Sunset Circle Vegetated Swale and Infiltration Basin System: Technical Appendix

This appendix complements the Sunset Circle site report by providing technical detail on the monitoring and analysis methods, data quality and results, as well as providing some suggested improvements for future GI monitoring by the Team.

Project Characteristics

The swale and basin system at the Sunset Circle parking lot receives stormwater runoff from a 92,000 ft^2 parking lot area (Table 1). Prior to Green Infrastructure (GI) implementation, untreated stormwater runoff drained directly into the separate sewer and eventually to Lake Merced. Stormwater from the parking lot now drains into the GI features and comparatively small runoff volumes exit this system during most events. The system includes two types of GI for infiltrating and detaining storm flows: vegetated swales and infiltration basins. The parking lot gently slopes (approximately 2% grade) towards the southwestern point and stormwater follows this drainage pattern. Vegetated swales border the lot on the southern and western sides between the parking area and the paved walking/biking path (Figure 1A). These swales detain and infiltrate runoff, and convey runoff towards the larger infiltration basin in the southwestern point of the lot (Figure 1B). The basins allow runoff to infiltrate and also pond stormwater. To prevent the infiltration basin from overflowing, a stormdrain grate (Figure 1C) is located at the highest elevation in the larger basin and discharges to Lake Merced any stormwater that ponds high enough to flow into the grate. Two islands in the parking lot also have vegetated swales and smaller infiltration basins located in the bulb out sections of the islands. Any overflow from these islands runs off towards the larger infiltration system.

Table 1. Select characteristics of the subcatchment.

Metric	Site Data
Drainage Area (ft^2)	92,000
Imperviousness of Drainage Area prior to construction	100%
Area of vegetated swales (ft^2)	8,500
Area of infiltration basins (ft^2)	6,600
% of Impervious Area Converted to GI	16%
% of Drainage Area that is GI	16%
Land Use(s)	Parking Lot

Figure 1. Views of Sunset Circle parking lot GI facilities, including A) vegetated swales lining the southern and western edges of the parking lot, B) swale and infiltration basin at the southwestern point of the parking lot, and C) the storm drain grate to the overflow catchbasin in the larger infiltration basin.

Methods

The hydrologic analysis presented in this report is based on the comparison of flow data empirically measured at the outlet of the swale and basin system post-construction (Figure 2B) and flows simulated using US EPA's Stormwater Management Model (SWMM) for the same storm events assuming pre-construction conditions (Figure 2A). The SWMM model was used since it has a simple platform, can be programmed to provide reasonably reliable outputs at a time step of minutes, and is widely accepted and verified for use in simulating runoff processes in small, urban catchments.

The post-construction outlet flow measurements were collected at the 1 or 2 minute interval during Rainy Season (October 1 – September 30) 2012-2013 and 2013-2014. Installation and maintenance of the measurement devices was carried out by the San Francisco Public Utilities Commission. Data from these sensors were downloaded manually throughout the period of record; the details of which are shown in Table 2. The Lake Merced rain gauge (gauge LKM-17) is the nearest rain gauge and data from this gauge were used in this analysis. This gauge is located 0.62 miles (1000 m) to the southwest of the Sunset Circle parking lot. Rainfall data were recorded at 5-minute intervals.

Flow characteristics were compared between the measured post-construction data and the data simulated for pre-construction conditions for individual storm events based on the rainfall for the same period. Individual storms and the corresponding flow from those storms were isolated and a suite of hydro-meteorological characteristics (storm duration, storm total rainfall depth, storm total rainfall volume, peak rainfall intensity, flow duration, total flow volume, peak flow rate, storm runoff coefficient, antecedent rainfall (for previous 1-, 2-, 3-, 4-, and 5-day time periods)) and various lag times were determined for each isolated storm. These characteristics were computed for the modeled pre-construction and measured post-construction scenario and compared to assess the effectiveness of the swale and basin system.

Figure 2. Flows at Sunset Circle were modeled for the pre-construction conditions (A) using SWMM hydrologic modeling software. Post-construction flows were measured in a catchbasin located within the large infiltration basin in the southwestern point of the parking lot (B).

Table 2. Period of record with both flow and rainfall data for Sunset Circle. Note: In addition to these detailed gaps, some smaller gaps existed during storm events; substantial storm events that did not have outflow monitoring data are noted in the annual hydrographs in Figure 4.

Rainy Season	Sunset Circle	Major gaps in data record
2012 - 2013	10/29/2012 – 9/30/2013	12/18/2012 – 12/27/2012 4/25/2013 – 6/17/2013 8/16/2013 – 9/19/2013
2013 - 2014	10/1/2013 – 3/29/2014	10/24/2013 – 11/06/2013

Data Quality

Data quality was assessed for the post-construction empirical flow data based on its completeness for the analyzed storm events, consistency (lack of erratic spikes), temporal coordination with the rainfall record, and total volume of flow per storm event based on our conceptual model of the hydrologic performance expected for a site with a ratio of GI surface area to managed impervious area of 16%[1]. Our conceptual model of stormwater runoff volume for such a site includes the following performance characteristics:

- A large proportion of stormwater runoff should be retained.
- Runoff from smaller storm events may be mostly or entirely retained due to GI.
- Retention should likely decrease as storm magnitudes increase or significant antecedent rainfall conditions exist.

Conversely, we would expect the simulated flows for the 100% impervious pre-construction conditions to be high in volume relative to total rainfall and for runoff to occur rapidly in response to rainfall intensity. Antecedent rainfall conditions are less likely to have significant impacts on the runoff characteristics for the more impervious pre-construction site conditions.

During Rainy Seasons 2012-13 and 2013-14, post-construction flow data were of high quality. Flow was determined by measurement of absolute pressure using a pressure transducer located in the catchbasin of the overflow storm drain grate (Figure 1C). Absolute pressure data from the sensor fluctuated temporally in unison with the regional atmospheric pressure (Gauge: San Francisco, USAF-WBAN_ID 994016; available from NOAA.gov) except during storm events in which pressure was elevated above atmospheric pressure due to water level inside the catchbasin. The absolute pressure data were normalized to atmospheric pressure and converted to provide a measure of water level within the catchbasin. A modified weir equation was developed by Sustainable Watershed Designs based on a correlation analysis for four storm events between the pressure transducer water level and flows measured by a Sigma 950 flow meter (Figure 3). This modified weir equation was applied to calculate flows from water level data. Quality of the water level and the calculated flow data for the outlet pipe was evaluated based on presence/absence and reasonableness in relation to rainfall magnitude and timing, general shape of the hydrograph, and results of the analytical outputs. The analyses resulted in hydrologic characteristics that matched a reasonable conceptual model for a site in which the ratio of GI surface area to managed impervious area is 16%. Data were also consistent relative to factors affecting the saturation conditions of the site, and were therefore deemed to be of good quality and appropriate for this type of analysis.

Modeled flow for the pre-construction conditions generally fit well with a reasonable conceptual model of hydrologic characteristics of a 100% impervious parking lot. Storm events at this site were defined as beginning at the initiation of measured rainfall (minimally 0.01 inches) and ending at the last measured rainfall preceding minimally a 6 hour period of no rainfall. Based on this definition, 32 individual storms were isolated during the measured period of record for Rainy Season 2012-2013 and 21 storms were isolated for the Rainy Season 2013-2014 period of record. Data for all 53 of these individual storm events were considered of sufficient quality for interpretative analysis.

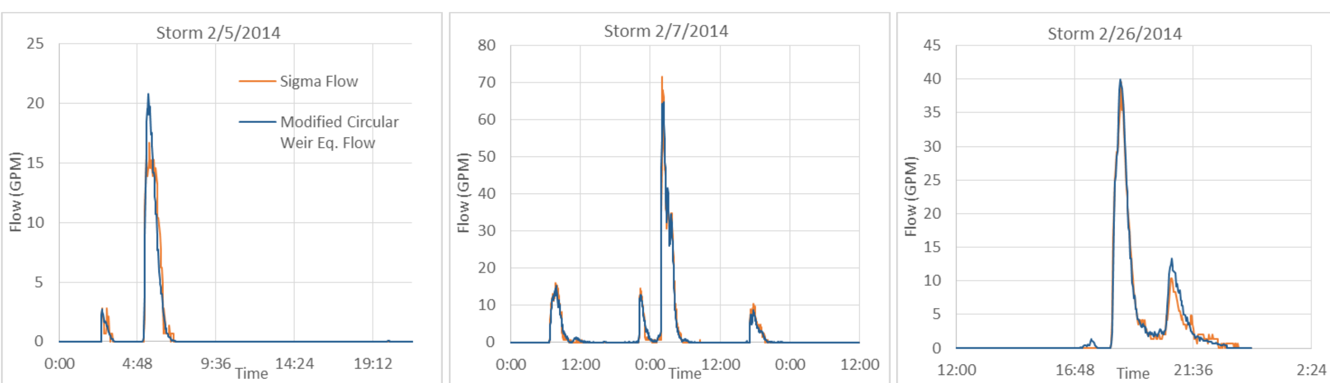

Figure 3. Example hydrographs illustrating flows measured by the Sigma 950 flow meter as compared with flows estimated using the modified circular weir equation (developed by Sustainable Watershed Designs) applied to the pressure transducer water level data.

[1] Provided that the SFPUC recommends the ratio be 5-10% for parcel-based features, it is likely that this site will achieve good performance relative to some other GI sites sized with lower ratios.

Results of Rainy Seasons 2012-2013 and 2013-2014

Based on the comparison of modeled versus observed rainfall-runoff characteristics, the vegetated swale and infiltration basin system at Sunset Circle is estimated to have reduced the total volume flowing into Lake Merced as well as reduced peak flow rates and delayed flows. Thus, it is asserted that Sunset Circle was successful in relation to programmatic objectives. The details of the results of the modeling and monitoring data are discussed below in relation to each of these three primary physical performance metrics.

Flow Volume Reduction

Sunset Circle parking lot received a total rainfall of 22.5 inches during the period of record for which runoff data were also available (10/29/2012 – 3/29/2014, with some data gaps), approximately 60% of which occurred during Rainy Season 2012-2013 and 40% during Rainy Season 2013-2014 (Figures 4 and 5). The maximum rainfall intensity (per 5 minute interval) occurred on November 28, 2012 and again on December 2, 2012 (0.13 in/5 minutes, equivalent to 1.56 in/hr (Figures 4 and 6)) and was approximately a 1-year event based on the 5-minute duration. Most 5-minute rainfall intensities remained below 0.9 in/hr and most storm events had an estimated return frequency of approximately 0.5-yr or smaller based on the 3-hour duration.

The seasonal hydrographs for Rainy Season 2012-13 (Figure 4A) and 2013-14 (Figure 4B) show the estimated changes to stormwater flows before and after construction of the swales and infiltration basin system. Flows simulated for the parking lot, assuming pre-construction conditions, were highly correlated with rainfall. Simulated pre-construction flows occurred in response to almost all storm events whereas the measured overflow runoff exiting the swale and basin system post-construction occurred infrequently, at reduced volumes and reduced peak flow rates. Overall, the swale and basin system is estimated to have substantially reduced the total stormwater runoff volume draining to Lake Merced (Figure 5). For the period monitored, total runoff volume exiting the system post-construction was estimated to be reduced by 96%; decreasing from an estimated 84% of the incident rainfall before installation down to a measured 3% of the incident rainfall after installation. In total, over 138,000 cubic feet (or 1.04 million gallons) of runoff were estimated to be retained by the swale and basin system during the monitoring period.

Typical storm event hydrographs in which post-construction outflow was measured (only 24 of 53 events had measurable outflow) illustrate the predicted changes to runoff patterns on the site (Figures 6 and 7). The patterns shown in these hydrographs follow a typical model of modifications to hydrology due to GI installations. Conceptually, after GI is implemented, we would expect to see both a reduction and flattening of the peak hydrograph and delay in timing of flow from the watershed drainage area into the lake. Additionally, total outflow volumes to the lake should decrease substantially as compared with simulated pre-construction condition flows.

The hydrograph shown in Figure 6 illustrates one of the larger storm events measured in December 2012 with associated typical hydrograph response. During this period, over an inch of rain fell within less than 8 hours and followed three days of antecedent rainfall totaling 3.6 inches. Despite these saturated conditions, only 11% of the rainfall measured in this event flowed to the lake. The hydrographs in Figure 7 illustrate a long duration low intensity storm period during February 2014. During this storm period, no outlet flow occurred during the first 2.8 inches of rainfall. Outflow finally did occur after saturation and in response to a moderately intense burst of rain. Even under these conditions, substantial retention still occurred. In total during this storm series, it is estimated that outflow decreased post-construction by 94% and peak flow rates were likely reduced by 99%.

On an individual storm basis, the relationship between rainfall and simulated flow volume for pre-construction conditions had excellent correlation for both rainy seasons (Figure 8). The correlation between rainfall and observed post-construction outflows was strong but less so ($R^2 = 0.80$) because overflows from the swale and basin system were only partly driven by rainfall volume. Antecedent rainfall also played a role as it affected the storage capacity of the swale and basin system going into the storm event.

The magnitude of antecedent rainfall and consequently the saturation condition of the catchment would be expected to vary the effectiveness of GI reducing flow volumes. Retention volume (the proportion of rainfall that was retained within the system) per storm was found to have an improved correlation with the combined 3-day antecedent plus storm rainfall total as compared with just the storm total rainfall depth (Figure 9) (antecedent time periods tested included 1-5 days).

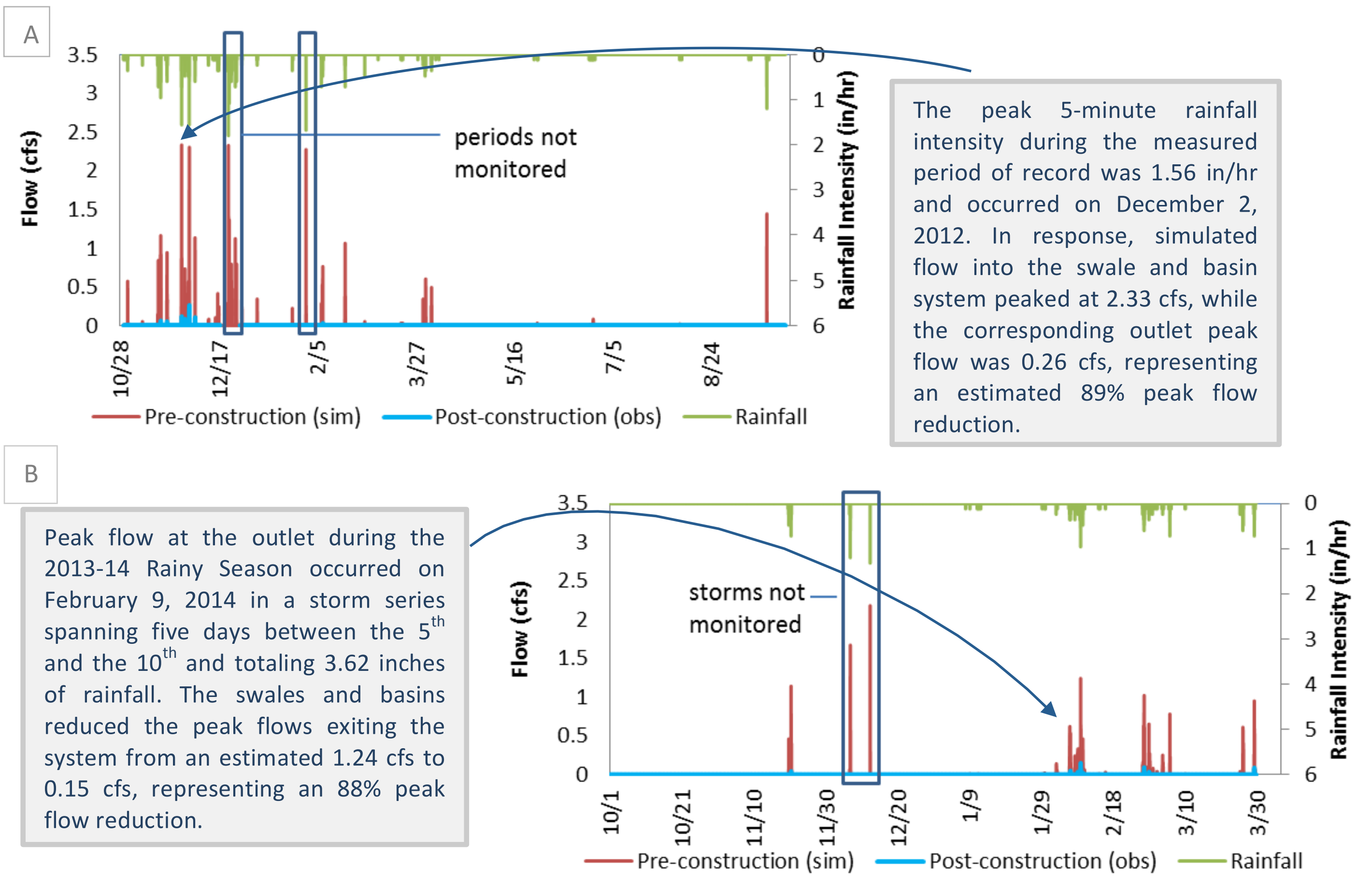

Figure 4. Modeled pre-construction versus monitored post-construction flow and rainfall intensity at Sunset Circle during A) the 2012-2013 rainy season and B) the 2013-2014 rainy season. Note: y-axis scales held constant to allow for an easier visual comparison between rainy seasons. "obs" = "observed data" and "sim" = "simulated data".

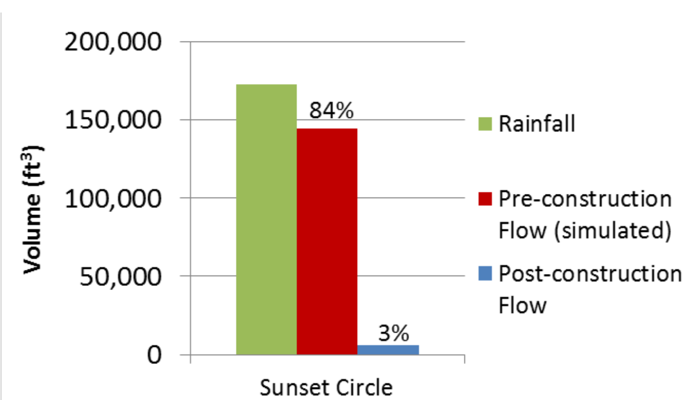

Figure 5. Total flow volume as a percentage of the incident rainfall for the monitoring period.

In summary, flow volumes were reduced post construction of the swale and basin system at Sunset Circle. In total, for the storms measured, flow volume was reduced from an estimated 84% to just 3% of the incident rainfall. On an individual storm basis, post-construction outflows were substantially lower than simulated pre-construction flows and correlated moderately well with total rainfall.

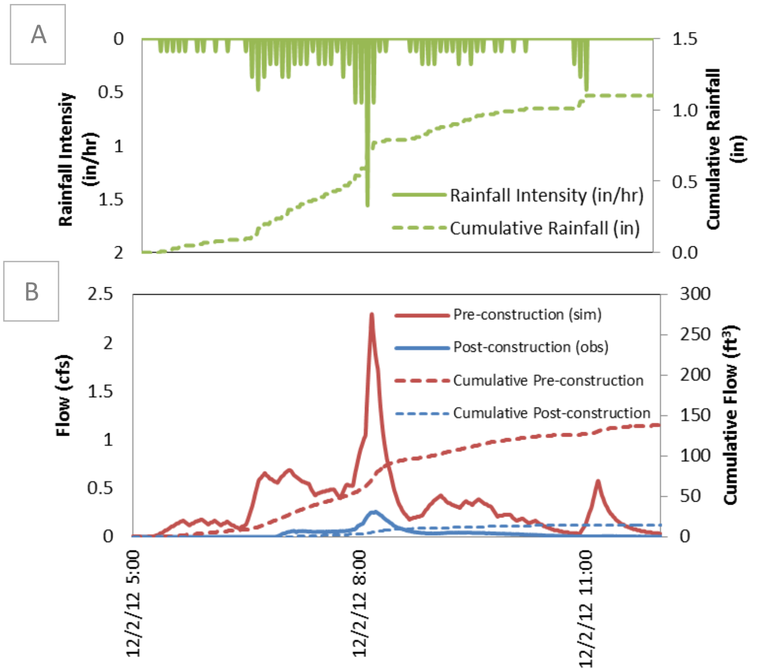

Figure 6. A) Rainfall intensity and cumulative rainfall on December 2, 2012, one of the largest storm events measured. B) Storm hydrographs and cumulative flow volumes during the same storm period.

Table 3. Storm and flow characteristics for the storm shown in Figure 5 graphs A-B.

Storm or Flow Characteristic	Sunset Circle
Storm Date(s)	December 2, 2012
Storm Total Rainfall (in)	1.1
Storm Duration (hrs)	7.2
Peak 5-minute Rainfall Intensity (in/hr)	1.56
% of Rainfall Flowing into Swales and Basin	99%
% of Rainfall Exiting Swales and Basin	11%
Peak Flow Rate into Swale and Basin (or peak flow off parking lot prior to construction) (cfs)	2.3
Peak Flow Rate Exiting Swale and Basin system (cfs)	0.26

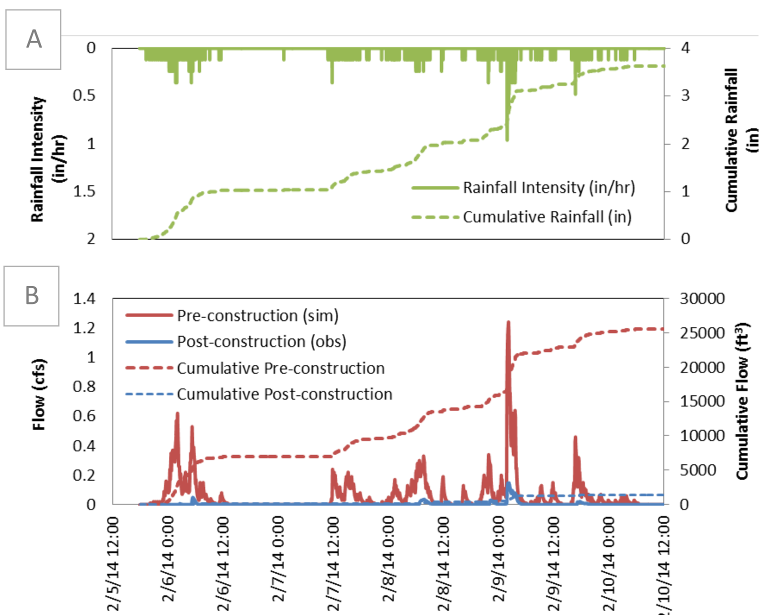

Figure 7. A) Rainfall intensity and cumulative rainfall during a multi-day storm series in February 2014. B) Storm hydrographs and cumulative flow volumes during the same period illustrating the impact of antecedent rainfall on post-construction observed flows.

Table 4. Storm and flow characteristics for the isolated storm event shown in Figure 6 graphs A-B.

Storm or Flow Characteristic	Sunset Circle
Storm Date(s)	February 5-10, 2014
Storm Total Rainfall (in)	3.63
Storm Series Duration (hrs)	106
Peak 5-minute Rainfall Intensity (in/hr)	0.96
% of Rainfall Flowing to Swales and Basin	92%
% of Rainfall Exiting Swales and Basin	5.1%
Peak Flow Rate into Swale and Basin (or peak flow off parking lot prior to construction) (cfs)	1.24
Peak Flow Rate Exiting Swale and Basin system (cfs)	0.015

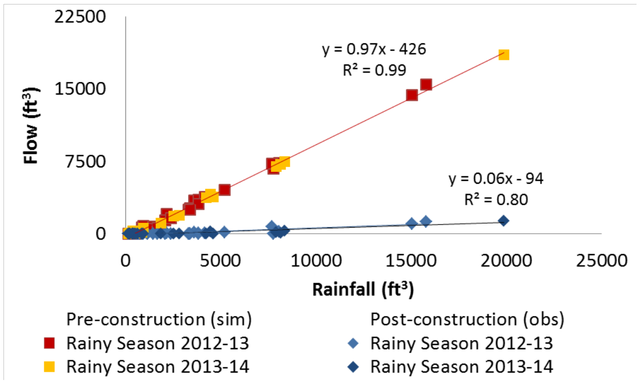

Figure 8. Rainfall and flow volume for all individual storm events monitored at Sunset Circle during Rainy Seasons 2012-13 and 2013-14.

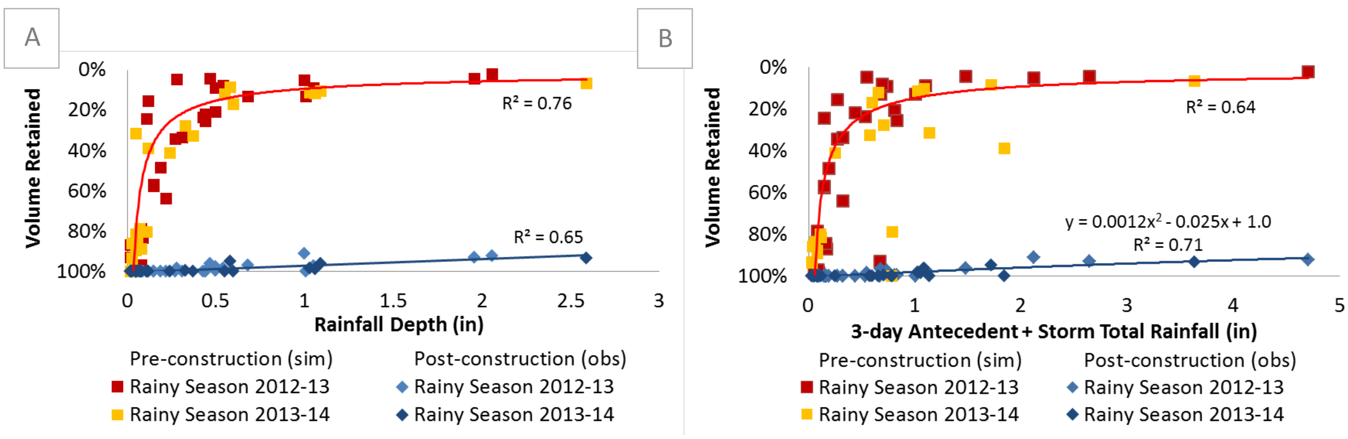

Figure 9. Percentage of rainfall volume retained within the swale system per storm event relative to A) the storm total rainfall depth, and B) the storm total rainfall depth plus antecedent rainfall depth over the preceding three days. [*Storms > 0.01 inch only*]

Peak Flow Rate Reduction

Twenty-four (24) storm events produced runoff at the outlet, post-construction, during the monitoring period. Estimated reductions in peak flows from pre-construction simulations ranged from 88% to 99% and averaged 96%. There was no measured stormwater runoff in an additional 29 storm events where there was 100% stormwater retention (and 100% peak flow reduction) within the vegetated swale and infiltration basin.

Peak flows simulated for the pre-construction conditions had good-to-excellent correlation ($R^2 > 0.80$ in all cases) with all peak rainfall depths tested (5-, 10-, 15-, 20-, 25-, 30- and 60-minute peaks) across the range of storms, with the strongest correlation at the peak 10-minute peak rainfall depth (Figure 10 and Table 5). Peak measured flows at the outlet post-construction did not correlate well with any peak rainfall durations tested ($R^2 < 0.58$ in all cases). As described previously, outflows from the swale and basin system post-construction were driven both by factors that affect the saturation condition of the system (e.g. storm rainfall total, antecedent precipitation) as well as by rainfall intensity.

Table 5. Coefficient of determination for peak inlet and outlet flow relative to peak rainfall for each storm event.

Rainfall Depth-Duration	Pre-construction R^2	Post-construction R^2
5 minute peak rainfall	0.92	0.51
10 minute peak rainfall	0.94	0.52
15 minute peak rainfall	0.93	0.52
20 minute peak rainfall	0.93	0.58
25 minute peak rainfall	0.91	0.56
30 minute peak rainfall	0.88	0.57
60 minute peak rainfall	0.8	0.55

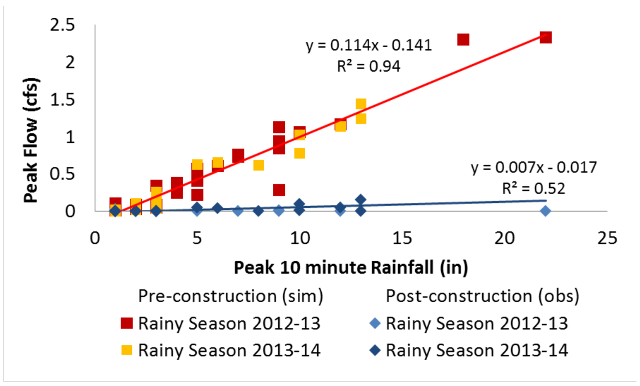

Figure 10. Peak flow at the inlet and outlet for corresponding peak 20 minute rainfall depths in each storm event.

Changes in Lag Time

Computed lag times from the start of rainfall[2] to the start of flow ($Start_I$ to $Start_F$), the peak rainfall[3] to the peak flow ($Peak_I$ to $Peak_F$), and the centroid[4] of rainfall to the centroid of flow ($Centroid_I$ to $Centroid_F$) would all be expected to increase due to the parking lot runoff now passing through the swale and basin system. The simulated lag times for the pre-construction condition flows were estimated to be very small, as would be expected for a 100% impervious catchment (Table 6). If the pre-construction lag-times are accepted, installation of the swales and infiltration basin led to substantially increased lag times in outflow characteristics. Post-construction, no discharge to the lake was observed for over half of the isolated storm events (Table 7); the median lag times reported in Table 6 only include analysis of storms in which there was runoff out of the GI installation post-construction. In contrast, the model simulation suggests that prior to construction, virtually all storms likely would have produced runoff to the lake, and would have been nearly instantaneous with rainfall.

Table 6. Changes in lag times at Sunset Circle parking lot due to GI.

	Median Lag Times (minutes)		
	$Start_I$ to $Start_F$	$Peak_I$ to $Peak_F$	$Centroid_I$ to $Centroid_F$
Pre-construction (simulated)	<1	1	30
Post-construction (observed)	88	38	124
Increase in Lag due to GI	**87**	**37**	**94**

[2] The start of rainfall was actually the time of the second one hundredth of rainfall. If runoff started after the first hundredth and prior to the second hundredth, the lag from $Start_I$ to $Start_F$ was given a value of 0 rather than allow a negative lag to result from this definition for $Start_I$.
[3] The time of peak rainfall used in this analysis was the time when the peak cumulative 10-minute rainfall occurred. Only storms with peak cumulative 10-minute rainfalls greater than 0.02 inches were included.
[4] Centroid is defined as the center of mass.

Lessons Learned and Adaptive Management Suggestions

Sunset Circle is an effective project that exemplifies the multi-benefit nature of GI. The site design required a loss of only 10% of the pre-existing parking places in the lot. The swales and infiltration basins add to the park-like aesthetics in this portion of Lake Merced and the GI design was coordinated with installation of a public art display (statue of Juan Bautista de Anza, Figure 11A) in which the landscaping within the larger infiltration basin helps to showcase the statue. The SFPUC contracted with a local non-profit job-training program to perform much of the initial planting work as well as to perform the necessary ongoing maintenance tasks (Figure 11B). From a stormwater analysis perspective, the site is performing well in the small and moderate storm events monitored to date. In relation to the performance metrics analyzed here, based on a mixture of model simulations and post construction observations, this project appears to have been successful.

Although stormwater runoff metrics indicate high performance, the plantings at this site have had a high mortality rate and the remaining survivors are not vigorous. This could have been caused by challenges during construction including the use of soil mix that was not to specification and over-compaction of the soils. Improving upon these issues in future projects would likely lead to improved plant survival as well as potentially even further improved stormwater runoff detention and retention.

Figure 11. A) View of the large infiltration basin and public art installation, the design of which was coordinated along with the GI construction, and B) members of the non-profit job-training program, Earth Stewards, maintaining the GI facilities.

Suggested Monitoring Program Improvements

Use of the pressure transducer in the catchbasin provided high quality data. However, data processing could be improved for this site by affixing the pressure transducer to a stable and consistent location within the catchbasin. Additionally, data processing could be improved by utilizing a vented pressure transducer or deploying a secondary transducer to measure atmospheric pressure on-site rather than relying on the regional hourly atmospheric data for normalization. In addition, calibration data for the modified weir equation should be extended to larger flows to minimize the extrapolation required.

Sunset Circle Swale and Basin System Reference Table

Table 7. Select individual storm metrics modeled for pre-construction runoff conditions and measured for post-construction runoff conditions at the Sunset Circle swale and basin system (storms >0.01 inches only)[5].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft^3)	Pre-construction			Post-construction			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft^3)	Volume Retention	Peak Flow (cfs)[A]	Flow (ft^3)	Volume Retention	
11/20/2012 7:05	0.9	0.02	153	0.01	11	93%	0.00	0	100%	100%
12/14/2012 9:00	0.2	0.02	153	0.01	20	87%	0.00	0	100%	100%
3/1/2014 21:10	1.8	0.02	153	0.00	0	100%	0.00	0	100%	100%
1/9/2014 5:15	1.4	0.03	230	0.01	32	86%	0.00	0	100%	100%
1/29/2014 8:55	3.4	0.03	230	0.01	15	93%	0.00	0	100%	100%
3/10/2014 3:50	2.6	0.03	230	0.01	14	94%	0.00	0	100%	100%
10/29/2012 22:15	9.7	0.05	383	0.01	5	99%	0.00	0	100%	100%
10/30/2012 21:15	9.3	0.05	383	0.01	5	99%	0.00	0	100%	100%
1/11/2014 6:50	8.0	0.05	383	0.01	47	88%	0.00	0	100%	100%
1/30/2014 0:55	6.1	0.05	383	0.02	40	90%	0.00	0	100%	100%
2/15/2014 23:25	1.1	0.05	383	0.03	71	82%	0.00	0	100%	100%
2/27/2014 6:05	0.6	0.05	383	0.10	262	32%	0.00	0	100%	100%
2/14/2014 2:25	3.7	0.06	460	0.01	74	84%	0.00	0	100%	100%
3/20/2013 13:05	3.7	0.07	537	0.03	82	85%	0.00	0	100%	100%
3/2/2014 7:20	1.8	0.07	537	0.04	113	79%	0.00	0	100%	99%
11/8/2012 12:05	1.0	0.08	613	0.05	131	79%	0.00	0	100%	100%
6/23/2013 17:30	14.7	0.08	613	0.01	18	97%	0.00	0	100%	100%
8/8/2013 4:25	5.9	0.08	613	0.02	70	89%	0.00	0	100%	100%
3/19/2013 18:25	8.0	0.09	690	0.03	115	83%	0.00	0	100%	100%
12/15/2012 12:55	5.2	0.11	843	0.10	638	24%	0.00	0	100%	100%
3/25/2014 11:20	2.7	0.11	843	0.04	167	80%	0.00	0	100%	100%
12/16/2012 18:15	0.6	0.12	920	0.41	778	15%	0.00	0	100%	100%
3/1/2014 1:00	5.4	0.12	920	0.08	563	39%	0.00	0	100%	100%
12/11/2012 23:30	5.7	0.15	1,150	0.08	487	58%	0.00	0	100%	100%
2/7/2013 7:55	1.2	0.15	1,150	0.28	496	57%	0.00	0	100%	100%
1/23/2013 14:15	8.7	0.19	1,457	0.22	749	49%	0.00	0	100%	100%
6/25/2013 2:10	8.9	0.22	1,687	0.08	607	64%	0.00	0	100%	100%
2/2/2014 6:20	8.4	0.24	1,840	0.14	1,081	41%	0.00	0	100%	100%
1/5/2013 15:15	9.9	0.27	2,070	0.34	1,357	34%	0.00	0	100%	100%
12/17/2012 0:55	8.1	0.28	2,147	0.24	2,044	5%	0.00	32	98%	98%
3/30/2013 19:20	6.1	0.31	2,377	0.34	1,578	34%	0.00	0	100%	100%
3/5/2014 21:35	2.3	0.33	2,530	0.78	1,825	28%	0.00	11	100%	100%
3/3/2014 17:00	12.0	0.37	2,837	0.25	1,908	33%	0.00	1	100%	100%
10/31/2012 19:45	7.9	0.43	3,297	0.57	2,517	24%	0.00	0	100%	100%
2/19/2013 6:50	6.5	0.44	3,373	1.06	2,633	22%	0.00	0	100%	100%
4/4/2013 3:20	7.1	0.44	3,373	0.49	2,512	26%	0.00	4	100%	99%
11/17/2012 19:25	2.9	0.47	3,603	1.16	3,447	4%	0.06	132	96%	95%
12/28/2012 20:35	7.9	0.50	3,833	0.38	3,488	9%	0.02	90	98%	96%
3/31/2013 21:30	12.2	0.50	3,833	0.60	3,035	21%	0.00	11	100%	100%
2/7/2013 19:00	14.2	0.54	4,140	0.76	3,808	8%	0.03	60	99%	96%
3/26/2014 5:45	5.7	0.55	4,217	0.61	3,711	12%	0.00	0	100%	100%
2/28/2014 0:55	9.5	0.58	4,447	0.65	4,064	9%	0.03	229	95%	95%
9/21/2013 8:50	3.4	0.60	4,600	1.44	3,814	17%	0.00	0	100%	100%
11/28/2012 7:00	4.1	0.68	5,213	2.33	4,532	13%	0.12	159	97%	95%
12/4/2012 23:15	12.6	1.00	7,667	1.13	7,271	5%	0.10	686	91%	91%
11/16/2012 3:35	29.5	1.01	7,743	0.84	6,733	13%	0.00	0	100%	100%
2/5/2014 19:25	16.3	1.03	7,897	0.62	6,995	11%	0.05	137	98%	92%
11/20/2012 21:20	9.4	1.05	8,050	0.94	7,342	9%	0.05	220	97%	95%
11/19/2013 14:55	22.8	1.06	8,127	1.14	7,189	12%	0.04	97	99%	96%
2/26/2014 7:20	15.3	1.09	8,357	1.02	7,486	10%	0.09	312	96%	91%
11/29/2012 17:45	25.3	1.96	15,027	0.73	14,375	4%	0.08	1,045	93%	89%
12/1/2012 2:55	32.2	2.06	15,793	2.30	15,487	2%	0.26	1,235	92%	89%
2/7/2014 10:55	66.6	2.59	19,857	1.24	18,523	7%	0.15	1,292	93%	88%
Total	**480**	**23**	**172,730**		**144,365**			**5,755**		
Average	**9.1**	**0.4**	**3,259**	**0.4**	**2,724**	**0.5**	**0.02**	**109**	**99%**	**98%**
Maximum	**66.6**	**2.6**	**19,857**	**2.3**	**18,523**	**1.0**	**0.26**	**1,292**	**100%**	**100%**

[5] Volume retention was calculated as the flow volume divided by the rainfall volume. "NA" was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.