Stormwater Management Manual

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Drawdown Tests in Green Street Facilities with an Underdrain and a High-Fines Soil Blend

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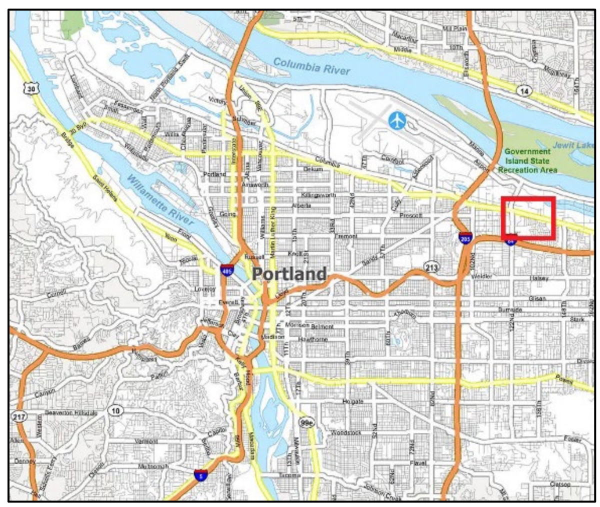
Summary

This report summarizes results from drawdown tests at five green streets constructed in 2018 in the Slough Outfall 104B project area. The facilities were about three years old at the time of the testing, with fully-established vegetation. All of them have underdrains and four are fully lined. They contain a "high-fines" soil blend with more loam than BES' standard blend. The results confirm the facilities generally were meeting BES' standard design assumption for infiltration of 6 in/hr.



Slough 104B Project (outlned in red)

The day-long tests were completed by staff from BES' CRM and Field Operations teams. The tests consisted of repeatedly flooding the facilities with a water truck and documenting the subsequent decline in the depth of ponded water. BES Staff flooded each facility four times in succession. Infiltration rates reached their minimum value during the final drawdown period for each facility, with final infiltration rates ranging between 5.1-12.1 in/hr among the five facilities. Testing took place in February 2022, during the winer when infiltration rates are typically at their seasonal low due to the high moisture content of the soil and relatively low temperatures.

A separate report documents results from a similar series of drawdown tests BES completed in 2017 for a group of older lined facilities (BES, 2018). More information about the high-fines soil blend and the monitoring program at the Slough 104B project are contained in a separate BES report (BES, 2022).

Background

BES completed this field work and analysis to investigate infiltration rates in established green street facilities containing a trial soil blend with more silt and clay (topsoil) than BES's standard soil blend. As documented in a separate report, the work was an important part of BES' development of a specification for a soil blend with better water-holding characteristics than the standard blend (BES, 2023). The trial soil blend for the Slough Outfall 104B project had a fines content of close to 20% passing the #200 sieve, which is substantially more than the fines content in typical blends from vendors meeting the specification for the standard soil blend (2008 specification). Vendors usually target the very low end of the allowable range (~10%) for fines passing the #200 sieve in the standard blend.

It has been well documented by engineering bench tests that bioretention soil blends containing loam have lower infiltration rates than blends without loam, and that increasing percentages of fines result in decreasing infiltration rates. Field performance is not as well documented for soil blends with more fines, however there is research indicating plant root systems, and their associated biological activity, are essential for aggregating and stabilizing soil particles and porosity in bioretention systems. Some research suggests bioretention systems drain somewhat better after plants are established, compared with initial installation, presumably due to the development of root systems and associated soil structure. Staff completed the tests a little more than three years after construction to obtain rates representative of fully-established systems.

The drawdown tests represent the culmination of an extended period of preparation for testing established facilities containing a high-fines blend. BES completed hydraulic column tests with high-fines soil blends in 2012 and over the next five years constructed a small number of green streets projects with modified soil blends containing more fines. Staff didn't observe evidence of inadequate infiltration rates during field visits, but there was no formal testing of drawdown rates. The Slough 104B project provided the first significant opportunity to plan and efficiently conduct larger-scale field testing.

Fully-lined system with underdrain visible, just prior to loading blended soil

Facility Configuration

The five facilities selected for testing are among 53 water quality facilities BES constructed in 2018 as part of the Slough 104B project to treat runoff draining from the project area to the Columbia Slough. They were all designed to pond six inches of water and have an underdrain that's about a quarter the length of the facility, consistent with the standards of the 2020 SWMM. Four of them have a full liner[1]. The depth of blended soil is 2 ft across ¾ of the length of each facility, with 1 ft of blended soil above the underdrain in the remaining section. The high-fines blend contains 30% loam, 50% sand, 10% compost, and 10% aged hemlock mulch, by volume. The facilities have treatment areas (facility footprints) ranging from 52.1 – 106.9 ft^2 (see Table 1.) Staff selected smaller facilities to conserve water and allow for more fillings by a water truck during a single day.

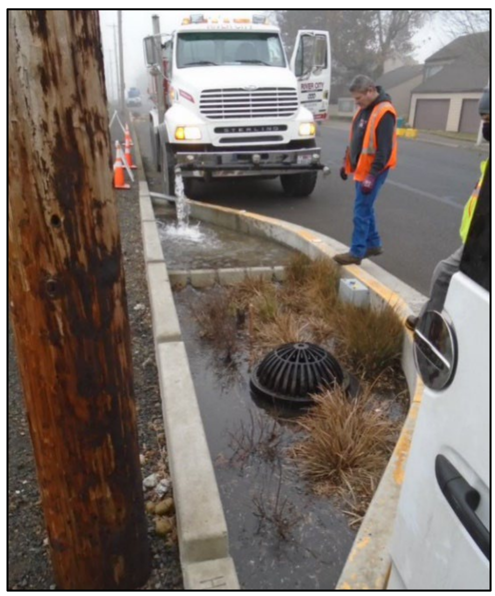
Table 1. Selected characteristics of Slough 104B facilities

Monitoring ID	Plan Set ID	Address	Treatment Area (ft^2)	Drainage Area (ft^2)	Under-drain	Soil	Liner
GS29	48	13250 Shaver St.	67	9,366	Short	HF*	Full
GS31	34	12601 NE Shaver St.	55	7,002	Short	HF	Full
GS37	15	13110 NE Prescott Dr.	70	13,293	Short	HF	Full
GS38	28	4106 NE 133rd Ave.	107	25,458	Short	HF	Street Side
GS39	44	13171 NE Shaver St.	52	2,288	Short	HF	Full

*High-fines soil blend containing ~17% combined silt and clay.

Test Methods

The drawdown tests consisted of flooding each facility and recording the subsequent decline in ponding depths via manual depth gauges as confirmed by HOBO pressure transducers. BES hired a private water truck to provide water for flooding the facilities. Using the valve on the truck, the operator released water along the edge of the street approximately 10 ft upslope of the facility entrance, adjusting the flow as needed to minimize soil erosion at the facility entrance. For facilities with a large concrete forebay, the truck released water directly into the forebay (see photo). It typically took only 10-15 minutes to fill a facility, which was due partly to the relatively small sizes of the facilities. This simple approach was time efficient and allowed for the logistics associated with filling each facility four times during the day (a total of 20 fillings at the five locations in the project area), including the



Water truck filling a facility, discharging into the concrete forebay

[1] It's assumed the permeability of the imported soil blend and the presence of an underdrain are the primary factors influencing drawdown rates, and that the results for the single unlined facility (GS38) should be comparable to the results from the other facilities.

movement of the truck between the facilities and refilling the truck two times at a nearby hydrant.

The facilities were filled until water started to enter the overflow bypass drain. Once overflow ceased, staff recorded each time interval during which the water depth decreased by an inch until the facility was completely drained. Simultaneously, Onset HOBO pressure transducers recorded the water depth in one minute intervals and the data were later verified against the manual depth records. Staff used data from the Onset HOBO pressure transducers to complete the analysis of infiltration rates.

Each facility infiltrated a total of approximately 24 inches of water during the testing, based on the average facility ponding depth of six inches and the four fillings. Assuming an average soil depth of more than 1.5 feet, and a soil porosity of 40-50%, the equivalent of at least two pore volumes[2] of water were infiltrated by the systems during the tests.

Antecedent Conditions

The tests were performed on February 10, 2022. The total measured rainfall at the closest HYDRA gauge for the 14-day period prior to the drawdown tests was 0.48 in. This represents a relatively dry period during the winter season in the Pacific Northwest. Staff therefore expected the soils to be unsaturated and that an additional filling would be required to reach conditions approaching saturation. This was a factor in deciding to directly release water from the truck in order to save time and complete four fillings.

Results

Infiltration rates for each drawdown period and facility are reported in Table 2. Infiltration rates (in/hr) by drawdown period and facility were visualized with line and scatter plots (Figure 1 & 2).

Table 2. Infiltration rates (in/hr) for each facility by drawdown period

	Drawdown Period			
Monitoring ID	**1**	**2**	**3**	**4**
GS29	23.8	18.9	11.5	8.9
GS31	31.9	25.7	15.1	12.1
GS37	12.6	11.4	6.4	6.5
GS38	14.7	12.5	5.6	5.1
GS39	22.6	19.3	10.2	8.6

[2] The total pore space within the layer of blended soil.

Figure 1. Plot displaying infiltration rate (in/hr) of facilities by drawdown period

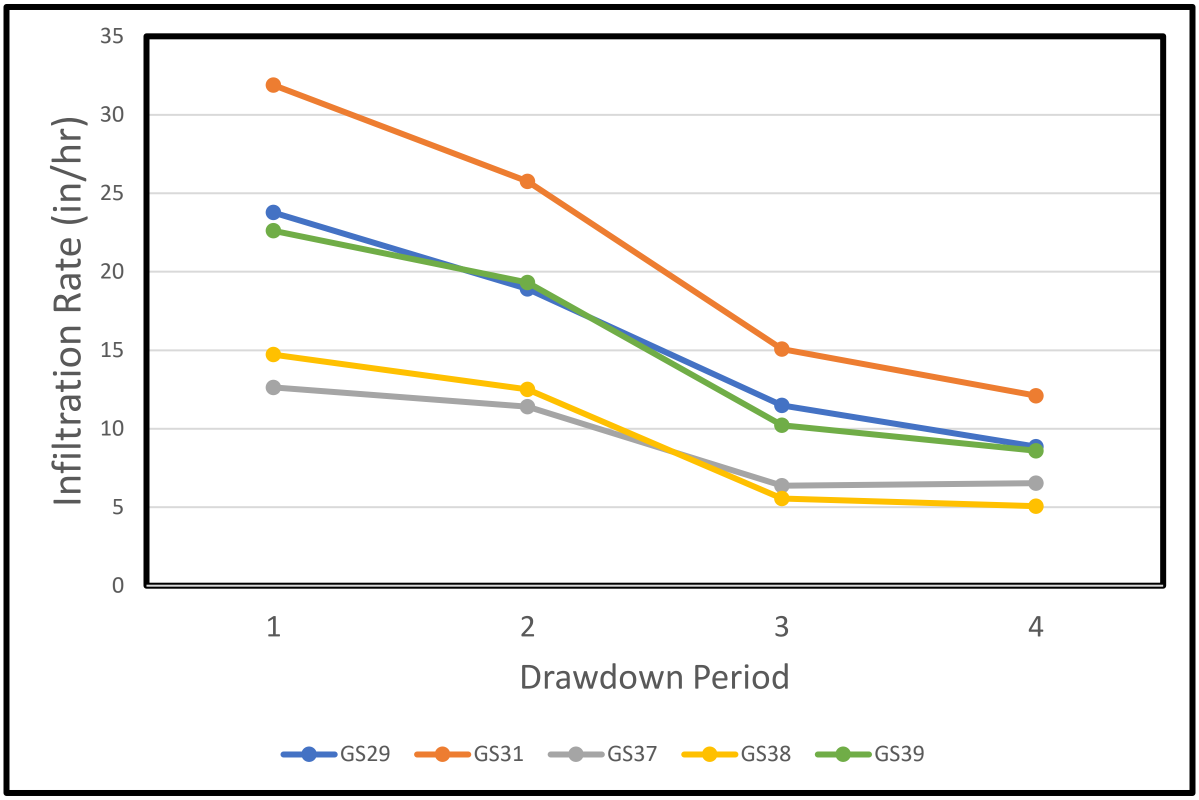


Figure 2. Plot displaying infiltration rate (in/hr) by facility

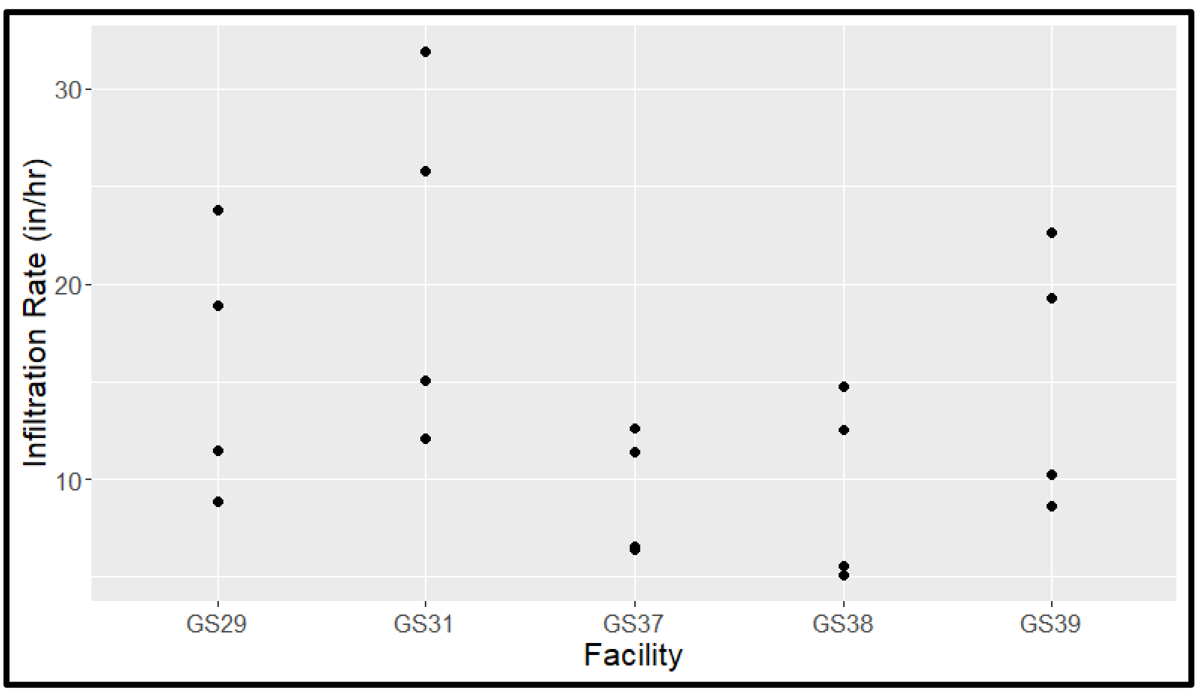


Table 3. Comparison of infiltration rates (in/hr) between 2017 drawdown tests with the standard soil blend and 2022 drawdown tests with the high-fines soil blend*

	First Filling (in/hr)	Final Filling (in/hr)
Standard Soil Blend (2017)	21.4 – 91.8	10.6 – 38.7
High-Fines Soil Blend (2022)	12.6 – 31.9	5.1 – 12.1

*Testing was completed in the winter in both cases.

Conclusion

Infiltration rates declined significantly during drawdown periods two and three, relative to the previous periods, with little or no change in rates during drawdown period four compared with the results for period three. These results suggest the systems may have been approaching steady-state conditions during which the imported soil blend was mostly saturated. (Figure 1). The rates ranged from 5.1-12.1 in/hr during the final drawdown period, with a much tighter grouping of results between the facilities during the final period compared with after the first filling.

As expected, the final rates were substantially lower than the range of rates documented by BES in 2017 during similar trials for a group of older green streets containing BES' standard soil blend. It's interesting to note the range of infiltration rates after the first filling for the high-fines soil blend are similar to results for the final drawdown period in the 2017 tests (Table 3).

These results provide solid evidence the Slough 104B facilities containing the high-fines blend were draining within an acceptable range in their third winter of service, relative to BES' design assumption of 6 in/hr for the blended soil. The data confirm the suitability of the high-fines blend in terms of its hydrologic performance in mature facilities and suggest facilities with the blend may provide substantially better flow-control performance than facilities containing BES' standard blend for facilities.

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