Holloway Green Street Annual Monitoring Report 2017-2018

Project Overview

The San Francisco Public Utilities Commission (SFPUC) is currently implementing the first phase of the 20-year $6.9 billion citywide Sewer System Improvement Program (SSIP). As part of the first phase of the SSIP, the SFPUC is constructing eight green infrastructure (GI) Early Implementation Projects (EIPs), one in each of San Francisco's urban watersheds. The Holloway Green Street project is the EIP in the Lake Merced watershed.

The Holloway Green Street project implements two types of green infrastructure, bioretention planters and permeable pavement, along eight blocks of Holloway Avenue starting at Ashton Avenue and extending east to Lee Avenue in the Ingleside neighborhood. Holloway Avenue is a typical 60-foot-wide neighborhood residential street with two lanes of traffic and parallel parking along both sides. The street blocks are short, approximately 225 linear feet. Sidewalks along Holloway and Harold are typically 12 feet wide and contained minimal landscaping or street trees prior to project construction.

Bioretention takes two forms. Corner bulbouts containing either flow-through planters or rain gardens are on the western end of six blocks. One block between Jules Ave and Faxon Ave has a series of mid-block infiltrative bioretention planters within the sidewalk in lieu of corner bulbouts, which were infeasible due to driveway conflicts. The final block between Faxon Ave and Capitol Ave has no bioretention, only permeable pavement. The bioretention planters are sized to manage stormwater runoff from the sidewalk, as well as a small portion of the roadway that drains directly to the planters.

Pervious concrete was installed within the 7-foot-wide parking lanes on both sides of Holloway Ave on all eight blocks in the project area. The pervious concrete removes additional stormwater from the combined sewer system by capturing the majority of the roadway runoff, storing it in a subsurface gravel reservoir layer, and infiltrating it into the underlying native soil as feasible.

The Holloway Green Street green infrastructure facilities are sized to manage stormwater from the street and sidewalks as well as the facilities themselves, collectively referred to as the drainage management area (DMA). The blocks have varying configurations and combinations of bioretention corner bulbouts, mid-block bioretention planters, and permeable pavement. One block has underdrained bioretention while the rest are infiltrative. All bioretention planters were initially sized by designers in accordance with the EIP Minimum Performance Metric, which calls for an aggregate 0.75 inches of unit storage[1]. For typical rain gardens, this translates into a sizing ratio[2] of around 5%. The equivalent sizing ratio for the permeable pavement is 25%. Facility sizing was refined during design development based on physical constraints and a site-specific hydrologic model[3] to more accurately reflect site conditions. Geotechnical exploration found a mixture of soil types[4]. Final design resulted in a bioretention sizing ratios ranging from 3.4% to 6.5% and permeable pavement sizing ratios ranging from 25% to 31%. Sizing ratios at the monitored blocks ranged from 4.0% to 4.7% for bioretention and 25% to 27% for pervious concrete.

[1] Unit Storage Depth is a measure of the storage capacity provided by GI relative to its DMA. It is equal to the depth of water that, if multiplied by the DMA, is equal to the storage provided by the GI facilities.

[2] Sizing Ratio is a measure of GI facility footprint relative to its DMA. It is equal to the facility size divided by the DMA.

[3] EPA Stormwater Management Model (SWMM), Version 5.1.

[4] Double-Ring Infiltrometer tests performed on five blocks indicated infiltration rates ranging from 0.30 in/hr to 3.67 in/hr. Per SFPUC guidance, a correction factor of 0.33 was applied to yield design infiltration rates ranging from 0.10 in/hr to 1.22 in/hr

Figure 1a, 1b and 1c: A mid-block sidewalk planter, end-of-block bulbout planter, and pervious concrete.

Four blocks, all with varying GI technologies and underlying soil infiltration rates, were monitored during the 2017-2018 water year. The performance was evaluated through post-construction flow monitoring in catch basins at the end of each block. Baseline flows (i.e., stormwater runoff under pre-construction conditions) were established by monitoring an unimproved block adjacent to Holloway Avenue. The end-of-block flows were compared against baseline flows, and the difference was credited to facility performance. No monitoring was conducted prior to construction. The five monitoring locations including the baseline block and four GI locations (Figure 2) are located at:

- Capitol @ DeMontfort (baseline block)
- Holloway @ Jules (Mid block planters & pervious concrete)
- Holloway @ Faxon (Only pervious concrete)
- Holloway @ Capitol (End of block planters & pervious concrete)
- Holloway @ Plymouth (Underdrained end of block planters & underdrained pervious concrete

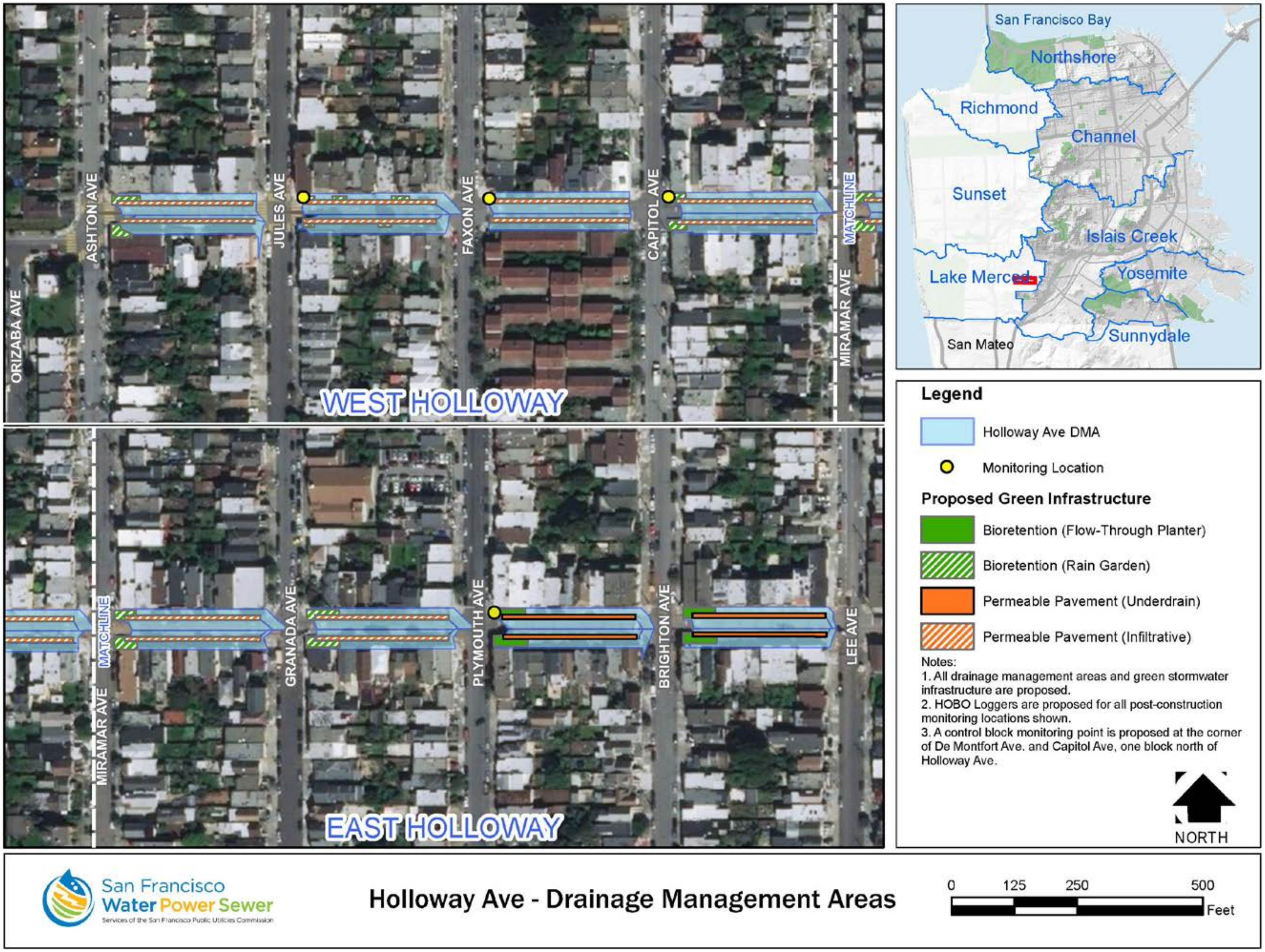

Figure 2: Project overview map

Figure 3 shows the spatial relationship between the baseline block and the project area.

Figure 3: Location of the baseline block relative to the project area

Table 1 provides the DMAs for both the baseline block and the monitored blocks, as well as the sizing ratio for the GI technologies. The baseline block DMA is larger than the project block DMAs because it is located on a corner where the two intersecting streets both drain to the catch basin. The DMAs were delineated using the subcatchment layer from the City and County of San Francisco (CCSF) Hydrologic and Hydraulic model and were then adjusted according to field observations of drainage patterns during wet conditions.

Table 1: Characteristics of the Holloway Green Street GI facilities and Drainage Management Areas (DMAs)

Metric		Capitol x DeMontfort (Baseline block)	Holloway x Jules	Holloway x Faxon	Holloway x Capitol	Holloway x Plymouth
Total DMA (ft^2)		28,700	7,020	5,170	7,010	6,900
Design Infiltration Rate (in/hr)		N/A	0.71	1.22	0.86	0.14
Bioretention	DMA (ft^2)	N/A	3,330	0	3,373	3,309
	Area (ft^2)	N/A	139	0	158	134
	Sizing Ratio (%) [1]	N/A	4.2%	N/A	4.7%	4.0%
Pervious Concrete	DMA (ft2)	N/A	3,691	5,165	3,635	3,589
	Area (ft2)	N/A	977	1,293	938	940
	Sizing Ratio (%)	N/A	26.5%	25.0%	25.8%	26.2%

The Holloway Green Street project is estimated to have reduced the total volume of stormwater entering the sewer system from the project area by 77% (655,000 gallons) during the 2017-18 rainy season.

Learning Goal

The Holloway Green Street project installed different combinations of bioretention and pervious concrete across eight blocks that were virtually identical on the surface in terms of size, layout, and slope. This provides an excellent setting to compare the variation in performance that may result from different forms and combinations of GI on similar blocks, as well as variable soil conditions across the project area. For example, performance at the two blocks with underdrained permeable pavement and flow-through bioretention planters can be compared to a block with infiltrative permeable pavement and bioretention. The block with only permeable pavement can be compared against blocks with both permeable pavement and bioretention, and blocks with bulb-out planters at the intersections can be compared against mid-block planters.

Results of Monitoring Period 2017-2018

All the monitored blocks reduced the total volume and peak discharge rates to the CSS. The results of the monitoring data are discussed below in relation to these two primary performance metrics.

Was Flow Volume Reduced?

Overflow from the monitored blocks was significantly less than the baseline flow for all blocks. Measured across the whole rainy season, monitored volume reduction ranged from 56%-96% with an average 77%. Performance is strongly correlated to infiltration rate with the best performance at the western end of the project and generally decreasing to the east. The SWMM model was in general agreement with the monitoring results, estimating that GI reduced runoff volume by 75% across the four monitored blocks, and by 70% across the full project area. According to both the monitoring results and the supporting modeling results, the overflow from the Model Block was significantly less than the baseline flow during the 2017-18 monitoring period (Figure 8).

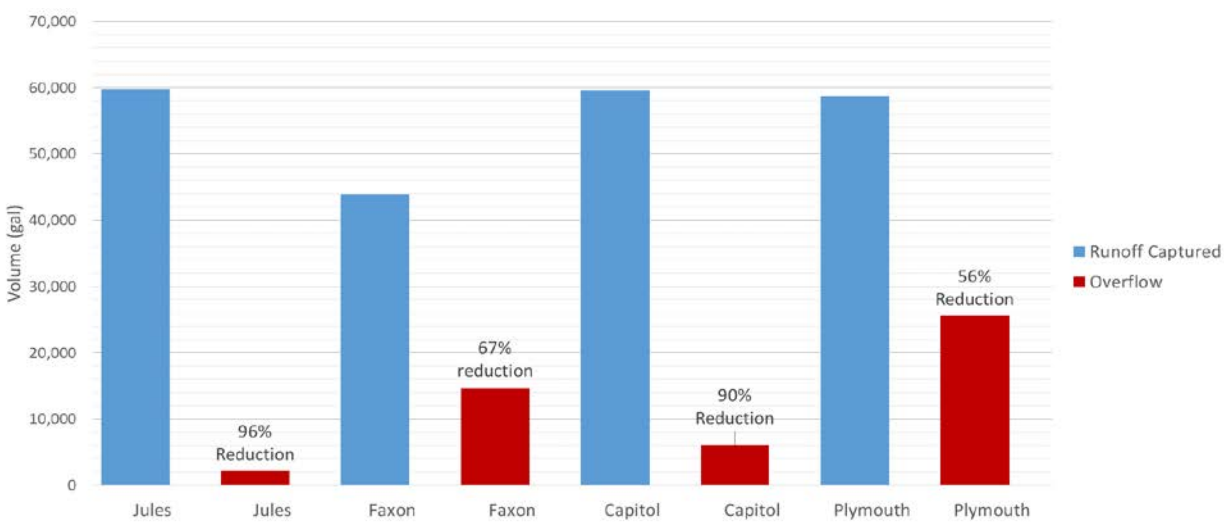

Figure 4: Monitored block performance for the 2017-2018 monitoring period.

Comparing modeled versus measured performance at the block scale (Table 3), three of the four monitored blocks significantly exceeded SWMM model predictions, while Holloway x Faxon saw a smaller reduction than predicted. As noted previously, the infiltration rate of the native soil is a major determinant of GI performance. The SWMM model simulates one-dimensional infiltration in the vertical direction only. In reality, lateral infiltration also occurs. Additionally, the SFPUC policy of applying a 0.33 correction factor to the infiltration rate as determined by double-ring infiltrometer testing, which is consistent with standard practice nationally, is intended to be a conservative measure that accounts for soil compaction, siltation, or other potential impacts over the lifetime of the facility that may diminish infiltration capacity. For example, the measured infiltration rate at the block of Holloway x Faxon was 3.67 inches per hour, and the corrected infiltration rate used by the model was 1.22 inches per hour. However, this project was monitored the first year after its construction, and the corrected infiltration rates likely underestimate the infiltration capacity of the native soil during the monitoring period.

Table 2: Modeled versus measured performance for the 2017-2018 rainy season

Block	Subcatchment	DMA Size	Facility Size	BMP Sizing Ratio	Design Infiltration Rate[1]	Modeled Flow Reduction				Measured Flow Reduction			Extrapolated Flow Reduction[3]		
						Volume			Peak Flow	Volume		Peak Flow[2]	Volume		Peak Flow
		(sf)	(sf)	(%)	(in/hr)	(gal)	(%)		(%)	(%)	(%)	(%)	(gal)	(%)	
Ashton	BR1-North	2,742	129	4.7%	0.20	13,748	40%	61%	57%	--	--	--	71,900	69%	82%
	PP1-North	3,555	926	26.0%		26,127	77%								
	BR1-South	3,122	204	6.5%		18,309	49%	64%	61%	--	--	--			
	PP1-South	3,555	926	26.0%		26,127	77%								
Jules	BR2-North	3,330	139	4.2%	0.71[4]	20,221	64%	83%	64%	57,500	96%	94%	105,100	96%	94%
	PP2-North	3,691	977	26.5%		25,951	100%								
	BR2-South	2,955	101	3.4%		16,415	58%	81%	62%	--	--	--			
	PP2-South	3,691	977	26.5%		25,951	100%								
Faxon	PP3-North	5,165	1,293	25.0%	1.22	36,828	100%	100%	100%	29,300	67%	65%	58,300	67%	65%
	PP3-South	5,709	1,429	25.0%		40,678	100%	100%	100%	--	--	--			
Capitol	BR4-North	3,373	158	4.7%	0.86[4]	22,488	70%	86%	70%	53,500	90%	89%	101,300	90%	89%
	PP4-North	3,635	938	25.8%		25,784	100%								
	BR4-South	3,404	168	4.9%		23,205	71%	86%	70%	--	--	--			
	PP4-South	3,635	938	25.8%		25,784	100%								
Miramar	BR5-North	3,498	153	4.4%	0.49	19,861	60%	80%	60%	--	--	--	96,200	89%	83%
	PP5-North	3,478	1,068	30.7%		33,151	100%								
	BR5-South	3,120	123	3.9%		16,974	57%	80%	60%	--	--	--			
	PP5-South	3,478	1,068	30.7%		33,151	100%								
Granada	BR6-North	3,451	160	4.6%	0.32[4]	18,645	50%	69%	58%	--	--	--	98,700	89%	83%
	PP6-North	3,655	917	25.1%		30,457	87%								
	BR6-South	3,163	206	6.5%		19,725	57%	73%	62%	--	--	--			
	PP6-South	3,655	917	25.1%		30,457	87%								
Plymouth	BR7-North	3,309	134	4.0%	0.14	5,880	14%	38%	32%	33,100	57%	38%	62,400	57%	38%
	PP7-North	3,589	940	26.2%		15,191	60%								
	BR7-South	3,172	165	5.2%		6,967	17%	40%	34%	--	--	--			
	PP7-South	3,589	940	26.2%		15,191	60%								
Brighton	BR8-North	3,141	128	4.1%	0.10[4]	4,909	16%	42%	32%	--	--	--	61,200	57%	38%
	PP8-North	3,588	920	25.7%		21,862	64%								
	BR8-South	3,095	180	5.8%		6,549	22%	44%	34%	--	--	--			
	PP8-South	3,588	920	25.7%		21,304	63%								
TOTAL		**106,132**	**18,244**	**16.3%**	**0.51**	**594,999**	**70%**	**70%**	**60%**	**173,400**	**78%**	**72%**	**655,100**	**77%**	**72%**

1 Values reflect a correction factor of 0.33 consistent with SFPUC policy for double-ring infiltrometer testing.

2 Values are an average from storms with greater than 0.1 inches of rainfall.

3 Extrapolated reductions at non-monitored blocks were scaled up from model results based on the ratio of monitored to modeled reductions at monitored blocks with the same combination of GI facility types.

4 Value was interpolated from measured rates at two neighboring blocks.

The SWMM modeling results were used to extrapolate monitored project performance from four blocks to the entire project area. The ratio of monitored to modeled volume reduction at the four monitored blocks was applied to the modeled performance at the other four blocks to estimate their annual performance. Estimated performance for the blocks of Ashton, Miramar, and Granada were extrapolated from Jules and Capitol since those five blocks all have infiltrative bioretention and pervious concrete. Estimated performance at Brighton was extrapolated from Plymouth since both blocks have underdrained bioretention and permeable pavement.

The SFPUC decided to install pervious concrete all the way up to the curb on the Holloway x Faxon block, with the knowledge that fines might accumulate at the low-lying edge along the curb. The advantages of this configuration include less formwork during construction and, even though the concrete adjacent to the curb may become clogged and function as an informal gutter, heavier flows during intense rainfall spill farther out into the street where they can infiltrate through the cleaner concrete. Field reconnaissance in January 2019 confirmed that a thin swath of the permeable pavement had become clogged (Figure 9). As a result, the sidewalk portion of the DMA on this block is not fully managed because it drains into the informal gutter and flows to the catch basin at the corner; there are no bioretention planters on this block to intercept gutter flow. This explains why monitored performance on this block was less than predicted by the model. Approximately 45% of the DMA on this block comes from the sidewalk. If the pervious concrete is assumed to manage 100% of the roadway runoff, as predicted by the model and supported by visual observation, then monitoring results indicate that effectively 25% of annual sidewalk runoff volume is managed by the pervious concrete while the other 75% flows directly to the catch basin.

Figure 5a and 9b: Fines clogging the pervious concrete, informal gutter formed at edge of curb.

A 3.96-inch storm occurring over 27.5 hours on January 8th was the largest storm fully managed by any of the blocks (Holloway x Jules). This was the largest storm that occurred during the monitoring period, and volume reduction for this storm on the other three blocks ranged from 16% at Plymouth to 81% at Capitol. The largest storm fully managed by Capitol was 0.72 inches on March 20th, and the largest at Plymouth was 0.34 inches on January 24th. Per the explanation above, Holloway x Faxon did not fully manage any storms larger than 0.1 inches.

Figure 10 through Figure 13 provide an overview for each monitored block showing the rainfall, inflow to the GI facilities, and overflow from the facilities to the sewer system during the full monitoring period from November through April. Rainfall is shown in green on the top axis with its values on the left axis. Inflow is shown in blue and outflow in red on the bottom axis with their values on right axis. Periods of intense rainfall exhausted facility storage and produced overlow to the sewer system, although significantly dampened from corresponding inflow to the facility. Many low-intensity storms produced little to no overflow from the green infrastructure, meaning that all runoff entering the GI facilities was fully infiltrated.

Figure 6: Hydrograph showing inflow and GI overflow of the 2017-2018 Monitoring Period at Holloway x Jules

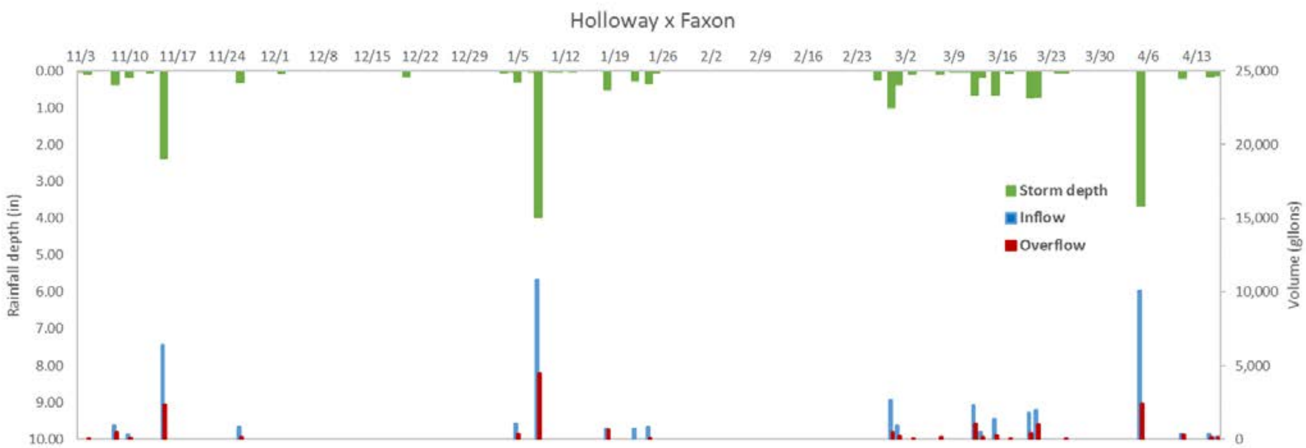

Figure 7: Hydrograph showing inflow and GI overflow of the 2017-2018 Monitoring Period at Holloway x Faxon

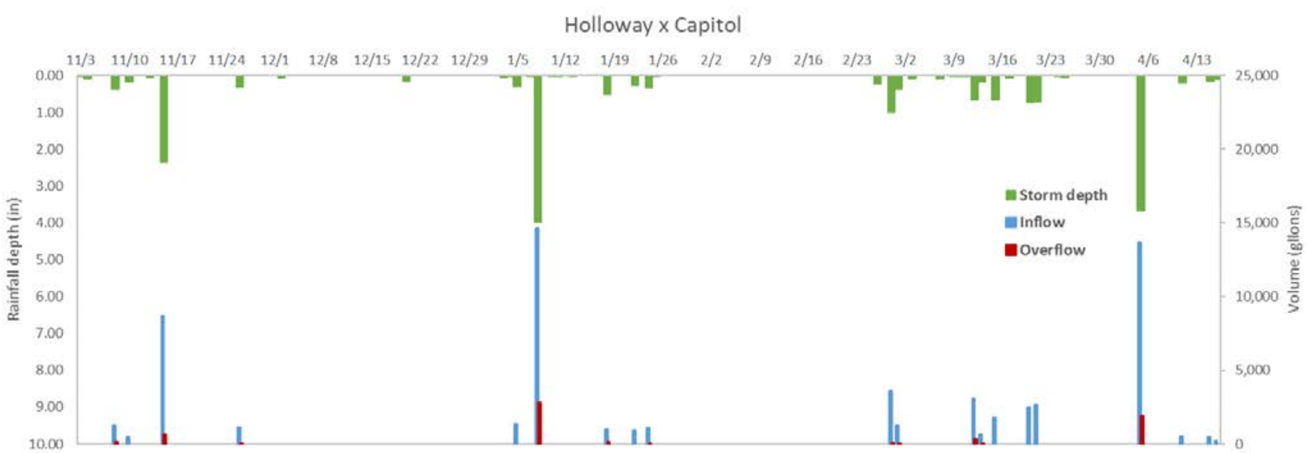

Figure 8: Hydrograph showing inflow and GI overflow of the 2017-2018 Monitoring Period at Holloway x Capitol

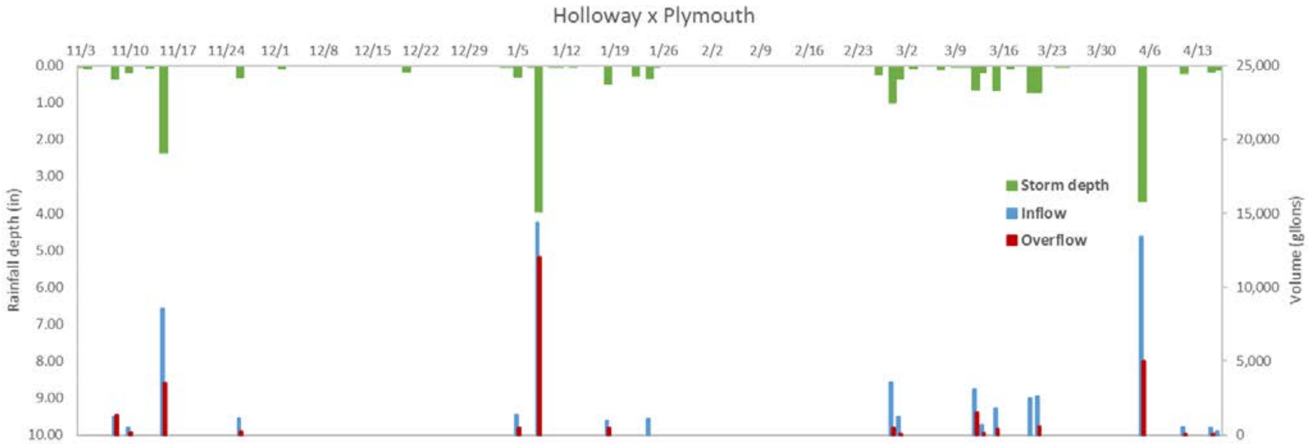

Figure 9: Hydrograph showing inflow and GI overflow of the 2017-2018 Monitoring Period at Holloway x Plymouth

The remainder of this section will report further on the performance of the green infrastructure during back-to-back storms and individual storms selected to represent various types of storms the site experienced during the 2017-2018 monitoring period.

How Did GI Hold Up During Back-to-Back Storms?

Back-to-back storms are defined as successive storm events with the second storm starting within 6 to 24 hours of the end of the first. Of the 19 storms greater than 0.1 inch, there were five storms that qualify as back-to-back. The average volume reduction during the second of back-to-back storms was slightly higher than other individual storms (Table 4). All things being equal, it is generally expected that performance might decrease in the second of back-to-back storms as the soil becomes saturated; however, in this instance the second storms were substantially smaller (0.30 inches versus 1.13 inches) which resulted in slightly increased performance on a percentage basis. The one block where performance did decrease was Holloway x Faxon. As shown in Figure 9, a portion of sidewalk runoff on this block flows directly to the downstream catch basin. The difference in performance on this block may be explained by higher gutter flows in the larger storm events spilling out farther to where the pervious concrete has not become clogged and water can infiltrate, thereby increasing the percentage reduction. The two other EIP sites analyzed thus far (Phase I of the Permeable Wiggle and Sunset Green Boulevard) found no discernible effects on performance for back-to-back storms.

Table 3: Back-to-back storm performance

Site	2nd of Back-to-Back Storms			All Other Individual Storms		
	Storm Depth (in)	Volume Reduction (%)	Storm Duration (hh:mm)	Storm Depth (in)	Volume Reduction (%)	Storm Duration (hh:mm)
Holloway x Jules	0.30	99%	12:17:00	1.13	96%	16:46:55
Holloway x Faxon		59%			68%	
Holloway x Capitol		99%			89%	
Holloway x Plymouth		87%			53%	
AVERAGE		**86%**			**76%**	

Were Peak Flow Rates Reduced?

Based on the 19 storms greater than 0.1 inch, GI reduced peak flow rates by 38-94% (Table 3), generally increasing from the east to the west. The average reduction across the four monitored blocks was 72%, compared to 65% predicted by the SWMM model. The model predicted a 60% reduction across the whole project area. Storms without any overflow had a 100% peak flow rate reduction. In general, the more intense the storm, the higher probability of an overflow. The storm must also last long enough and produce enough runoff volume to exceed the storage capacity of the GI, meaning that duration is also a factor in determining which storms produce overflow.

There was a strong correlation between volume reduction and peak flow reduction. Holloway x Jules fully managed 14 of the 19 storms during the 2017-2018 rainy season with an average 94% peak flow reduction. Holloway x Capital fully managed 8 storms with an average reduction of 89%. Holloway x Faxon, the block with pervious concrete only, did not fully manage any storms due to some gutter flow draining directly to the downstream catch basin; the average reduction was 64%. Holloway x Plymouth, the block with underdrains, fully managed only 4 smaller storms with an average 38% reduction. GI facilities at Holloway x Plymouth entered a flow-through condition during eight storms, producing no effective peak flow reduction.

The Holloway Green Street project is estimated to have reduced peak flows by a range of 38% to 94% with an average reduction of 72% during the 2017-18 rainy season.

Table 5 characterizes performance during the storms that did produce overflow, and summarizes the number of storms that were fully managed (i.e., produced no overflow) on each block.

Table 4: Peak flow reduction characteristics

Site	Storms with Overflow			Storms with no overflow (fully managed)	
	# of Storm Events	Min Peak Reduction	Average Peak Reduction	# of Storm Events	Largest Storm Event with No Overflow (in)
Holloway x Jules	5	67%	94%	14	3.96
Holloway x Faxon	19	32%	64%	0	0.09
Holloway x Capitol	11	59%	89%	8	0.72
Holloway x Plymouth	15	0%	38%	4	0.34

Examples of Individual Storm Analyses

Three storms were selected to represent various types of events the site experienced during the 2017-2018 monitoring period. Storm 7 was a fairly long storm with some bursts of intense rainfall. It had the third largest storm depth, and performance varied significantly across the four blocks. Storm 8 was a short and intense rainstorm with relatively high performance across all blocks. Storm 26 represents a storm with low intensity and long duration, the type of storm where GI performs best. Monitoring data for these representative storms show that the green infrastructure reduce both the total discharge rate and peak discharge rate to the CSS (Table 6).

Table 5: Discharge characteristics for highlighted storms

		Storm 7	Storm 8	Storm 26
Storm Characteristics	Dates	Nov 15-17, 2017	Nov 26, 2017	Feb 28 – Mar 1, 2018
	Total Rainfall (in)	2.36	0.31	1.00
	Duration (hh:mm)	31:55	5:15	14:00
	Peak 5-minute Rainfall Intensity (in/hr)	0.96	0.60	0.60
Holloway x Jules	Volume Reduction (%)	100%	100%	94%
	Peak Flow Reduction (%)	100%	100%	88%
Holloway x Faxon	Volume Reduction (%)	63%	88%	83%
	Peak Flow Reduction (%)	80%	85%	91%
Holloway x Capitol	Volume Reduction (%)	92%	96%	98%
	Peak Flow Reduction (%)	91%	85%	98%
Holloway x Plymouth	Volume Reduction (%)	59%	78%	93%
	Peak Flow Reduction (%)	0%	60%	55%

Figure 14 shows the hydrographs for a large storm event, Storm 7, which produced 2.36 inches of rainfall over the course of 32 hours from the evening of November 15th to early morning of November 17th, 2017. This was the first large storm of the season, and the dry soil appears to have been more absorbent then later in the rainy season. There was a wide range of monitored performance across the four blocks during this storm. Holloway x Jules fully managed the storm while Holloway x Plymouth reduced volume by 59% with no effective peak flow reduction. The data show that less intense periods of rainfall were mostly or fully managed on all blocks. Peak flows during intense bursts of rainfall were dampened to a fraction of baseline flows at the three infiltrative blocks, while the underdrained block at Plymouth became fully saturated and entered a flow-through conditions during these periods. There was a dry period of over five hours prior to the final burst of rainfall, which allowed facilities on the infiltrative blocks to regenerate storage capacity and absorb most or all runoff from that burst; Plymouth was still fully saturated and provided no effective management during that final burst.

Storm 8 (Figure 15) was a short rainstorm with a few bursts of intense rainfall totaling 0.31 inch over five hours on November 26, 2017. As with Storm 7, Holloway x Jules was able to fully manage the storm. All blocks performed well. This storm provides a clear illustration of how the initial portion of a storm is absorbed by the storage within the GI facilities. As can be seen in the figure, no significant overflow occurred until the end of the storm when facility storage was exhausted on three of the blocks.

Storm 26 (Figure 16) represents a low-intensity storm with steady rainfall totaling 1.0 inch over the course of 14 hours starting on February 28, 2018. Even though this storm was the 4th largest of the monitoring period in terms of rainfall depth, performance exceeded the respective annual averages on each monitored block. There was a smaller storm two days earlier so the soil was partially saturated when this larger storm hit, which likely contributed to none of the blocks fully managing the storm. Still, the low-intensity nature of the storm is well suited to GI so both volume and peak flow reduction were above the annual average despite the larger rainfall volume.

and d)

Figure 10: Hydrographs for large Storm 7 at Holloway x a) Jules, b) Faxon, c) Capitol, d) Plymouth

Figure 11: Hydrographs for small Storm 8 at Holloway x a) Jules, b) Faxon, c) Capitol, and d) Plymouth

Figure 12: Hydrographs for medium Storm 26 at Holloway x a) Jules, b) Faxon, c) Capitol, and d) Plymouth

Summary

GI significantly reduced the volume and peak flow of stormwater entering the CSS within the project area. The monitored volume reduction on the four monitored blocks was approximately 173,000 gallons (78%) during the 2017-2018 rainy season, and the monitored peak flow reduction averaged 72% across those blocks.

Total performance across the entire project area was extrapolated from measured performance at the four monitored blocks based on a SWMM model built to represent the full project area. The ratio of monitored to modeled performance for both volume and peak flow reduction at the four monitored blocks was applied to the modeled performance at the unmonitored blocks to estimate their annual performance. Overall, the Holloway Green Street project is estimated to have reduced the volume of stormwater flowing to the CSS by 77% (655,000 gallons) and the peak flows by an average of 72% during the 2017-2018 rainy season.

Modeling results were strongly correlated to the monitoring results, although the monitored performance was higher at three of the four blocks due to conservative infiltration assumptions in the model (i.e., the 0.33 infiltration rate correction factor applied to the double-ring infiltrometer testing results). Monitored performance at Holloway x Faxon, which had pervious concrete in the parking aisle all the way up to the curb, was lower than model predictions because an informal gutter formed against the curb where sediment accumulated and clogged the pervious concrete resulting in the majority of sidewalk runoff draining directly to the downstream catch basin.

Overflow from the green infrastructure was related to three main characteristics: 1) storm intensity – less intense storms produced little to no overflow while more intense storms produced overflow on most blocks; 2) infiltration capacity of the native soil – more infiltrative soil yields higher performance; and 3) facility size – larger sizing ratios improve performance. The underlying soil infiltration capacity is the single largest factor affecting project performance. Pre-construction site investigation revealed more infiltrative soils at the western end of the project, decreasing in infiltration capacity to the east. Similarly, facility performance was highest at the west end and decreased to the east.

Lesson Learned

There were two primary lessons learned from the Holloway Green Street project that should be carried forward to future GI monitoring projects.

1) The method of concurrently monitoring an unimproved baseline block and an improved block allows for direct comparison of their hydrologic responses during the same storms as a means to calculate performance. However, there were drawbacks to using this approach on the Sunset Green Boulevard Model Block due to unexpected runoff patterns on both the baseline block and the improved block, which created new sources of error and required additional effort to complete the analysis. Additionally, the baseline block was ½ mile from the improved Model Block, resulting in some timing errors. In response, a SWMM model was built as a QA/QC check for the Sunset project. Performing a parallel modeling analysis increases the level of confidence in the monitoring results. It is preferable, though, to eliminate as many sources of error as possible. Whenever feasible, future projects should directly monitor the inlets and outlets of GI facilities to isolate facility performance from outside sources of error.

   A SWMM model was also built in support of the monitoring results for this Holloway Green Street project. Additionally, the baseline block was adjacent to the project area, and no unexpected runoff patterns occurred. Thus, there is a high level of confidence in the monitoring results presented in this report.

2) Pervious concrete was installed all the way up to the curb on the Holloway x Faxon block; i.e., there is no formal gutter. This was done with the knowledge that fines might accumulate and clog a narrow swath along the low-lying edge against the curb. An informal gutter was in fact observed to have formed in the few inches adjacent to the gutter. While this had a significant impact on performance – approximately 75% of the sidewalk runoff drained directly to the downstream catchbasin during the 2017-18 monitoring period - advantages of this configuration versus a traditional curb and gutter include less formwork during construction and partial management of sidewalk runoff (heavier flows during intense rainfall spill farther out into the street where they can infiltrate through the cleaner concrete). Overall, this configuration was not problematic and increased cost effectiveness compared to pervious concrete with a traditional curb and gutter.