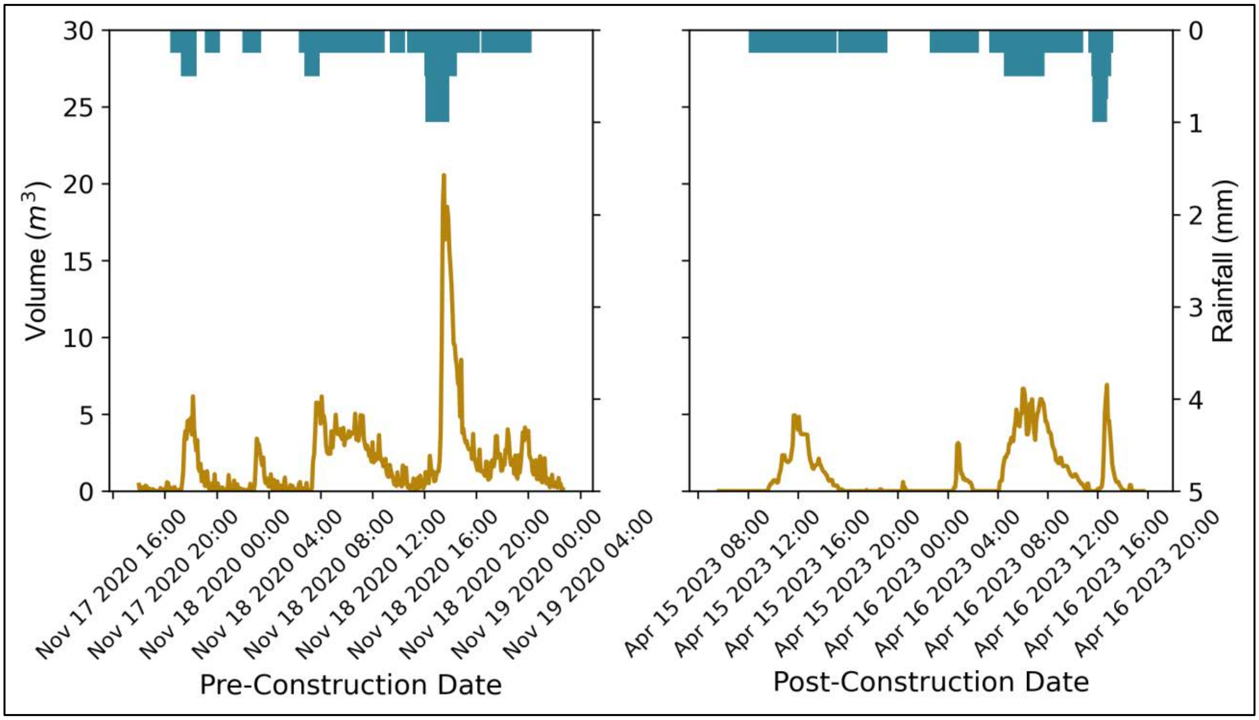



*Figure 32: Pre- and post-construction large rainfall event sewer volume comparison*

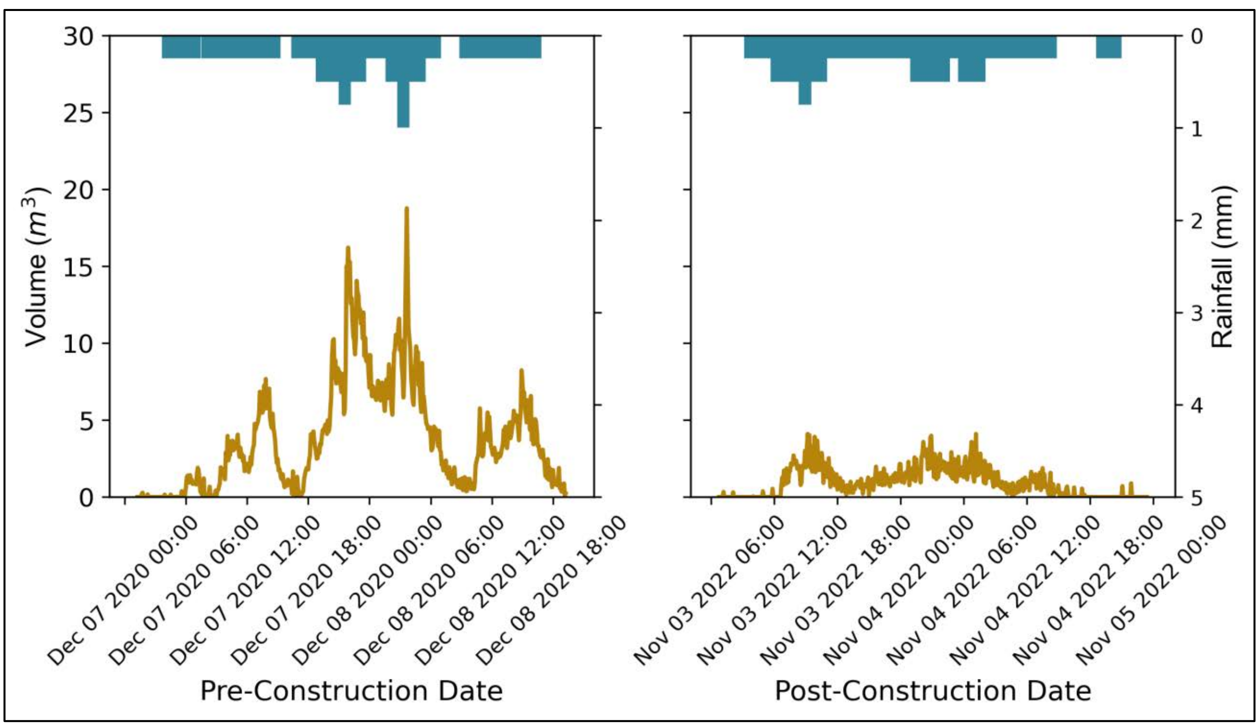



*Figure 33: Pre- and post-construction extreme rainfall event sewer volume comparison*

## 4.4 Conclusion

Flow monitoring in the storm sewer downstream of the Richards St. GRI construction showed a significant difference in flow volumes from pre-construction to post-construction, whereas the rainfall over the two time periods was not significantly different. Comparing similar individual rainfall events of all sizes (typical, large, and extreme), the rainfall runoff coefficient in the post-construction period was lower than pre-construction period. Though it is difficult to determine the exact magnitude of the effect of GRI on storm sewer flow, due to the statistically significant difference in flow volumes from pre- to post-construction, it is likely that portion of the flow reduction volumes are due to the Richards St. GRI installation. Other contributions to storm sewer flow may have changed in the catchment, such as amount of groundwater infiltration or individual building connections, but this is unlikely due to the climate data being similar over the time periods, and since no other construction was occurring in the catchment area. Even if there were some changes to the catchment, they are unlikely to be as significant of an impact as the construction of eight blocks of RTT on Richards St. Therefore we believe this shows that GRI construction significantly reduces flow in sewers, which in turn improves water quality by ensuring less polluted water making it to our waterways.

# 5 Permeable pavements require significant routine maintenance

## 5.1 Introduction

The City of Vancouver currently has 59 permeable pavement assets, 45 of which are permeable interlocking concrete pavers (PICP). There are 37 PICP assets that were built around 2010, and have not had any cleaning maintenance since their construction. We have been experimenting with a cleaning maintenance program for these assets to regain their infiltration capacity. We have been power washing and monitoring 8 PICP assets which were constructed between 2019 and 2023. This section covers the cleaning and infiltration testing conducted in winter 2023 and winter 2024, to help with determining how frequent PICP assets should be cleaned.

## 5.2 Methods

The PICPs are cleaned by power washing the surface and then replacing any aggregate material in the joints that had been lost due to power washing. Infiltration testing was conducted before power washing, and after power washing.

Infiltration testing for PICPs is the ASTM C1781 standard method, constant head method. A 300-mm diameter ring is sealed to the surface of the PICPs using clay, and two lines are marked at 10-mm and 15-mm from the base of the ring. Then a known mass of water is poured at a constant rate to keep the head of water between 10-mm and 15-mm. The time it takes for water to infiltrate was recorded and the infiltration rate is calculated using:

$$I = \frac{KM}{D^2T}$$

Where:

I = infiltration rate (mm/h)

K = constant 4.58 x $10^9$

M = mass of water infiltrated (kg)

D = diameter of ring (mm)

T = time required for water to infiltrate pavement surface (s)

We determined that a test time of greater than 30 minutes, or an infiltration rate of approximately 100 mm/h indicated system failure, based on guidance from ASTM C1781 and literature on permeable pavements.

## 5.3 Results

In the previous monitoring report (2021-2023 time period), we reported that cleaning followed by infiltration testing at 6 assets (which represented a subset of the 45 PICP assets) showed that annual or more frequent cleaning was necessary because the time to failure was 6-13 months. The 4 sites representing the oldest systems (constructed in 2008 and 2010) were cleaned and tested again 12 months later. These sites failed the infiltration testing after cleaning so it was decided to no longer maintain the PICP sites from this area.

We continued with power washing and before and after infiltration testing for eight assets representing our newer permeable pavers in December 2023 and December 2024. In 2023, seven of the eight sites failed the infiltration test before cleaning, and only one site failed the infiltration test after cleaning. In 2024, five out of the eight sites failed the before test (and three others were quite close to failing), and the same one asset still failed the after test. We are unsure why the one asset constructed in 2019 is failing and not recoverable with cleaning, while a similar asset constructed in the same year does recover its infiltration capacity after cleaning. However it remains clear that power washing of PICP is required every year, and for some assets more frequent may be necessary. The infiltration test results of before and after power washing are shown in Table 19, with red highlights indicating where the infiltration rate was a failure (ie. test took longer than 30 minutes).

*Table 19: Infiltration test results before and after power washing at 8 PICP sites in 2023 and 2024*

| Site | Year Constructed | 2023 - Before | 2023 - After | December 2024 - Before | December 2024 - After |
|---|---|---|---|---|---|
| **1** | 2019 | <100 mm/hr | <100 mm/hr | <100 mm/hr | <100 mm/hr |
| **2** | 2019 | <100 mm/hr | 763 mm/hr | <100 mm/hr | 509 mm/hr |
| **3** | 2021 | 278 mm/hr | 509 mm/hr | 305 mm/hr | 763 mm/hr |
| **4** | 2021 | <100 mm/hr | 679 mm/hr | 235 mm/hr | 509 mm/hr |
| **5** | 2022 | <100 mm/hr | 1018 mm/hr | <100 mm/hr | 509 mm/hr |
| **6** | 2022 | <100 mm/hr | 718 mm/hr | <100 mm/hr | 763 mm/hr |
| **7** | 2022 | <100 mm/hr | 1018 mm/hr | 381 mm/hr | 1018 mm/hr |
| **8** | 2022 | <100 mm/hr | 763 mm/hr | <100 mm/hr | 509 mm/hr |

## 5.4 Conclusion

In the 2021-2023 monitoring report, we found that PICPs that were much older and had not had routine power washing were not recoverable, and that their infiltration rates were failing. For newer assets (2019 and later), power washing of the PICP is conducted annually as well as before and after cleaning infiltration tests. Most PICP sites have failing infiltration capacity after less than one year, but manage to have passing infiltration rates after the cleaning. Some PICP assets may require cleaning more than once per year, depending on the contributing drainage area. One asset constructed in 2019 routinely fails infiltration testing, and we are unsure why this asset is performing much worse than the others, considering the similarities in time of construction, materials, design and construction.

# 6 GRI systems do better when we take care of the soil

## 6.1 Introduction

Soil health within bioretention systems has been prioritized to ensure plant longevity, increase biodiversity of the soil and ensure water infiltration. The goals of focusing on soil composition are to increase the overall vigour, drought tolerance and ultimate longevity of the bioretention system.

The majority of the soils used in City of Vancouver GRI are compost and sand blends derived from a soil supply facility. The compost is typically derived either from mushroom manure, municipal green waste, yard waste or Class A Biosolids. It is then blended with sawdust or wood fibre to create a carbon to nitrogen ratio. The compost is then blended with river sand. Due to variability in feedstock composition, laboratory analysis is conducted for each project to ensure compliance with the City's bioretention soil specifications.

Following observations of poor plant health and compacted, sand-heavy soils in aging assets, we revised our bioretention soil specification to improve water holding capacity and reduce compaction (see Table 20). As part of ongoing maintenance, bioretention assets receive a biennial 5-cm top-up of composted mulch. This mulch must be aged for at least one year or compost blended with wood fibre to ensure nutrient availability.

*Table 20: Updated bioretention soil specifications*

| Properties | Bioretention Soil Parameters |
|---|---|
| C:N (Carbon : Nitrogen) | 30:1 - 10:1 |
| % OM (of tot. dry wt.) (Organic Matter) | 8-17% |
| % Sand (of tot. dry wt.) | 50-60% |
| % Silt (of tot. dry wt.) | 10-30% |
| % Clay (of tot. dry wt.) | 0-20% |
| Total Silt and Clay | 50% MAX |
| Acidity (pH) | 5.5-8.0 |
| Max Particle Size | 100% passing 12.5 mm sieve |
| Nitrogen (N) | 0.2-0.6% by weight |
| Phosphorus (P) (ppm) | 20-250 |
| Potassium (K) (ppm) | 50-1000 |
| EC (sat extr.) @ 25° C (Electrical Conductivity) (ds/cm) | <2.5 |
| SAR (sat extr.) (Sodium Adsorption Ratio) | <4 |
| Minimum saturated hydraulic conductivity (mm/hr) | 70 |
| CEC Ratio (Cation Exchange Capacity) | 30-50 |

Planting strategies have also evolved to support soil health. Plant species are chosen based on root system interaction within the soil. A matrix of species are installed where rhizome spreading, deeply rooting and nitrogen fixing root systems are placed together to interact and provide benefit to each other (see example in Figure 34). Deeply rooted plants bring moisture and stability to the soil. Shallow rootzone aid in aeration and stability, and nitrogen fixing bacterial enable the plants to absorb nitrogen. These strategies are outlined in *The City of Vancouver Planting and Ecology Design Guidelines for Green Rainwater Infrastructure*, published in 2024.

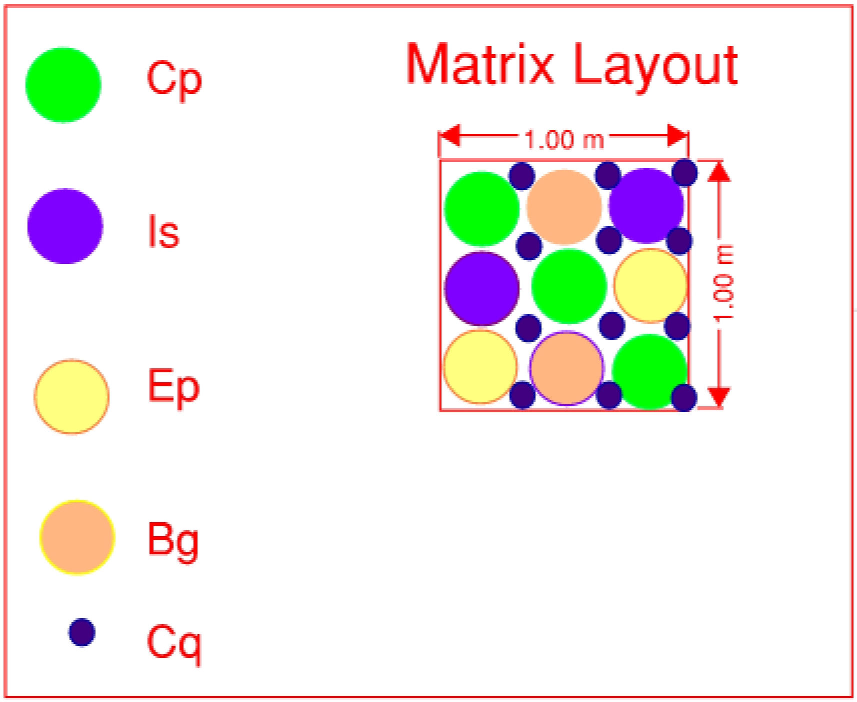



*Figure 34: Example matrix planting area layout. Layout is randomized while generally keeping within the planting ratio per m²*

Soil inoculation has been conducted at a number of newly planted assets in order to ensure adequate microbial life within the soil. As much of the soil installed within our systems is engineered, the necessary biological activity may be absent. To further enhance soil biology, we have trialed liquid soil inoculants containing nematodes, fungal hyphae, and bacteria. These organisms stimulate microbial activity, improve soil structure, and mobilize nutrients essential for plant health and infiltration.

## 6.2 Methods

Two primary methods are being tested for its impact on the health of soil and vegetation: soil inoculation and matrix planting. Table 21 shows the sites where these methods were tried and the year conducted. We also tried cover crop planting at one location, as it was evident from initial soil analysis that significant soil re-building was necessary. The soil was analyzed prior to the soil rebuilding with inoculation and cover crop planting, and progress is being tracked monthly. Soil samples were collected and sent to three laboratories to be analyzed for microbial activity, structure and contamination. The same suite of analysis will be conducted upon trial completion in the fall of 2026. Plant installation includes cover crop planting for soil rebuilding and matrix planting the following season. Liquid inoculation also occurred at Quebec St. and 1st Ave. bioretention systems in 2024 and 2025.

*Table 21: Sites and methods for soil restoration*

| Project Location | Assets Studied | Inoculation | Matrix Planting | Cover Crop Planting |
|---|---|---|---|---|
| **West King Edward** | 5 bioretention corner bulges | ✓ (2025) | ✓ (2025) | |
| **St. George Rainway** | 4 blocks of bioretention | ✓ (2024, 2025) | ✓ (2024, 2025) | |
| **Cambie St. and 31st Ave.** | 3 bioretention cells | | ✓ (2025) | |
| **Quebec St. and 1st Ave.** | 6 bioretention planters | ✓ (2024, 2025) | | ✓ (2024) |

The results of these methods will be monitored via visual inspection of plant health and survival. The plant survival is also logged separately in our local plant database, to help with understanding different factors on plant survival in GRI systems (such as micro-climate).

## 6.3 Results

Visual evidence is showing the plants are responding well to the efforts. In July 2025, Vancouver received less than half of the average July rainfall. Plants were highly stressed in many areas. However, the areas of soil inoculation have experienced a high degree of survival, and newly planted areas were blooming vigorously.

Still, monitoring the soil composition over time and the plant vigour is an ongoing effort. Results are not yet conclusive. We plan to include more specific results in the next monitoring report.

## 6.4 Conclusion

One goal of bioretention is to create long-term, self-sustaining systems that will require the right combination of plant species, soil composition and maintenance. We are experimenting with soil inoculation and matrix planting to help develop soil structure that support plants in the long term. Except for Quebec St. and 1st Ave., all the inoculated areas are new plantings, with the updated soil specification (see Table 20), still under warranty and receiving establishment watering. We have yet to see how these strategies will work in the long term. Further documentation and monitoring of the efforts will help in determining chosen species, soil and inoculation for the right microclimate. In the meantime, please use *The City of Vancouver Planting and Ecology Design Guidelines for Green Rainwater Infrastructure* to learn more about plant species and interactions with soil and biodiversity in GRI systems.

# 7 Does GRI improve local biodiversity?

To better understand the impact of the benefits of GRI, we are attempting a new program of measuring biodiversity at GRI assets. By tracking biodiversity within our assets, we are helping to support many of the objectives in the City of Vancouver *Biodiversity Strategy* including:

Objective 2: Support biodiversity within city parks and streets

Objective 4: Celebrate biodiversity through education and stewardship

Objective 5: Monitor biodiversity

We have monitored biodiversity before the construction of the St George Rainway (a 4-block long bioretention system recently completed), and will continue monitoring this in the years after its construction. We used citizen science and iNaturalist to document the types of species along St George St. (between $5^{th}$ Ave. and East Broadway) during 4 bioblitzes in 2022. We used this data to determine the number of species within a two-block radius of St George St. We will then repeat bioblitzes following construction, once plants have time to establish to measure changes. For the full methodology, results and recommendations, please see our *St George Rainway 2022 bioblitz report-back*. In the next monitoring report, we will include more detailed results of post-construction biodiversity monitoring at St George Rainway.

# 8 Routine maintenance sustains GRI condition

## 8.1 Introduction

The condition assessment program began in 2022 with the objective of identifying non-routine maintenance needs, failed assets requiring rehabilitation and tracking condition scores over time. The program began with permeable pavement and bioretention systems, and has been expanded to rainwater tree trenches and infiltration trenches in 2024. The first full set of scores was finalized in 2024.

This section presents the results of condition assessments conducted in 2022 and 2024.

## 8.2 Methods

### 8.2.1 All condition scores

Condition scores range from 1-5, with 1 being very good, and 5 being very poor. Different components of the systems are visually evaluated including the contributing drainage area, inlet, outlet, monitoring well, cleanouts, planting bed, ponding area, vegetation and soil. Wet weather and post-24 hour rain inspection data are also incorporated into the condition scoring to measure bypass, short-circuiting and excessive ponding. An inspection form was created and is available upon request. The results of the forms were downloaded and assigned scores, then averaged across all score categories to come up with the average condition score for that asset.

### 8.2.2 Bioretention condition scores over time

Bioretention condition assessment program began in 2022 and was repeated in 2024. With results from both rounds of monitoring we can start to see changes in asset conditions over time. In 2022, 147 assets were under routine operation, and were included in condition assessments. Several assets were removed temporarily in 2023-2024 for rehabilitation or were removed because they were found to be non-functional during condition assessments. Those assets not inspected again in 2024 and maintained the same asset score as in 2022. Many will be re-assessed in the next round of condition assessments in 2026. In 2024, 108 assets were under routine operation and included for condition assessments, 102 of those were overlaps with those inspected in 2022.

## 8.3 Results

### 8.3.1 All condition scores

The majority of GRI assets (76%) have condition scores of 1-3, representing very good to fair condition status and a requirement for only routine operation at these assets. Figure 35 shows the distribution of condition scores by asset type. There are a significant number of “very poor” assets in bioretention and subsurface infiltration trenches, and these are largely from assets that were constructed prior to the Rain City Strategy and current standards for GRI construction. These systems often have design or construction flaws that require rehabilitation. Rainwater tree trenches are all newer assets after the adoption of the Rain City Strategy in 2019, and are all operating well. Permeable pavement condition scores and their relation to infiltration rate is discussed in the previous section.

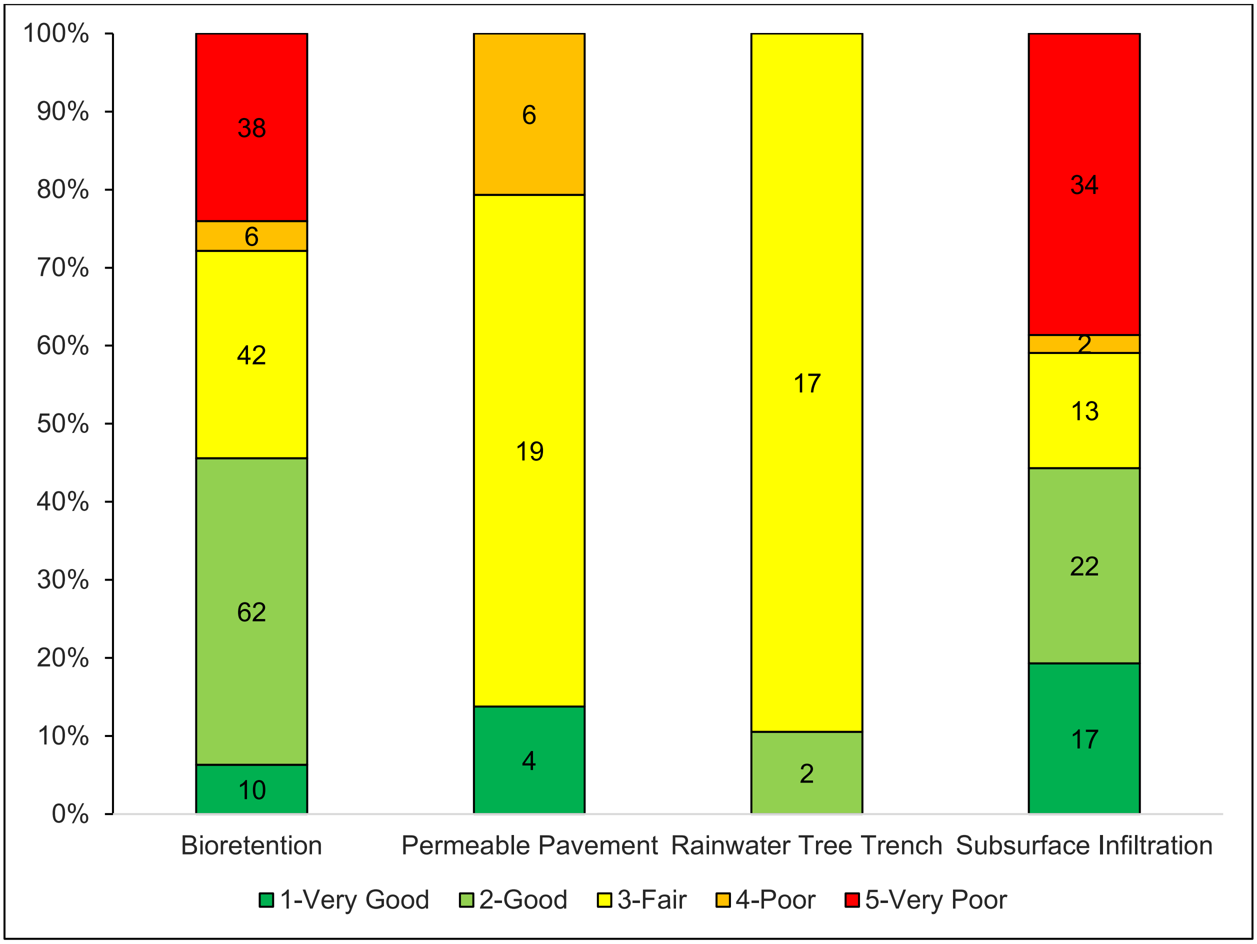



*Figure 35: Condition score by asset type*

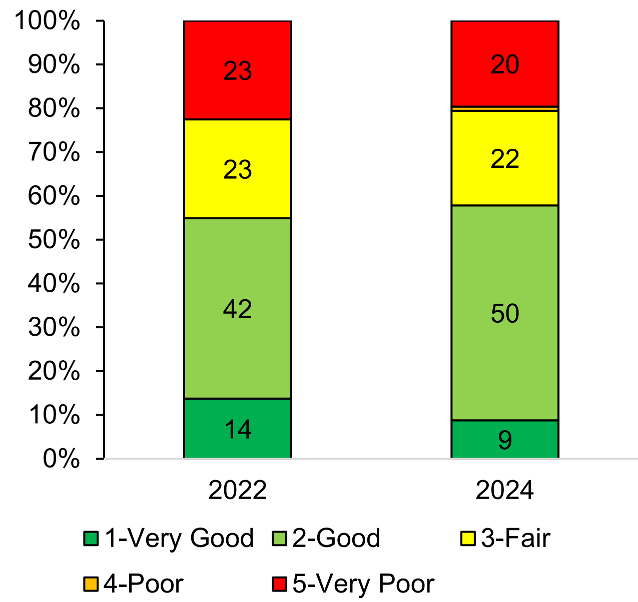
### 8.3.2 Bioretention condition scores over time

Longitudinal data tracking began with bioretention assessments in 2022 and 2024. The average condition score improved slightly from 3.1 in 2022 to 2.7 in 2024. Of the 102 assets assessed in both years:

- 56 assets maintained the same score,
- 23 assets showed improvement,
- 23 assets showed deterioration.

Only 3 assets experienced significant decline (from score 2 to 5), while 6 assets which had undergone rehabilitation showed substantial improvement (from score 5 to 2 or 3). Some score discrepancies may be attributed to interpretation of field data or errors in form completion.

Overall, the majority of bioretention assets (nearly 80%) fall within scores 1–3 and require only routine maintenance. Continued monitoring over a longer period will be necessary to identify trends and rates of deterioration.




| 2022 vs 2024 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| 1 | 2 | 11 | 1 | 0 | 0 |
| 2 | 5 | 27 | 7 | 0 | 3 |
| 3 | 2 | 10 | 10 | 1 | 0 |
| 4 | 0 | 0 | 0 | 0 | 0 |
| 5 | 0 | 2 | 4 | 0 | 17 |

*Figure 36: Condition scores for bioretention assets in 2022 and 2024. The graph on the left shows the distribution of scores. The table on the right shows the change in scores from 2022 (rows) to 2024 (columns)*

## 8.4 Conclusion

The condition assessment program began in 2022 to identify maintenance needs and track asset performance over time. Currently 76% of all GRI assets are in very good to fair condition, requiring only routine operation and maintenance. In observing changes in condition scores from 2022 to 2024 for bioretention assets, we saw equal amounts of improving and deteriorating. This is different from conventional infrastructure asset management where assets tend to degrade linearly over time, and so we will continue to monitor and complete condition assessments to determine progress over time.

# 9 Conclusion

The importance of monitoring GRI systems is a vital step to understanding how the systems perform in the real-world. Monitoring GRI systems enables us to:

- adapt designs to maximize runoff collection and infiltration
- decide appropriate maintenance practices
- optimize plant selection
- determine life cycle of systems and identify degradation
- meet performance and regulatory standards
- understand the biodiversity benefits
- engage with the public

Using data from our monitored sites, we have determined that GRI systems across the City are performing as expected. Below are the key findings from the 2023-2025 monitoring period and next steps for the monitoring program:

**GRI systems drain down quickly**

From our monitoring results we can answer the three objectives that fall under this key finding:

1. Do GRI systems drawdown at the surface within 24hrs?
2. Do GRI systems drawdown at the subsurface within 72hrs?
3. Does the drawdown rate of real systems match the design infiltration rate?

Using visual inspections during extreme rainfall events, none of our bioretention systems had surface ponding after 24 hours.

Using water level loggers, we found that on average our systems do drawdown at the subsurface in under 72 hours. Our sites show a fairly even distribution of drawdown rates, with 4/13 sites having a low average drawdown rate (<15 mm/hr), 6/13 sites have a medium average drawdown rate (15-50 mm/hr), and 3/13 sites have a high average drawdown rate (>50 mm/hr).

Newer bioretention sites without an underdrain are slightly lower than their design infiltration rate, however these sites still exhibit very quick drawdown rates.

_Next Steps_

We will continue with rainfall and post rainfall inspections to check for surface ponding and how system perform in rainfall.

Level loggers will be deployed at a set of representative sites to ensure that they are functioning as designed and to compare their drawdown rates and duration to design data. We will continue to monitor at a subset of existing sites to detect any changes in drawdown rates and drawdown durations and to make general findings about long-term performance of GRI systems.

**GRI retains moisture in soil**

Seven RTTs and two bioretention have had soil moisture monitored for several years, and moisture content never goes below 5%, the lowest wilting point for sandy soils commonly used in GRI. Across all systems, the lowest moisture content occurs in September/October after a long dry summer. Sensors below pavements show the least amount of variation likely due to not being exposed to the atmosphere and losing moisture through evaporation.

*Next Steps*

We will continue to monitor at existing sites until sensors are no longer functional. Sensor reliability and data quality have been issues; therefore we will not be adding new sensors to sites. Once installed they are difficult to remove, as many are under pavement.

**GRI systems reduce the amount of runoff entering the sewer system**

We found a significant difference in the sewer flow volumes downstream of GRI pre- and post-construction. It is likely that some of the volume reduction is due to the GRI systems, however it is hard to isolate all the variables that could be affecting the flow volume.

*Next Steps*

We are currently collecting sewer flow data for a paired catchment study. The purpose of this study is to collect data from two similar catchment areas, one with GRI and one without. With this type of study, we use one catchment as a control and can attribute changes to the flow volume in the other catchment to the effects of GRI, while also accounting for climate variability and other external influences. This will help address some of the uncertainty for the sewer flow monitoring results that were included in this report.

**Permeable pavements require significant routine maintenance**

Previous lessons learned from PICP maintenance taught us that restoring the infiltration capacity of older systems that never received maintenance is not possible. Annual power washing of new assets is required to maintain the infiltration capacity of the systems.

*Next Steps*

We will continue with the annual power washing of our newer PICP systems. There are new permeable pavement typologies being installed (porous asphalt and grass grid pavers) that will be monitored in the future for performance.

**GRI systems do better when we take care of the soil**

Soil is an integral component of a bioretention system as it is the backbone of plant health and water infiltration.  Current efforts are being made to ensure healthy living soils in the bioretention systems.

*Next Steps*

We will continue to monitor using the plant database, soil inoculation and sampling to delineate the right combination of plant matrices, soil specification and inoculation. Quebec St. and 1st Ave. soil renewal trials report will be written in the fall of 2026.

**Does GRI improve local biodiversity?**

Biodiversity was monitored using citizen science and bioblitzes before the construction of the St. George Rainway. Post construction biodiversity monitoring still needs to be conducted, as the system is only newly finished and has not had a chance to establish.

**Routine maintenance sustains GRI condition**

Using conditions assessments, we found 76% of all GRI assets are in very good to good condition and only require routine operation. Bioretention have shown mostly an improvement over time, mostly due to routine maintenance and the bioretention rehabilitation program for assets with poor scores.

*Next Steps*

We will continue with our condition assessment program, to track our systems over time, and establish the best maintenance practices moving forward for our new systems being constructed.

The City of Vancouver also has several monitoring programs underway that we will report on at a later time. This includes performance monitoring at an engineered wetland, soil rebuilding at five bioretention sites, condition assessments and scores for all subsurface practices and monitoring of oil-grit separators.

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