Prop. 84 Stormwater LID Retrofit Project

OC Public Works Glassell Campus

Orange County

PIN 24108

2017

Project Title: Prop. 84 OC Public Works Glassell Campus Stormwater LID Retrofit Project

Date: June 21, 2017

Watershed: Santa Ana River Watershed

Project Type: Stormwater LID Retrofit Project and Case Study

Funding Sources: Prop. 84 Stormwater Grant Program, Orange County Flood Control District

Total Cost: Orange County has set aside over $2.6 million to retrofit the Glassell Campus

Photo Courtesy of Orange County Environmental Resources

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Executive Summary

In April 2017, OC Public Works completed construction of the Glassell Campus Stormwater Low Impact Development (LID) Retrofit Project (Project) at its 9.4-acre complex in north Orange County, California. The Campus is comprised of office and warehouse buildings and a public works storage yard. It houses several OC Public Works service areas including OC Environmental Resources, which oversees the countywide stormwater program and is responsible for supporting the protection and enhancement of water quality throughout Orange County.

Prior to the Project, over 90% of the Campus was impervious surface and extensive stormwater runoff containing elevated levels of heavy metals, sediment, and bacteria would discharge from the site into the local storm drain system. To showcase leadership and commitment to stormwater quality and to demonstrate the feasibility of completing a complex stormwater retrofit, OC Public Works applied for and received a $2.9 million Proposition 84 stormwater grant from the State of California. The Orange County Flood Control District provided $1.7 million in matching funds and OC Public Works coordinated the cutting edge design, construction, and project management seamlessly with the local city jurisdiction, multiple internal divisions, and the selected contractor.

The Project was designed to achieve 100% stormwater treatment and 85% retention for the design storm (up to 0.85 inch of rainfall in a 24-hour period). This was accomplished through a series of LID best management practices including cisterns, permeable paving (pavers, asphalt, and concrete), bioswales (with native and drought-tolerant plants), flow-through planters, modular wetland, and tree box media filters. Placed strategically within the Project site, these LID best management practices collectively remove 95% of the pollutants, capture more than 80,000 gallons of stormwater for each major storm event for onsite irrigation, and recharge stormwater to the regional groundwater aquifer. To ensure that these performance targets are achieved, comprehensive site survey, modeling, and monitoring were conducted prior to the project design. This information was used to develop a performance assessment and evaluation plan that includes a monitoring plan and a quality assurance project plan. The post-project performance data is limited due to lack of storms, but the monitoring will continue and performance data will be shared on an ongoing basis through the Project website, statewide database, and other channels.

The Project was also designed to be a regional education center for stormwater and sustainability. The Project's education and outreach program includes brochures, educational video, web pages, and a dedicated walking tour with educational panels showcasing all aspects of the Project. Since the start of the Project construction, over 30 groups and more than 300 individuals have toured the Project, including K-12 and college students, the general public, researchers, and governmental and private sector stormwater practitioners. The Project has already inspired work on similar retrofitting projects within Orange County.

The Project also incorporates a number of monitoring and research elements into its design to allow studies into the efficacy and long term performance of the LID best management practices. Every type of LID best management practice will be monitored and its performance reported. Controlled experiments will be conducted on a series of biofilter test cells and other LID features to test their effectiveness in removing stormwater pollutants, especially fecal indicator bacterial and pathogens. It is currently part of two National Science Foundation funded research projects being carried out by local academic institutions.

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Chapter 1. Background

1.1 Project Location

The project site, OC Public Works' Glassell Yard Campus in the City of Orange, California, is a 9.4 acre office/warehouse complex consisting of three parcels, each with a building and surrounding parking lots (Figure 1-1). The campus is bounded by Glassell, Orange-Olive, Bristol, and Emerson and is located in an industrial-commercial district. Of the three parcels, Building 1 is the office building that houses OC Public Works' Operations and Maintenance (O&M), Survey, and OC Watersheds. Building 2 is a warehouse/office duplex that houses part of OC Watersheds and is also used as the indoor parking structure for some of O&M's specialized vehicles. Building 3 is also a warehouse/office duplex that houses Orange County Agricultural Commissioner, O&M's main warehouse, and other smaller facilities. The large parking lot to the south of Building 3 is used by a large fleet of heavy maintenance vehicles operated by O&M. There is also a vehicle wash rack and a dynamometer for taxi calibration.

Figure 1-1. *Project site overview (pre-Project condition).*

1.2 Pre-Project Site Characteristics and Hydrology

The campus and surrounding commercial buildings were built in the mid-1980s from a strawberry field. Prior to the Project, approximately 90% of the parcel was impervious surface with about 2% slope. Stormwater runoff from the campus would discharge unhindered into two catch basins along Glassell Street.

Based on the historical rainfall information for this location, the 85^{th} percentile of rain events has been defined for the campus area to be 0.85 inches in 24 hours. Most of the annual rainfall occurs between November and April.

The campus experiences heavy traffic of passenger vehicles, external commercial vehicles to be tested by Agricultural Commissioner, and heavy trucks, equipment, and specialized vehicles. Many maintenance, washing, and material handling activities take place at different parts of the campus, especially at Building 3 and its parking lot. Prior to the Project, since the three parcels were not connected, much of the traffic used public streets to move from one parcel to another.

The green belts surrounding the perimeter of the buildings were old-fashioned, above-grade type and were prone to over irrigation and breakage (see Figure 1-2). During wet weather, flooding and erosion were common (Figure 1-3).

a. Parking Lot at Parcel 1

b. Parking Lot at Parcel 2

c. Parking Lot at Parcel 3 With O&M's Maintenance Fleet

d. Irrigation Runoff at Parcel 1

Figure 1-2. *Pre-Project dry weather conditions.*

a. Flooding at Glassell-Bristol Intersection

b. High Volume and Turbid Roof Drain Runoff Onto Parking Lot

c. Flooding at Parcel 3. Sump Pump Is Required to Remove Ponded Runoff

d. Run-on from Parcel 3 to Parcel 2 Causes Erosion of Greenbelt

Figure 1-3. *Pre-Project wet weather conditions.*

1.3 Regulatory Background

New development and significant redevelopment projects are subject to increasingly stringent regulatory requirements regarding post-construction management of stormwater runoff. In response to these requirements, the County developed the Model Water Quality Management Plan and the companion Technical Guidance Document (available at www.ocwatersheds.com). The Project itself was not a regulatory requirement at the time of planning/construction, but the rationale of BMP design and selection met or exceeded all core requirements with regard to achieving pre-development hydrology and water quality.

The recent progresses on LID planning and implementation coincided with increasingly prescriptive requirements for LID in the most recent municipal separate storm sewer systems (MS4) permits in Southern California including those for the County. In the 4th MS4 Permit for the County issued by the Santa Ana Regional Water Quality Control Board (Regional Board), the term 'LID' appeared 45 times with most of the requirements stipulated in the new development and significant redevelopment projects. Agencies such as Southern California Stormwater Monitoring Coalition (SMC), California Stormwater Quality Association (CASQA); Southern California Coastal Water Research Project (SCCWRP) have all conducted studies that indicated that LID are effective stormwater management tools that minimize adverse impacts on stormwater runoff quality and quantity resulting from urban developments. Collectively, these agencies developed a Low Impact Development Manual for Southern California, a compendium of LID design process, case studies, plant selection, and planning and regulatory framework for LID. However, the manual also acknowledged that LID is still being integrated into the California planning process. Very few general plans have water or water resources elements, and even fewer specifically address LID and hydro-modification.

In the Santa Ana Region (where the Project is located) specifically, the MS4 permit requires priority development projects to ascertain the impact of the development on the site's hydrologic regime, and attempt to maintain or replicate the predevelopment hydrologic regime through the use of design techniques that create a functionally equivalent post-development hydrologic regime. LID site design principles must be followed to reduce runoff to a level consistent with the maximum extent practicable (MEP) standard. Priority development projects are required to infiltrate, harvest and re-use, evapotranspire, or bio-treat the 85^{th} percentile storm event. A Water Quality Management Plan (WQMP) is required to include BMPs for source control, pollution prevention, site design, LID implementation and structural treatment control BMPs.

1.4 Project Conception

The project work was initiated in 2009 as an internal project to revamp the existing landscape for the campus after the County purchased the property (including all three parcels) in 2007. The County also planned to resurface the aging hardscapes. When the Prop.84 Stormwater Grant Program became available, a preliminary LID-based conceptual design was prepared. The aftermath of the 2008 financial crisis caused the Prop.84 fund to be put on hold from 2009 to 2011, but County staff continued to work on the conceptual design and baseline monitoring during the funding hiatus. In 2011 when the Prop.84 fund became available again, a conceptual proposal and then a full proposal were submitted and the project was awarded $2,918,597. The County allocated $1.7M internal fund as the local funding match.

<u>Demonstration of LID Design, construction, long-term O&M, performance</u>

The ultimate motivation for the County to lead the Project is to showcase its leadership in LID implementation and to use the Project as a platform for stormwater training, education, and outreach. As the lead agency for both north and south Orange County for implementing the stormwater programs with an increasing emphasis on LID, County lagged behind some cities in the number and scale of LID projects and lacked direct experience on LID design, project management, monitoring, and performance assessment. On a countywide scale, there were deficiencies in the understanding of LID performance, especially long term and in association with design parameters and various maintenance frequencies. This lack of understanding also contributed to the fact that LID is still rarely, if at all, included in the general plans. Most of the LID design elements are incorporated in the site planning stage, which is too late in the process to make the kinds of impacts that are possible and desirable.

The County's Stormwater Program has a $500,000 annual budget for public education and outreach, with key messages promoting water conservation, native/drought tolerant plants, pollution source control, among others. Prior to the Project, there was a lack of County-managed, in-the-ground projects that promote these messages. This Project filled in the gap. The public education and outreach elements permeated the process of Project conception, planning, design, and other related activities.

Chapter 2. Project Description

2.1 Project Design

2.1.1 Qualitative Design Considerations

The Project aimed to restore the pre-development hydrology by retrofitting the campus with LID BMPs. They include permeable paving, bioswales, cisterns (both above ground and underground, flow-through planters, planter box, and modular wetlands. These BMPs were strategically located and tailored for each parcel based on hydrology, usage, and existing conditions. One key design consideration was to use the 'design train' concept, where stormwater runoff is channeled through a series of different BMPs to progressively reduce the pollutant load along the flow path. The design also considered different pollutant removal performance of these various BMPs. The 'treatment train' concept was used where feasible to maximize the treatment of stormwater runoff by routing the flow through as many LID BMPs as possible.

2.1.2 Cost Considerations

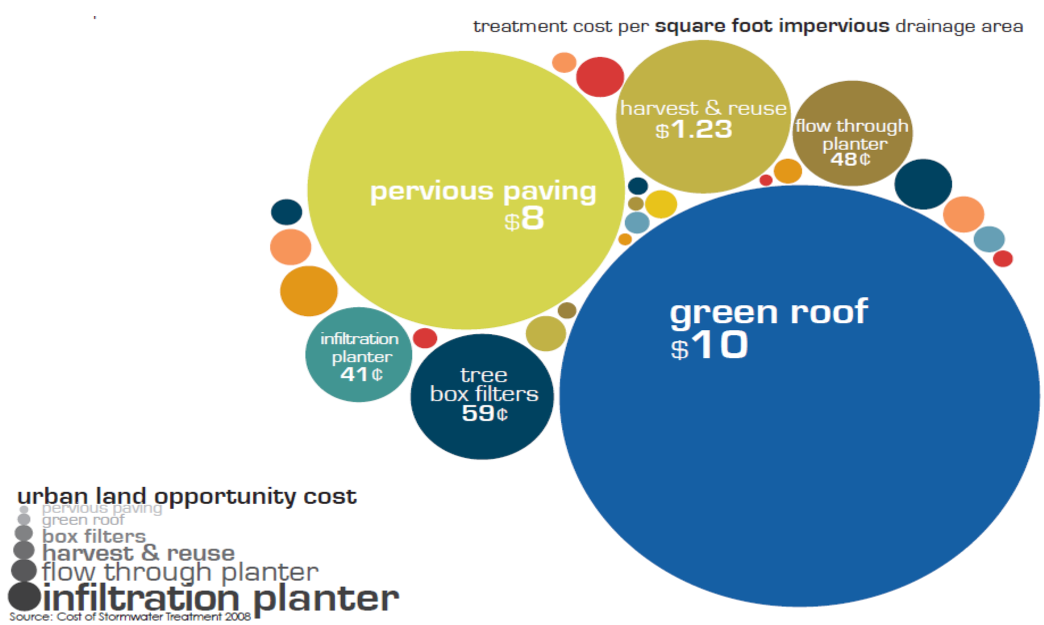


Figure 2-1. *Unit costs of various LID BMPs.*

Cost-effectiveness of different LID BMPs was assessed by evaluative relative costs to treat a square foot of impervious area (Figure 2.1). The main goals of the Project are demonstration and public education and outreach, therefore the cost is not the deciding factor. Certain types of LID BMPs were not selected due to various considerations. For example, a green roof was not implemented chiefly due to its high cost and irrigation requirements in southern California. At the same time, only Building 1 has the structural strength to support a green roof.

2.1.2 Quantitative Design Considerations and Approaches

a. Pre-Project Runoff Calculation

Based on USDA's Technical Release 55 (USDA, 1986), the pre-development condition (strawberry field; soil type B; good condition) has a curve number of 78. Therefore, a 0.85" rainfall will produce approximately 0.04" runoff. Currently, with 93% impervious surface and 2-3% slope, the runoff quantity can be estimated by TR-55 as well. The actual calculation was conducted based on a computer-based program (WINTR-55, see Figure 2-5) and later on by a SWMM model.

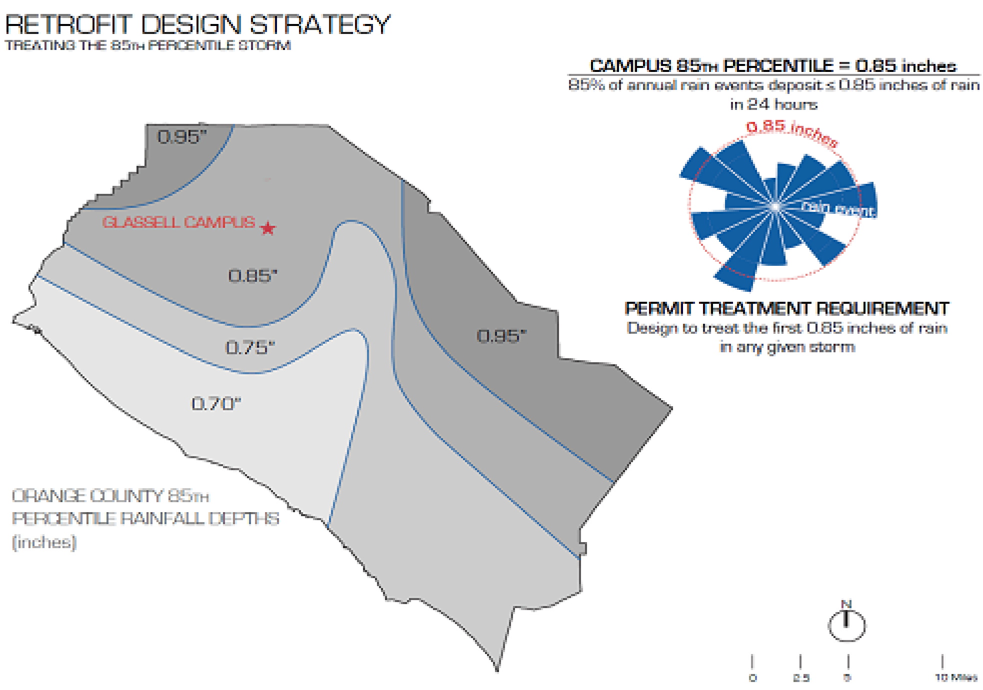


Figure 2-2. *Orange County 85th percentile rainfall depth (inches). For the Project site this depth is 0.85".*

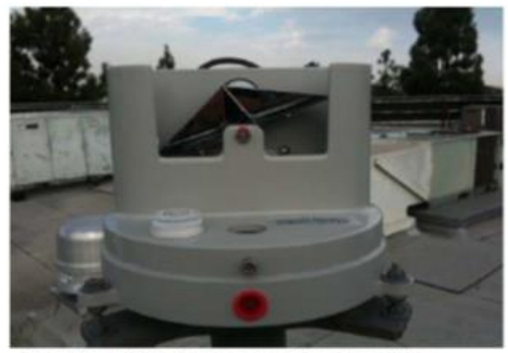
The approach to restoring pre-development hydrology investigated quantitatively as well. To achieve pre-development hydrology, BMPs were selected, located, and sized based on subdrainage hydrology, amount and quality of runoff, and other actual site conditions (Figure 2-

4). In addition, for each parcel, pre- and post-BMP hydrographs are simulated (Figure 2-5) to ensure the achievement of designed the runoff reduction performances.

a. ISCO 4210 Ultrasonic Flow Meter at Curbside of Parcel 1

b. ISCO 3700 Sampler at Curbside of Parcel 1 (Samples Shown)

c. Soil Testing and Infiltration Testing Conducted on All Parcels

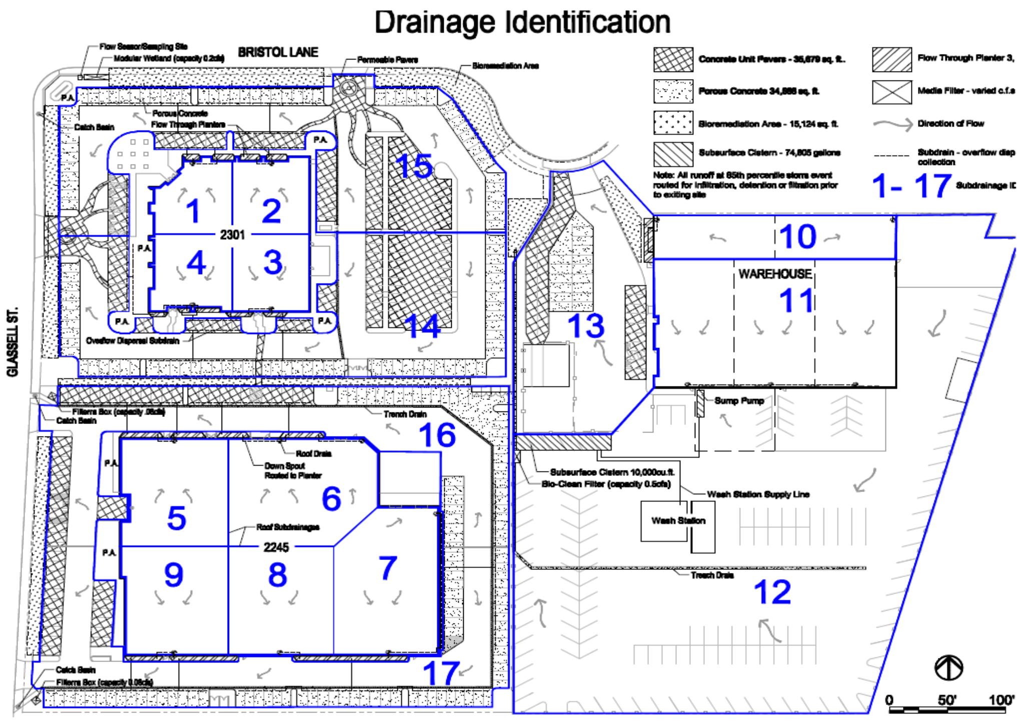


d. TB3 Raingauge Installed on the Rooftop of Parcel 1

Figure 2-3. *Pre-Project monitoring and investigations of site conditions and rainfall pattern.*

<u>b. Stormwater Runoff Reduction</u>

The design treats 100% of the 85th percentile storm event by utilizing a treatment train approach which includes filtration, bioremediation, infiltration, and capture for reuse. WinTR-55, a computer model that performs hydrology calculations based on USDA's TR-55 was used to produce these hydrographs. The hydrographs as shown in Figures 6a-d demonstrate the hydrologic performance of each lot during the 85th percentile storm event, under current conditions (pre), and projected performance at full implementation (post). The hydrographs illustrate significant flow reductions resulting from retrofit implementation. Of the remaining flows at full implementation, 100% of runoff will be treated through filtration prior to exiting the site, or captured in cisterns for reuse.



85th Percentile Design Storm :0.20in/hr - 0.85in/24hr

Drainage ID	Surface	Runoff Coefficient	Drainage Area sq.ft.	Runoff Volume (cu.ft.)	Primary BMP Treatment	Treatment Area (sizing %) Volume Capacity	85th % Treatment	High Flow Bypass	Secondary BMP Treatment	85th % Treatment
1	Roof	0.85	4,322.00	260.22	Flow Through Planter (F)	170 sq. ft. - 4%	Yes	Yes	12" Infiltration Bed (F,V)	Yes
2	Roof	0.85	4,707.00	283.40	Flow Through Planter (F)	189 sq. ft. - 4%	Yes	Yes	12" Infiltration Bed (F,V)	Yes
3	Roof	0.85	4,707.00	283.40	Flow Through Planter (F)	150 sq. ft. - 3%	**No**	Yes	12" Infiltration Bed (F,V)	Yes
4	Roof	0.85	4,707.00	283.40	Flow Through Planter (F)	175 sq. ft. - 4%	Yes	Yes	12" Infiltration Bed (F,V)	Yes
5	Roof	0.85	9,374.00	564.39	Flow Through Planter (F)	287 sq. ft. - 3%	**No**	Yes	12" Infiltration Bed (F,V)	Yes
6	Roof	0.85	12,374.00	745.02	Flow Through Planter (F)	276 sq.ft. - 2%	**No**	Yes	12" Infiltration Bed (F,V)	Yes
7	Roof	0.85	12,374.00	745.02	Flow Through Planter (F)	693 sq. ft - 5.5%	Yes	Yes	12" Infiltration Bed (F,V)	Yes
8	Roof	0.85	9,374.00	564.39	Flow Through Planter (F)	397 sq. ft. - 4%	Yes	Yes	12" Infiltration Bed (F,V)	Yes
9	Roof	0.85	9,374.00	564.39	Flow Through Planter (F)	383 sq. ft. - 4%	Yes	Yes	12" Infiltration Bed (F,V)	Yes
10	Roof	0.85	9,025.00	543.38	Flow Through Planter (F)	330 sq. ft. - 3.6%	**No**	Yes	12" Infiltration Bed (F,V)	Yes
11	Roof	0.85	25,320.00	1,524.48	Detention (V)	2,000 cu.ft.	Yes	Yes	Bioremediation Swale (F,V)	Yes
12	Asphalt	0.85	113,363.00	6,825.40	Detention (V)	8,000 cu.ft.	Yes	Yes	Bioremediation Swale (F,V)	Yes
13	Asphalt	0.85	14,760.00	888.68	12" Infiltration Bed (F,V)	2540 cu. ft.	Yes	Yes	Bioremediation Swale (F,V)	Yes
14	Asphalt	0.85	15,744.00	947.92	12" Infiltration Bed (F,V)	3246 cu. ft.	Yes	Yes	Bioremediation Swale (F,V)	Yes
15	Asphalt	0.85	14,235.00	857.07	12" Infiltration Bed (F,V)	2881 cu. ft.	Yes	Yes	Bioremediation Swale (F,V)	Yes
16	Asphalt	0.85	16,805.00	1,011.80	12" Infiltration Bed (F,V)	4210 cu. ft.	Yes	Yes	Media Filter (F)	Yes
17	Asphalt	0.85	16,523.00	994.82	12" Infiltration Bed (F,V)	3,872 cu.ft.	Yes	Yes	Media Filter (F)	Yes

Figure 2-4. *Top: 17 drainage areas of the Project site calculated for stormwater runoff.*

Bottom: calculation details using TR-55 method.

Figure 2-5 below shows the simulated hydrograph of the combined flow from all lots under existing conditions (pre-Project) and at full retrofit implementation (post-Project). Retrofit runoff flows are expected to be reduced by 85%. All remaining flows are slated for filtration and bioremediation during the 85th percentile event prior to exiting the site. The simulations were carried out for all three parcels on a conceptual level during the pre-design phase as guidelines for the engineering design. The actual hydrology of the site changed as the result of the Project (for example, some flows from Parcel 1, 2, and 3 will be combined to one storm drain), but the overall flow reduction met or exceeded the 85% retention ratio.

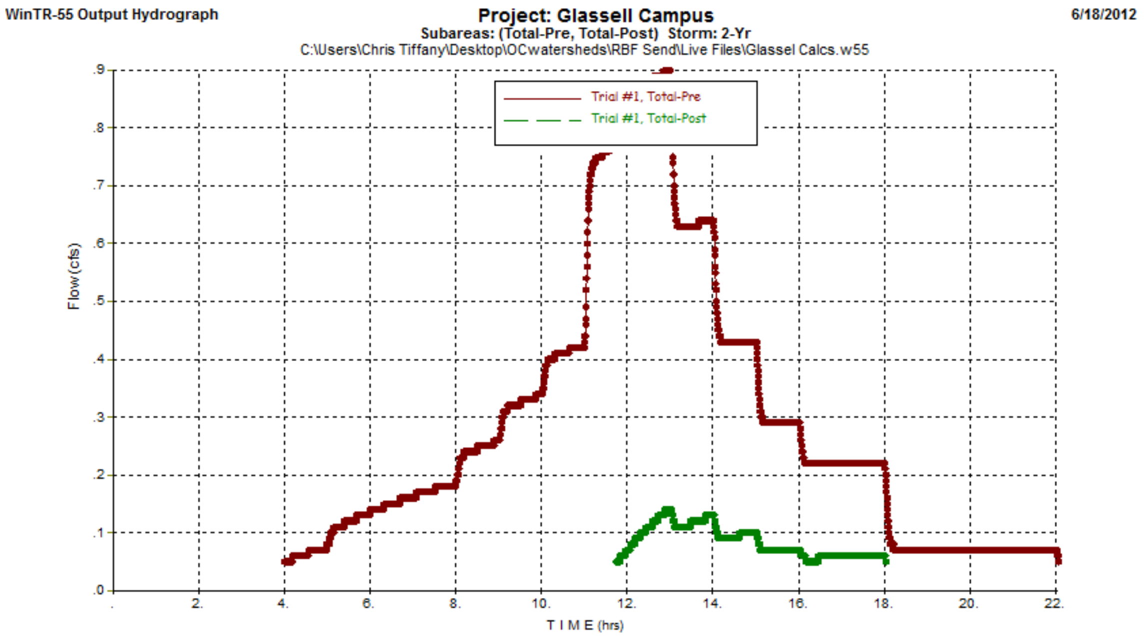


Figure 2-5. *WIN TR-55 simulation of pre- (red) and post- (green) project runoff duration curve. This was carried out to ensure that the target of 85% runoff retention on site is achieved.*

c. Stormwater Pollutant Load Reduction

Another critical factor in selecting BMPs is its pollutant removal efficiency (Figure 2-6) based on the International Stormwater BMP Database (2011). In all cases, the average or median values are used for expected load reduction performance.

d. Rainwater Harvesting and Reuse

As calculated, for an 85th percentile storm event, two cisterns (one above ground, one underground) will capture more than 80,000 gallons of filtered stormwater per event and the captured water for irrigation and other purposes.

e. Groundwater Recharge

Groundwater recharge estimates will be carried out by OCWD staff based on a water balance model. At the time when this report was finalized, this has not been done since no major storm event have been monitored after the Project was completed in April 2017. The model will take into consideration rainfall amount and intensity, the soil antecedent moisture content, evapotranspiration, soil infiltration rate, and residence time of water in biofitration areas.

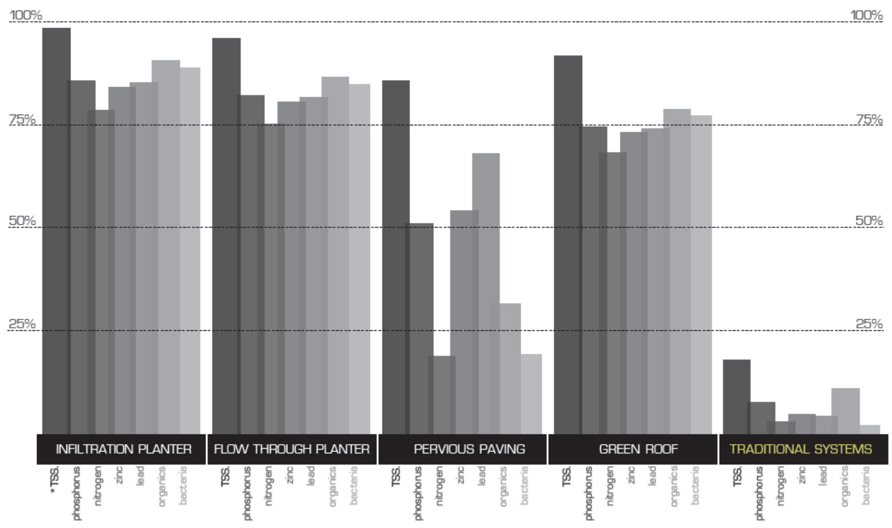


Figure 2-6. *Average pollutant removal efficiencies for each BMP type and each pollutant based on the International BMP Database. These data were averaged and used for estimate of pollutant removal efficiency by the Project.*

f. Irrigation Water Savings

Even under ideal conditions (i.e. no overirrigation or breakage), the pre-Project landscape would require 4.024 acre feet of water for irrigation per year. In comparison, the post-Project landscape is expected to decrease the irrigation water demand down to 1.57 acre feet per year, a saving of 2.45 acre feet per year (an estimated 61% savings; see Figure 2-7). To achieve this goal, in-line drip irrigation will be used in all planting areas (with the exception of bioswales) and be connected with smart controller (e.g. Hunter I-Core with Solar Sync ET) to maximize water use efficiency.

In addition to water conservation considerations, the Project design also included complete renovation of landscape areas to enhance visual aesthetics, maximize wet and dry weather performance, and support local ecosystems with drought-tolerant and/or native plants.

Estimated landscape irrigation water use based on Landscape Coefficient Method (LCM) and WUCOLS III set forth by the California Department of Water Resources 2000. This method describes irrigation needs of landscape plantings in California and is the industry standard for calculating landscape irrigation water use.

g. Greenhouse Gas Reduction

The project will reduce greenhouse gas emissions by reducing the traffic in between buildings by building driveways in between each of the three parcels, which are now segregated by above-grade greenbelts. It is estimated that 765 pounds of carbon dioxide emission can be reduced by the project.

EWU = Estimated Total Water Use

$$\frac{Eto \times Cco}{IEA} \times LA \times const = EWU$$

Where
- Eto = Reference Evapotranspiration (CIMIS)
- Cco = Crop Coefficient (WUCOLS)
- LA = Landscape Area (sq.ft.)
- IEA = Irrigation Efficiency
- Const = Constant to convert to gallons per year (GPY)
- GPY = Gallons Per Year
- AC.FT = Acre Feet Per Year

Existing Landscape				
Shrub Area	$\frac{49 \times 0.5}{0.65}$	X 15,307 X 0.62 =	357,713 GPY	1.0978 AC.FT/YR.
Turf Area	$\frac{49 \times 0.9}{0.65}$	X 22,667 X 0.62 =	953,479 GPY	2.9261 AC.FT/YR.
Total Landscape Irrigation Water Use			1,311,191 GPY	4.0239 AC.FT/YR.

Proposed Landscape				
Shrub Area	$\frac{49 \times 0.4}{0.90}$	X 37,974 X 0.62 =	512,733 GPY	1.5735 AC.FT/YR.
Total Landscape Irrigation Water Use			512,733 GPY	1.5735 AC.FT/YR.

Projected Landscape Irrigation Water Savings : 60.89% 798,458 GPY 2.4504 AC.FT/YR.

Figure 2-7. *The calculation scheme for estimating the reduction of potable water consumption as a result of the Project.*

2.1.3 Site Survey and Geotechnical Investigations

Survey was carried out by OC Survey. Geotechnical investigation and testing were conducted by NMG Geotechnical Company and OC Public Works' Materials Laboratory. Overall 11 borings were made throughout the campus and infiltration tests were conducted. Based on the infiltration tests, the placement of infiltration LID BMPs were placed at locations with the highest infiltration rates (i.e. toward the northwest perimeter of the campus, see Figure 1-1. Survey also located most of the underground utilities. This was necessary since the building's as-built drawings were missing.

2.1.4 Final Project Design

The final project design, based on the above considerations, was completed in September 2015 as planned. See Figure 2-8 for an overview of the Project final design and Attachment A for the detailed 100% design drawings.

2.1.5 Third Party Review of Project Design

After the first draft of the 100% design, to ensure that the quantitative project design goals were all achieved, an LID expert, Kevin Perry, was retained to conduct third party, independent review and re-calculation of the key design parameters. The re-calculation of the post-project runoff volume for Parcel 1 is shown in Figure 2-9 as an example. The results of the independent review indicated that the design will achieve the runoff volume reduction target. The report is included as Appendix C.

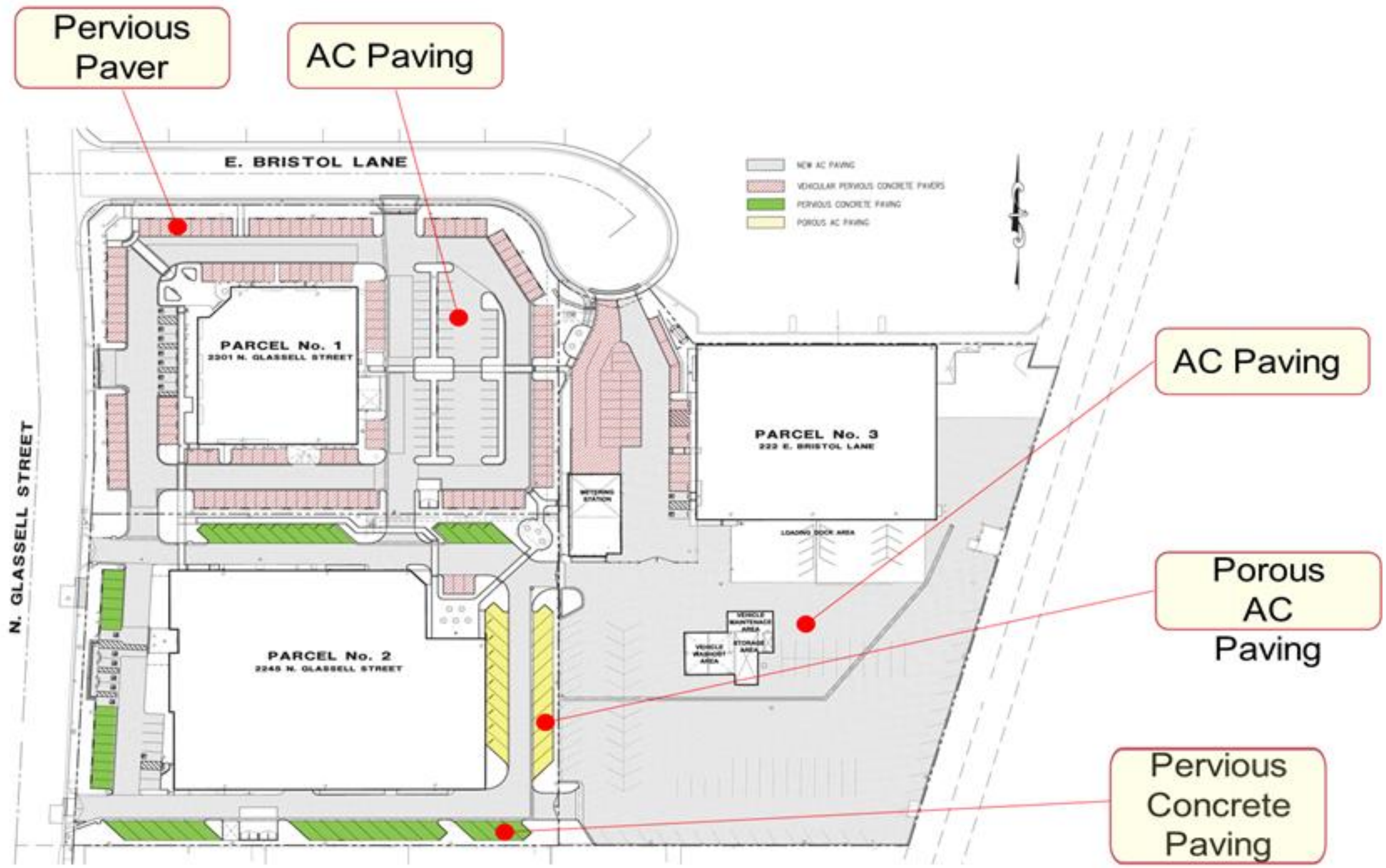


Figure 2-8a. *Project Paving Plan.*

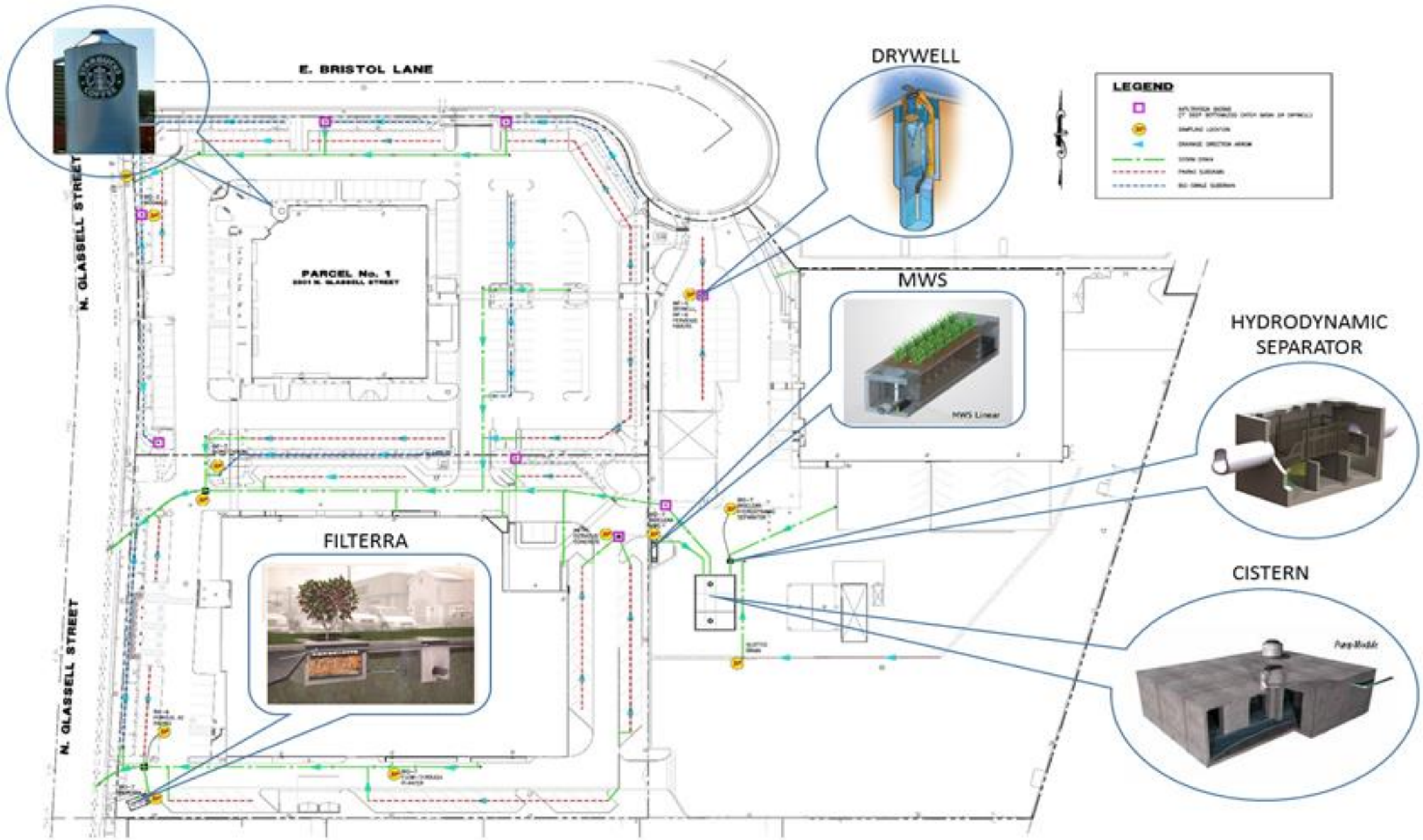


Figure 2-8b. *Project final BMP and drainage plan.*

2.2 Project Construction

The Project was the first comprehensive LID project managed by the County. Because the County is the lead agency for MS4 permits and oversees many LID projects throughout the County, a conscious decision was made to have County staff oversee the construction to gain experience on LID project management. The County construction inspector Jeaniene Casiello has over 20 years of experience but this was the first LID project she had worked on. From her perspective, there were many unique issues of managing the construction of an LID project compared to conventional construction projects.

First, there were issues specific to retrofitting of an existing facility. During active construction, access between parcels was required to be maintained because several critical County agencies and functions, including the Department Operation Center that will be operational and open during storm or other emergency events. Dust control was more challenging. Stockpiling materials was challenging due to lack of space. Access to areas with newly established plants was difficult. To this end, seven (7) phases were established (See Figure 2-9).

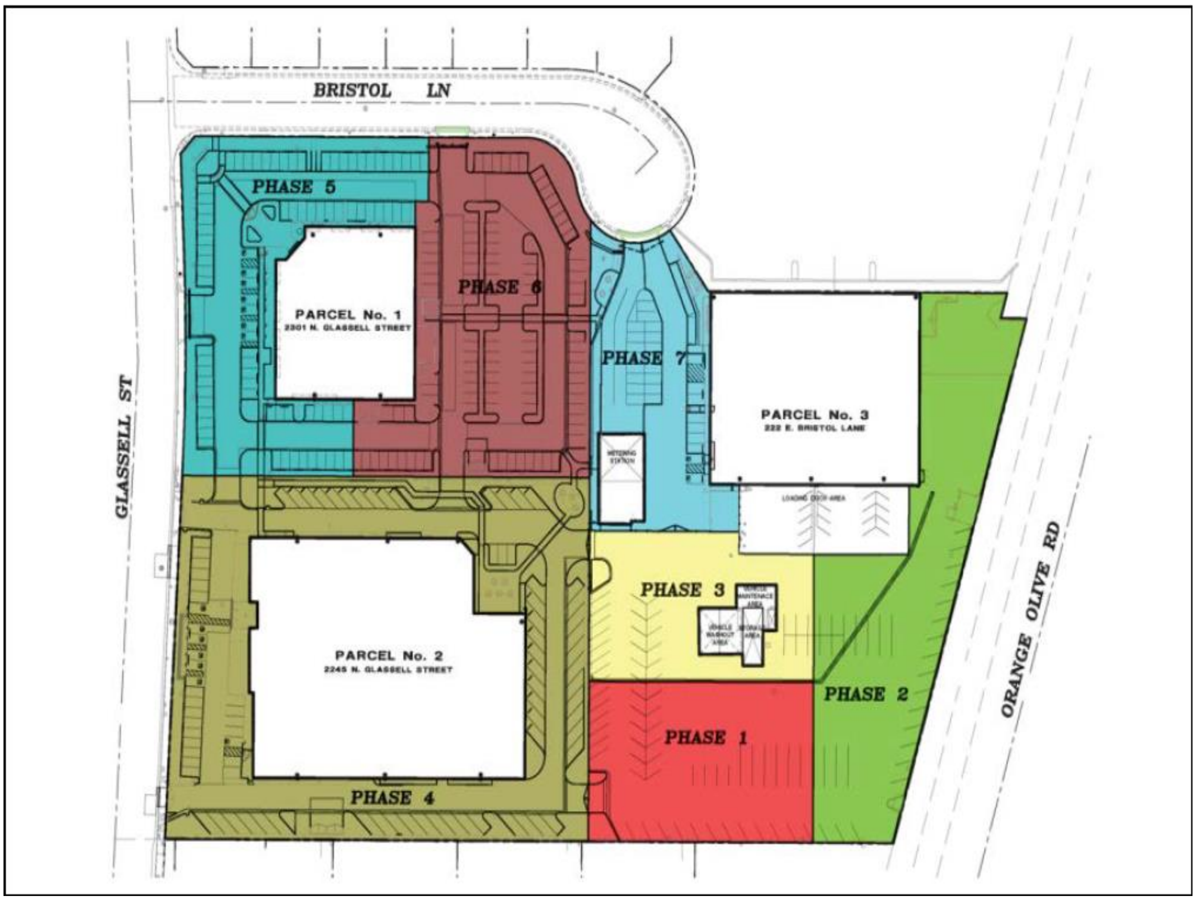


Figure 2-9. *Project phasing plan.*

Second, retrofitting existing facility with many underground utility lines posed unique challenges. This site did not have as-built plans associated with it so a utility disposition was created by design which was very helpful but not thoroughly complete. The contractor did hit a few unknown utilities (gas, water, power, etc.) during construction and also had to work around existing storm drain lines with revised project plans.

Third, the construction contractor management could be a challenge. The contractor, Tobo Construction, was selected through a competitive bidding process. The company had a prior LID construction project experience in Orange County. However, the construction process encountered many issues. Utilities including natural gas, electric, and water lines were damaged multiple times. Flow-through planters and pervious pavers were constructed incorrectly initially and had to be rebuilt. Porous concrete were constructed inconsistently and there are patches with virtually zero infiltration. Grading at some places were finished incorrectly, causing stormwater runoff to exit the site instead of being diverted to the bioswales as designed. Many overflow structure in the bioswales were constructed incorrectly, mostly due to the lack of freeboard, allowing the stormwater to drain out too early during heavy storms. As a result, the construction period nearly doubled from its original 180 days (excluding weekends, holidays, and rainy days).

2.3 Operation and Maintenance

The operations and maintenance of the facility presented a major challenge. Despite the seemingly widespread implementation of LID projects throughout Southern California, simply locating a firm with the capability of maintaining an LID facility proved to be challenging. County's purchasing staff sent out the initial request for bid (RFB) as a landscape maintenance project. No bid was received, presumably because of the extensive requirements for maintenance of a wide range of LID BMPs that are outside of the expertise of general landscape maintenance contractors. After the issue was corrected, a competent LID maintenance contractor, Downstream Services, the only contractor that entered a bid for the maintenance RBF, was retained.

Due to construction delays that resulted in delay in the initiation of the maintenance contract (late April 2017), no actual maintenance has been conducted by the maintenance contractor at the time when this report was finalized. With an annual cost of approximately $84,988 (service only; time and materials for non-routine work extra), the County is committed to maintaining the Project site for 20 years.

The maintenance contractors will work collaboratively with the Project team to finalize the detail of the Operation and Maintenance Plan (Appendix C) for the purpose of testing the effect of LID BMP effectiveness under different, preset maintenance frequencies. This information will be reported on an ongoing basis. For example, extensive infiltration tests have been conducted for all three types of pervious surfaces (pavers, asphalt, and concrete), as shown in Figure 2-10. The data are summarized in Table 2.1 below.

Table 2-1. Summary of infiltration test results for permeable paving

Site Material	Site ID	First run	Second run	Performance change (Second run-First run)		
Pervious Concrete	1	582.3	424.6	-157.8	Mean	-41.4
	2	540.0	486.8	-53.2		
	3*	0.0	0.0	0.0		
	4	66.0	62.1	3.9	Std. deviation	69.2
	5*	0.0	0.0	0.0		
Pervious Paver	1	139.3	162.9	23.6	Mean	21.8
	2	123.9	149.4	25.5		
	3	127.9	152.6	24.7		
	4	174.7	213.6	38.9	Std. deviation	15.5
	5	65.6	61.9	-3.6		
Pervious Asphalt	1	124.3	108.3	-16.0	Mean	0.1
	2	109.1	101.1	-8.0		
	3	68.9	95.7	26.8		
	4	32.6	46.9	14.3	Std. deviation	19.5
	5	169.4	152.9	-16.5		

* Test not conducted for second run because of virtually non-existent infiltration at the test site

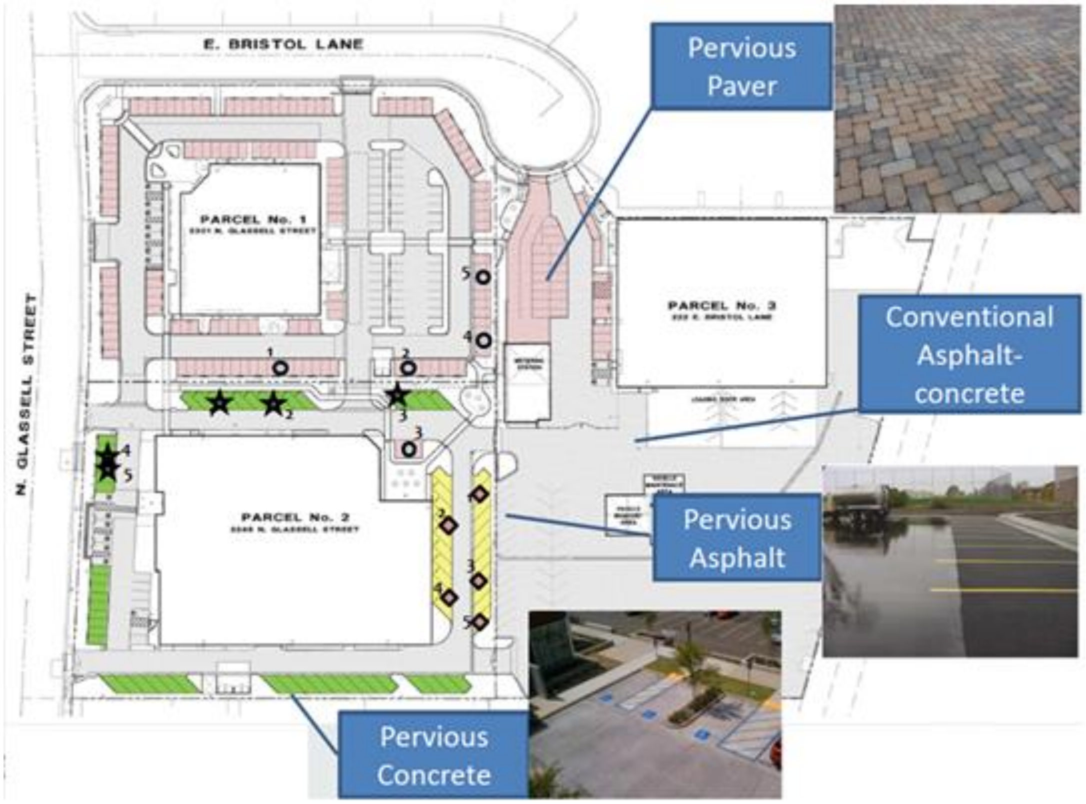


Figure 2-10. *Locations of infiltration tests for three types of pervious surfaces. Both rounds were conducted at the same five locations for each surface type.*

Chapter 3. Public Outreach

3.1 Significance of Public Education and Outreach

Public education and outreach was the original impetus of the Project and has been an integral part of the Project since its conception in 2009. Consideration of the public education and outreach elements was manifested in project planning and design stages as well.

As a stormwater agency and required by MS4 permits, OC Watersheds' Stormwater Program has a robust public education program that has an annual budget of $500,000. The keyword 'Public Education' appeared in the MS4 Permit appeared 23 and 27 times in the permits for the Santa Ana and San Diego Region, respectively. For The dropdown menu of the website for the Public Education Program can be seen in Figure 3.1 below. Geared toward the general public, the website has a collection of information on stormwater (including LID), watershed, water conservation, pollution control, recycling, and information for K-12 students, among others. The brochures are written in 5 different languages.

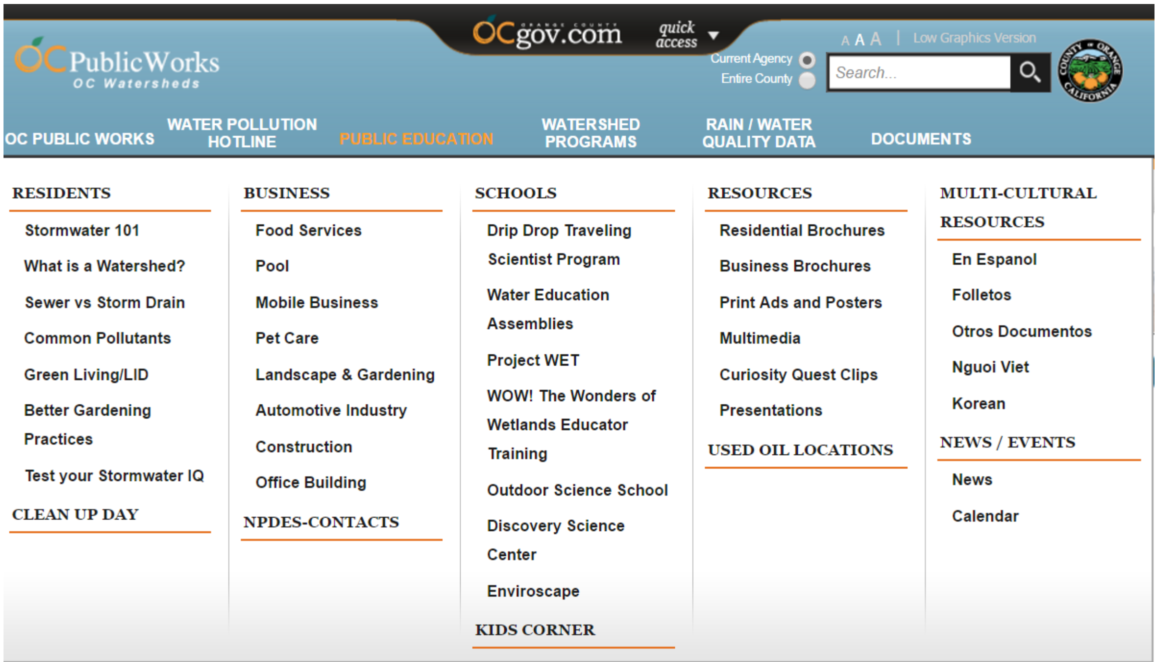


Figure 3-1. *Programs and projects for Orange County Stormwater Program's Public Education Program*

3.2 Public Education and Outreach Elements in the Project Design

3.2.1 LID BMP Selection

To our knowledge, there has not been such a LID project with such a comprehensive selection of different LID types. They were selected so that different types of LID BMPs can be monitored and their performance data shared among the stormwater community. The other main consideration is for public education and education purposes because by putting them together on the Project site, the visitors and tour participants can learn about them without going to many places. The BMPs were sited based on site conditions (slope, drainage areas, and infiltration rates) as well as to maximize the educational value.

3.2.2 Walk Way Design

The walkway design (Figure 3.2) was based on where these BMPs were located so that the tour participants can learn about these BMPs from the walkway in one single loop. See Figures 2-8a and b as well as Attachment A 1 for details about the BMP location, walkway design, and LID types.

Lastly, both City of Orange and OCWD will use the project site in their public education effort to promote low impact development, water conservation, and groundwater recharge. Both will add project web links on their website to guide interested individuals to OC Watersheds project website.

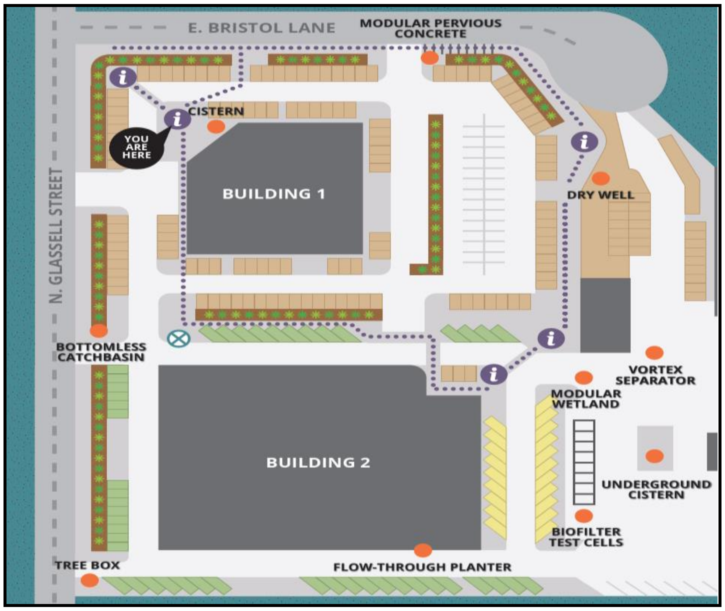


Figure 3.2. *Walkways (dotted lines) with interpretive signage for public tours of the Project. Most of the main LID BMP features are on or near the path.*

3.3 Public Education and Outreach Implementation

3.3.1 Signage

The educational signage design is presented in Appendix D. They summarize, in plain language, all key Project information on five permanent interpretative panels strategically placed throughout the campus along a dedicated pathway. The signage panels will have QR codes that guide the tour participants to the Project website.

3.3.2 Website

The project will also be promoted at OC Watershed's public education webpage (www.ocwatersheds.com, and www.ocwatersheds.com/publiced, see Figure 3.3), which is viewed over 10 million times annually. An electronic form could be filled out and submitted by the public or other agencies to request information or a campus tour. Designated OC Watersheds staff will be trained to give the campus tour.

Figure 3-3. *Project website with all key Project information, including reservations for docent-led tours*

3.3.3 Brochures

The brochures, to be distributed to tour participants, will be based on the signage design but will be on a single A4 paper. County is in the process of producing such a brochure with consultant support.

3.3.4 Tours

The Project team has trained volunteer docents (County staff located at the Glassell Campus) on conducting Project tours for different groups of potential visitors. By the time when this report was drafted, more than 300 individuals have participated in more than 20 guided tours of the Project site. These tours were conducted before, during, and after the Project construction by a wide spectrum of people, including K-12 students, college students, researchers, governmental officials, stormwater practitioners from academia, regulators. See Appendix E for a complete list of tour participants.

3.3.5 Educational Videos

At the time when this project was finalized, the educational video was under production by MBI Media, Inc. The scope of work includes:

PRE-PRODUCTION:

- Logistics
- Content Collection and Development
- Story Development
- Scripting for Narratives
- Meetings (Client/Crew)
- Communications (Phone/Email)
- Reviewing Existing Footage Provided by County

PRODUCTION

- Interviews of Project Team Members
- B-Roll (i.e. Supplemental or Alternative Footage Intercut with the Main Shot)
- Footage for 'Overwateringisout' Campaign and Gnorman the Gnome (Green Screen)
- Audio

POST-PRODUCTION

- Content Editing
- Existing Footage Editing
- Audio Editing
- Graphics Creation
- Animation
- Gnorman the Gnome (Green Screen) Edits
- Build Story
- Consultation with Project Team on the above tasks

DELIVERABLES

- Fully edited educational video delivered before Wednesday, May 31, 2017

• Possible use at OCPW event on Saturday, May 20, 2017

MEETINGS and REVIEW

- meetings/conference calls/webinars (as needed) with the Project Team to check progress and go over the intermediate work products
- 2 rounds of review for the draft final deliverables

Once completed, the education videos will be featured on the Project website, County's main website, Project Partners' website, and other promotional materials, including social media sites.

3.3.6 Outreach by Partners

The partners of the Project include Orange County Coastkeepers, City of Orange, Santa Ana Watershed Project Authority, Orange County Water District, the University of California Irvine.

The public education and outreach elements of the Project will be put on each of the partner's website and they will promote the Project through a range of activities, including organizing tours, staff training, research, and other tasks. County will keep track of these activities on an ongoing basis.

3.3.7 Awards

By the time when this report was completed, the Project has received the following awards:

- The 2016 American Society of Civil Engineers (ASCE) Orange County Chapter's "Sustainable Engineering Project of the Year" Award;
- The 2016 American Public Works Association (APWA) Southern California Chapter's Building Excellence, Shape Tomorrow (B.E.S.T) Award in the category of Regional Storm Water Quality;
- 2017 National Association of Counties Achievement Awards in the category of County Resilience: Infrastructure, Energy, and Sustainability.\

3.3.8 Conferences, seminars and publications

By the time when this report was completed, the Project team members have attended several conferences and seminars to receiving training on the LID practices and to use the Project as an example of LID implementation. These conference include the International LID Conferences in Houston, Texas (2015) and Beijing, China (2016); the International Digital Symposium hosted by UCI Water-PIRE project (see Chapter 5); and various seminars. One peer-reviewed critical review paper with Jian Peng as the lead author "*Indicator and pathogen removal by low impact development best management practices*" was published by the journal of *Water* in 2016

Chapter 4. Project Evaluation and Effectiveness

4.1 Pre-Project Monitoring

Extensive pre-Project monitoring including water quality sampling, flow measurements, infiltration tests, and model simulation was conducted from 2009 through 2015. For the period between 2009 and 2012, the monitoring data were used as the basis of Project design. From 2012 to 2015, additional monitoring was conducted to better establish the baseline for the pre-Project condition. The information was previously presented in Section 2.1 and data is summarized and discussed later in this chapter. Figure 4-1 shows some examples of pre-Project monitoring activities.

Figure 4-1. *Example of pre-project monitoring activities. Upper left: infiltration test of pervious surfaces with standard method ASTM C1701(see Table 2-1 for results); upper right: NMG consultants testing the soil infiltration rate at the bore hole; lower left: OC Public Work staff collecting stormwater samples and downloading flow data after the February 2014 storm; lower right: time-series stormwater samples collected by autosampler on February 28, 2017, showing distinct turbidity pattern (see Figure 4-2 for results).*

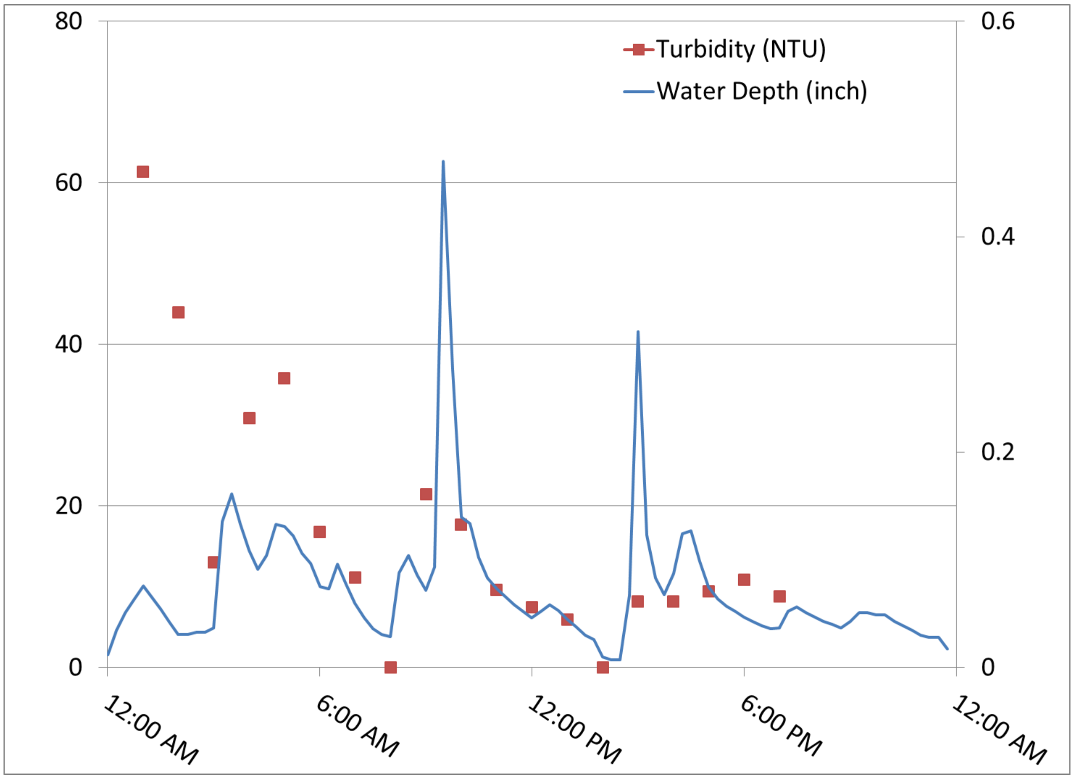


Figure 4-2. *Time-series results of hydrograph and corresponding turbidity results for the February 27-March 3, 2014 storm. The data covered the 24-hour period on February 28, 2014.*

For the February 27 to March 3, 2014, a series of storms occurred and a time series measurement of both flow (as measured by water height) and water quality sampling were conducted. Figure 4-2 shows a strong correlation between turbidity and hydrograph. The water quality data for the composite sample (including all 24 time series samples collected by the ISCO autosampler) were incorporated in Table 4-1.

4.2 Quality Assurance Project Plan

A QAPP has been developed in 2014 before the start of the Project as part of the Prop.84 Grant requirements. The QAPP has guided the implementation of quality programs for the project, including the pre-Project monitoring activities. The QAPP is fully comparable to the Surface Water Ambient Monitoring Program (SWAMP) guidelines and contains the Project Performance Assessment and Evaluation Plan (PAEP) outlined below.

4.3 Performance Assessment and Evaluation Plan

The Performance Assessment and Evaluation Plan was developed as part of the QAPP and includes specific and measureable targets for each of the following categories:

- Runoff volume reduction to mimic pre-development hydrology
- Pollutant load reduction compared to project site existing conditions
- Rainwater Harvesting
- Stormwater Reuse
- Groundwater Recharge
- Native, Drought Tolerant Vegetation
- Public Education and Outreach
- Reduction of Greenhouse Gas Emission

The goals for these categories were set conservatively. However, it is possible certain performance goals cannot be met due to one of the following reasons:

1. Project design deficiency (e.g. error in BMP volume, infiltration rate etc);
2. Project implementation/construction deficiency (e.g. construction not per spec);
3. Monitoring data not specific enough to quantify performance;
4. Lack of monitoring data to provide statistically significant determination;
5. Expert panel disagreement with the data interpretation methods

Since the project design performance relies on the published/anticipated performance data for a number of BMPs, non-achievement of some Project performance goals could also happen due to non-performance of certain commercial BMPs even if installation and sizing are conducted as specified. The failure of these BMPs will also be documented and reported.

4.4 Monitoring Plan

The Monitoring Plan is also part of the QAPP. Pursuant to the Monitoring Plan, the project performance targets in the PAEP will be evaluated on a quantitative basis with monitoring data collected consistent with the quality assurance requirements. The detailed information is presented in the QAPP in Appendix B. All data collected will be reported to California Environmental Data Exchange Network (CEDEN), the statewide database for ambient water quality data collected pursuant to SWAMP requirements.

On the next page, Figure 4-3 shows the planned monitoring locations for the LID BMPs located in the Project site.

Further, the following Figure 4-4 shows the monitoring shed with a flow meter and refrigerated ISCO ® autosampler for flow measurement and automated stormwater sampling. The shed was constructed until after the conclusion of the 2016-17 storm season and no storm was monitored. The system will be tested in the spring of 2017 using a fire hydrant with metered flows.

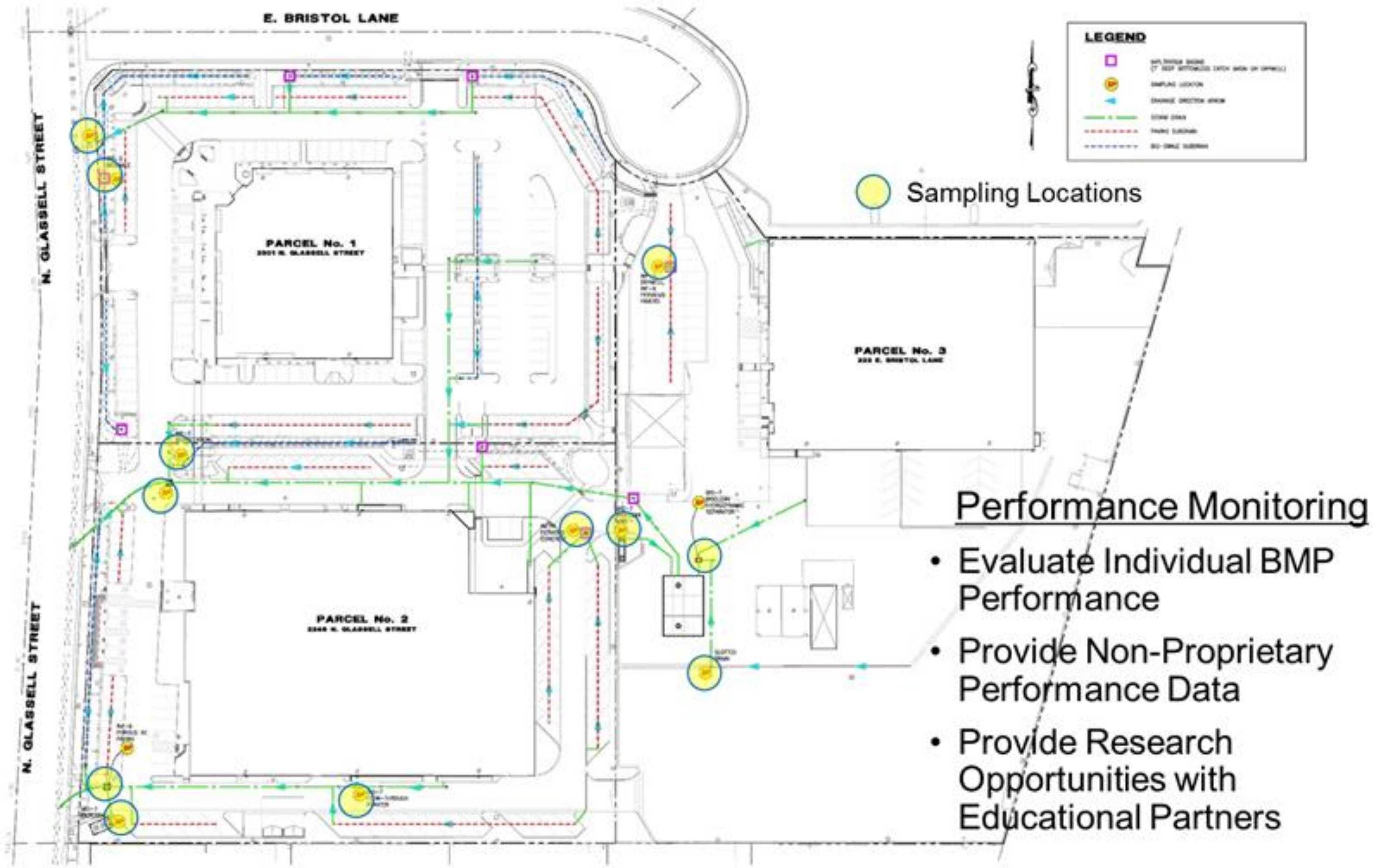


Figure 4-3. *LID BMP performance monitoring locations.*

Figure 4-4. *Monitoring shed located between Parcels 1 and 2. Inset: the inside of the shed, with ISCO 4230 Bubbler flow meter on the top right and ISCO 6712 FR refrigerated autosampler on the lower left. They monitor continuous flows and take samples at preset intervals from the underground pipe that drains approximately 50% of the entire site.*

A permanent monitoring station was constructed to monitor stormwater volume and quality in the underground storm drain between Parcel 1 and 2 (see Figure 4.4). This site drains most of Parcel 3 and about half of Parcel 1 and Parcel 2. Therefore it is the ideal location to assess the overall runoff quantity and stormwater quality. At the same time, autosampler or grab samples will be collected at other outfall locations during storm events to assess the runoff at other locations if feasible.

4.5 Post-Project Monitoring and Stormwater Runoff Simulation

Table 4-1 shows the pre- and post-Project monitoring results for a range of stormwater-related pollutants. With the exception of Arsenic and total coliform, which showed moderate increases in the post-Project condition, all other pollutants showed reduction ranging from 30% to more than 95%. With the considerable reduction of runoff volume based on observation only, it is anticipated that the goal of 95% overall pollutant load reduction goal will be met or exceeded. Continued monitoring will be conducted in the coming years with automatic sampling and discharge measurements.

A preliminary computer simulation using USEPA's Stormwater Management Model (SWMM) was conducted to establish the modeling framework for the Project for assessing the effectiveness of the Project. Due to the fact that drainage was modified, conducting strict pre- and post-project comparison for both runoff volume and water quality would not be possible without the modeling approach. To this end, a team of UC Irvine researchers and graduate students established the modeling framework. The preliminary modeling results are shown in Figures 4-5 to 4-7. The model needs further testing and calibration before it will be fully functional.

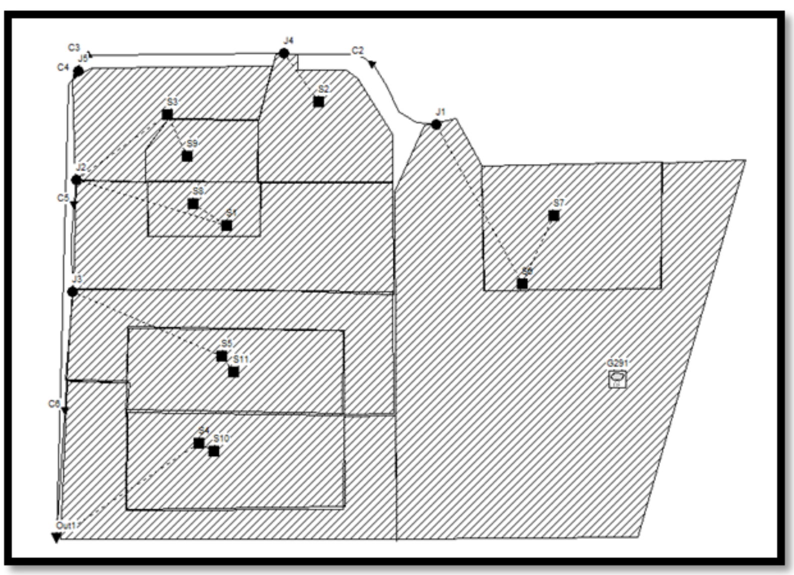


Figure 4-5. Project SWMM modeling domain and control points.

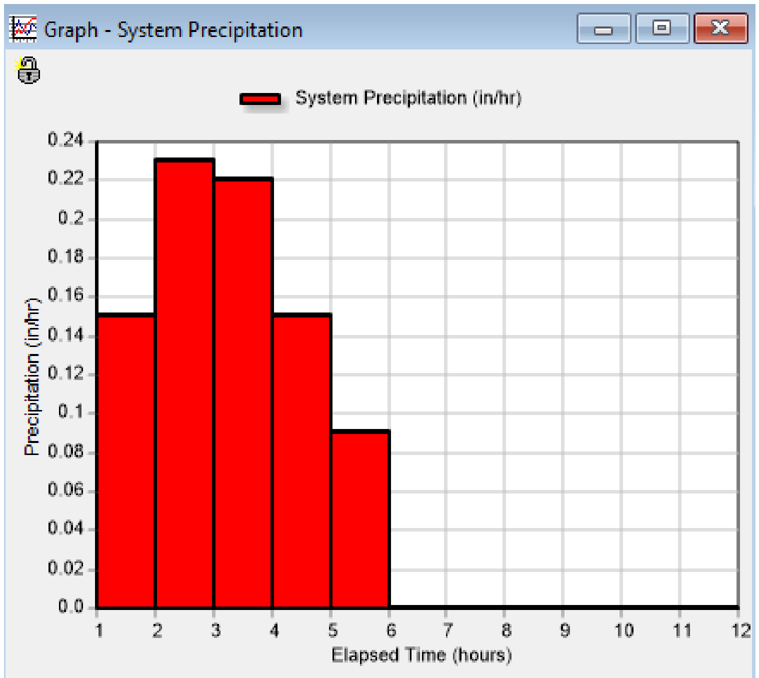


Figure 4-6. *Computer representation of the storm event on February 28, 2014.*

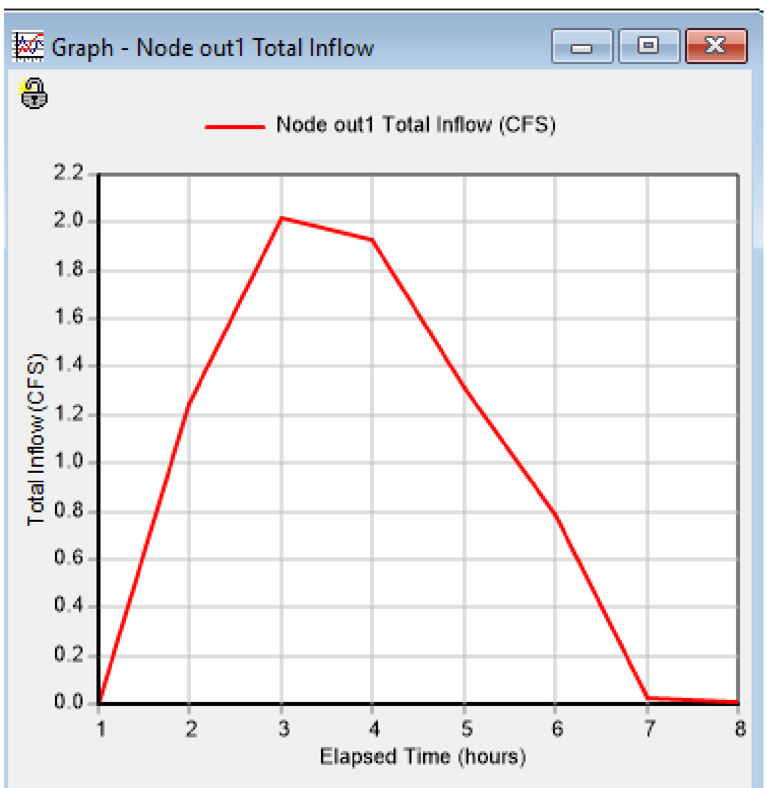


Figure 4-7. *SWMM simulated runoff hydrograph in the gutter at the Bristol-Glassell intersection.*

Table 4-1. Summary of Water Quality Monitoring Data

Pollutant	Unit	Pre-LID*	Post-LID**
Total Coliform	MPN	4100	9100
Fecal Coliform	MPN	83	9
Enterococcus	MPN	1340	1190
Turbidity (in situ measurement)	NTU	218	15
Total Suspended Solids	mg/L	320	15
Disel Range Organics	mg/L	2.03	
Orange Range Organics	mg/L	1.02	
Conductivity	uS/cm2	415.5	120
Volatile Suspended Solid	mg/L	118	5
Turbidity	NTU	169.67	15
Ammonia as N	mg/L	0.95	0.21
Total Kjedahl Nitrogen	mg/L	7.87	
NO3+NO2	mg/L	477.8	1.6
Total Suspended Solids	mg/L	273	15
pH		6.78	8.08
Total Phosphorus as PO4	mg/L	2.28	0.72
Ortho Phosphorus as P	mg/L	0.19	0.16
Methyl Blue Active Substance	mg/L	1.2	0.13
Cadmium	ug/L		0.58
Chromium	ug/L		1.8
Copper	ug/L		9.5
Iron	ug/L		800
Lead	ug/L		1
Nickel	ug/L		3.4
Selenium	ug/L		ND
Silver	ug/L		NA
Zinc	ug/L		130
Polycyclic Aromatic Hydrocarbons			NA
Phthalates			NA
Phenols			NA

** Based on multiple samples collected from 2010-2014*

***Based on one single sample collected in 2017*

4.6. LID Stormwater Research

As part of the public education and outreach effort and to maximize the value of the project site for stormwater-related research and education, the Project team has collaborated with scientists at the University of California (including the Irvine, Los Angeles, and San Diego campuses); Scripps Institute of Oceanography; Stanford University; and Southern California Coastal Water Research Project on the following projects:

The Project team is collaborating with University of California Irvine (led by Dr. Stanley Grant) on the National Science Foundation's Partnerships for International Research and Education (PIRE) grant project (funding amount: $4.8 million) focused on sustainable urban water systems including stormwater issues in both USA and Australia. The Project team member Jian Peng has presented multiple times at PIRE events about stormwater issues.

The Project has also provided an excellent LID BMP demonstration/testing facility for the above institutions for research and educational activities for several grant applications. The funded projects include a $600,000 National Science Foundation Research Experiences for Teachers (RET) Program. The Project site will be used to train 30 community college teachers for 8 weeks each year for a 3 year period. The training will focus on stormwater issues, biofilters, and water resource management. These teachers can then share their experiences and training to a large number of community college students for years to come.

Another project that received significant funding is University of California's Multicampus Research Program and Initiatives (MRPI) titled "Fighting Drought with Stormwater" ($1.9 million). In this project, a multidisciplinary team of researchers from across the five southern California UC campuses (Irvine, Los Angeles, Santa Barbara, San Diego, and Riverside) will join forces to catalyze dramatic changes in the form and function of urban stormwater infrastructure in Southern California and beyond. The ambitious project aims at transforming stormwater from a leading cause of environmental degradation into a multi-functional green system that augments urban water supply, protects human and ecosystem health, minimizes flood risk, and ensures public safety. The Project site and many of its LID BMPs will be the prototype testing units to support the MRPI project.

Figure 4-8. *The flyer of one of the four International Digital Symposium hosted by UCI Water-PIRE project. Project Consultant Jian Peng participated in the symposia. The other three topics were: LID and Flood Risk; LID and the Environment; LID and Water Resources.*

PIRE team, MRPI team, Stanford University, and SCCWRP researchers have been collaborating on utilizing the biofilter test cells (see Figure 4-9) and studying the effects of biochar and other design parameters (plants; soil media; hydraulic retention time; benthic infauna) on the removal efficiencies for fecal indicator bacteria and pathogens, microbial ecology, and treatment efficiencies for other pollutants.

Recently SCCWRP has allocated internal funding ($59,406) for research on the following three main themes: 1. Filter biofilter spiking experiments (using indicator bacteria as well as synthetic stormwater spiked with raw sewage or novel human indicators such as HF-183 and coliphage; 2. Laboratory batch experiment of biofilter media evaluation; 3. Cutting edge molecular methods to detect single cell vitality to distinguish live and dead indicator microbes in the environment.

Figure 4-9. *Eight identical biofilter test cells (5'x8'x6') built for stormwater research. At the far end of the cells are large bags of biochar supplied by Stanford University researchers that will be used for amending the soil media for pathogen removal experiment.*

In addition to the above funded projects, there are several projects with pending funding decisions. One such project is CISTERN: Community-based Intelligent StormwaTER Networks (funding requested: $7M), proposed by Professors Stanley Grant and Nalini Venkatasubramanian of the University of California, Irvine. The proposal has been submitted to the National Science Foundation's Emerging Frontiers in Research and Innovation Program (EFRI).

Other collaborative projects include Southern California Stormwater Monitoring Coalition (SMC) CLEAN (California LID Effectiveness Assessment Network) (funding requested: $50k) project. The Project site is the principal location where the bulk of monitoring and performance assessment will be conducted. The CLEAN project includes the following elements:

- Identify the key questions regarding LID BMP performance over time;
- Evaluate other relevant LID BMP monitoring work;
- Compile available existing LID BMP performance data/information (including LID conceptual model;
- Pollutant removal efficiency, and runoff flow parameters compared to pre-LID conditions);
- Evaluate LID BMP performance over time.

These are all critical questions faced by Southern California stormwater practitioners. By supporting the SMC CLEAN project, this Project will help built a LID BMP effectiveness database that includes meta data, which will be a significant improvement over the existing International BMP Database, which is widely cited but lacks meta data that guide the design and implementation of LID BMPs.

Chapter 5. Conclusion

The Project has been a success in many ways. As the lead agency for stormwater-related compliance for the entire county, OC Public Works managed the project site reconnaissance, project design, construction, and operation and maintenance. In each step, valuable experiences were gained and lessons learned. The extensive monitoring work conducted and planned will be used to supplement the existing LID BMP database and support innovative monitoring method, database design and data sharing. The extensive research work planned for the Project site will lead the nation on stormwater research, including the state-of-the-art research on the removal efficiency of pathogens and alternative fecal indicator bacteria. This research will have profound implication on the implementation of regional stormwater permits, where bacterial water quality is the principal driver for the implementation costs.

The Project work, in terms of deliverables to the funding agency (the State Board), has completed. However, in the sense that the Project has become the regional hub for stormwater education and outreach, BMP performance testing and data sharing, and cutting-edge stormwater research, the Project is entering into a new phase. Continued work will be carried out on an ongoing basis for the following:

- Ongoing operations and maintenance
- Ongoing monitoring and report the data to CEDEN
- Ongoing public education and outreach
- Ongoing stormwater research

The Project team understands that the true value and potential of the Project cannot be fully realized unless the above future work is carried on until the foreseeable future. Therefore, the team is extremely motivated to continue the work, build existing partnerships, forge new partnerships, and explore new ways to leverage the value of the Project.

Acknowledgements

The Project team (Robert McLean, Jian Peng, Chris Crompton, and Jeaniene Casiello) would like to thank the Prop.84 Stormwater Grant Program for the funding that made this Project possible. The Grant Manager Brandon Davison and his team have been instrumental in overseeing the project. His guidance has been critical to the success of the Project.

The Project team would like to thank many colleagues from OC Public Works and OC Flood Control District. They include but not limited to: Ron Gaut (retired), Ann Mesa, Stella Shao, Suzan Given, Rita Abellar, Robert Rodarte, Jonathan Lewengrub, Christy Suppes, Iris Corpus, Amanda Carr, Kevin Onuma, and many others from different service areas and divisions that collaborated seamlessly on this Project. Special thanks are given to Chris Tiffany, who as a graduate intern helped with the conceptual design in 2011.

We would also like to thank our partners for their support and participation over the years. They include: Santa Ana Watershed Project Authority; City of Orange; Orange County Coastkeeper; Orange County Water District; Southern California Coastal Water Research Project; Stanford University; and especially the research group led by Dr. Stanley Grant of the University of California Irvine.

Appendices

A. References

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B. List of Deliverables

- Project Final Design
- Performance Assessment and Evaluation Plan
- Independent Review Report by Urban Rain Design
- Operations and Maintenance Plan
- Project Educational Signage
- List of Project Tour Participants
- Presentation slides for Project tour docent training

C. Photographs Courtesy of Orange County Environmental Resources





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