UNIVERSITY OF CALIFORNIA, LOS ANGELES - STUDENT TEAM D34

LITTLE STEPS TO A SUSTAINABLE FUTURE

BROCKTON AVENUE ELEMENTARY SCHOOL

EDUCATING THOSE WHO WILL GROW TO SHAPE OUR WORLD

THE TEAM

Students

Samuel Hwang - Civil & Environmental Engineering

Camille Ituralde - Civil & Environmental Engineering, Urban and Regional Studies Minor

Allison Lee - Civil & Environmental Engineering, Geography Minor

Joyce Lee - Environmental Science

Annika Mellquist - Civil & Environmental Engineering

Patience Olsen - Civil & Environmental Engineering

Kyle Willenborg - Environmental Science

Faculty Advisor

Sanjay K. Mohanty, Ph.D. - Assistant Professor Environmental Engineering

Facilities Manager

Robert Laughton - LAUSD Maintenance & Operations Director

ABSTRACT

Located 3 miles southwest of the University of California, Los Angeles, Brockton Avenue Elementary School is built much like the rest of Los Angeles: almost entirely on concrete and asphalt. The existing urban landscape at Brockton Elementary not only prevents stormwater infiltration and increases runoff but also raises surface temperatures, which, coupled with the lack of large canopy trees on campus, causes heat exhaustion in students and inhibits play. Implementing stormwater capture and reuse systems on campus could support Los Angeles County's goal to achieve 100% local water supply by 2050, provide green spaces for community needs, and improve students' physical and mental health[1]. We thereby propose a variety of green infrastructure interventions, including a green roof, permeable pavement, underground cistern, bioretention areas, and drought tolerant gardens, complemented with benches and inclusive educational signage. Community inclusion is prioritized through volunteer workdays and areas for students to play, rest, and learn about rainwater capture on their campus. "Little Steps to A Sustainable Future" works directly with the staff and students of Brockton Elementary to cater to their specific needs, while also addressing the broader issues of water resource management in Los Angeles County and inspiring the future generation of environmental activists, scientists, and engineers.

INTRODUCTION

Regional Context

The Los Angeles (LA) County, one of the most populous counties in the United States, has faced severe water scarcity issues over the past century that threaten the county's long-term growth. To meet growing water demand, LA imports 85% of its water supply from Sierra Nevada snowmelt, the LA Aqueduct, the Colorado River[2]. However, population growth, extreme weather patterns associated with climate change, and regional competing interests present risks to the reliability of the imported water and pressure the city of LA to find its own reliable, sustainable, and local sources of water. In response, the mayor of LA initiated the Green New Deal, to triple the stormwater amount captured by 2035 and increase tree canopy in low-income, heat-impacted areas by at least 50% by 2028[3].

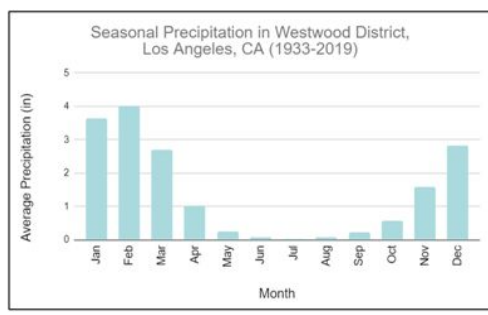

***Figure 1** plots the average precipitation in the neighboring Westwood District by month from data accumulated since 1933.*

Los Angeles receives around 15 inches of precipitation annually[4], most of which falls during the winter months as shown in **Figure 1**. Unfortunately, much of this potential resource is wasted from inefficient stormwater management, since the California Supreme Court removed incentives to regulate stormwater to the maximum extent practicable" when it ruled the storm sewer system to not be covered by the Clean Water Act[5]. Without regulation, urban surface runoff picks up pollutants and is shuttled directly into rivers and the ocean without treatment[6]. A complete shift in the city's perspective on stormwater, from liability to resource, will decrease surface water pollution, and promote riparian and coastal ecosystem health. Aside from its filtration capacity, green infrastructure provides numerous social benefits: improving issues of public health concern related to air and water pollution, raising mental health and productivity, and reducing stress[7]. It is critical to evaluate potential avenues to install stormwater infrastructure that could not only help achieve water sustainability, but also increase awareness and public acceptance.

Motivation

Schools provide the unique opportunity to educate and inspire the next generation of environmental stewards, so our objective of this project is to reduce and treat stormwater runoff while educating students and the school community. Recent studies have shown that addition of green space in school could also improve mental and physical health of students by creating a more natural landscape and reducing surface temperatures[1,7]. Braddock Drive Gifted Magnet and Elementary School in the LA Unified School District (LAUSD) introduced a 14,000 square foot (sq ft) interactive garden with native, drought-resistant plants and interpretive signs on plant, bird, and insect names, demonstrating possible educational benefits supplementing stormwater capture [8,9].

SITE SELECTION

Site Background

Brockton Avenue Elementary School is located on the outskirts of the Westwood district in Los Angeles and was founded in 1919. Juxtaposed with its wealthy neighbors, Brockton Avenue Elementary is a Title I funded school, indicating that its students predominantly come from lower-income families or are of greater risk of failing their classes[10]. This is reflected by their demographics: 73 percent of students at Brockton qualify for free or reduced lunches, and 41 percent are English-Language Learners[11]. Title I funded schools receive grants to provide students with additional instruction support outside the regular curriculum to help low-achieving students meet state standards of achievement.

Site Problems

60 percent of surface area at the school is asphalt, and only 15 percent of surface area is permeable area[12]. The campus uniquely spans an elevation gradient of 20 feet over three terraces.

Approximately 62,400 sq ft of asphalt is paved in total, and is used primarily for parking on the upper level and recreational activities on the lower levels[12]. The lack of vegetation on campus results in a slew of problems including heavily polluted stormwater runoff, poor air quality, and a lack of shade for students playing outside during recess.

SITE ANALYSIS

Soils & Existing Vegetation

The soil at the site is primarily Ramona Loam[13]. Loam is an ideal soil for plant growth and is typically composed of less than 52 percent sand, 28 to 50 percent silt, and between 7 and 20 percent clay. The low clay to sand ratio means that the soil is well-drained, producing slow to rapid runoff with moderately slow permeability and replenishing the underlying Santa Monica Basin aquifer during major rain events[14,15]. An introduction of green infrastructure to the area will capitalize on these existing favorable soil conditions to restore the depleted Los Angeles groundwater supply.

Existing vegetation at the site includes three grass patches of varying size, seventeen trees, and thirty-one shrubs. The largest grass patches spans 9,900 sq ft in the southern area, another grassy area spans 2,100 sq ft on the northwestern corner, and the smallest grass patch covers 1,000 sq ft of space under a tree in the center of the campus. The trees and shrubbery surround the perimeter of the school, with two trees in the center of the school with the smallest grass patch.

Water Flow and Drainage

Since the school is located within the Santa Monica watershed, any precipitation over Brockton Elementary that is not infiltrated is instead expelled as runoff into the Santa Monica Bay. This runoff is conducted mainly via three catch basins installed and maintained by the LA County Storm Drain System at the east and south corners of the property[16]. The three major drainage areas are shown in **Figure 2**. The vegetated area on the upper left corner of the campus was not included in any of the three drainage areas since its natural topography directs runoff into the street and does not affect the campus drainage.

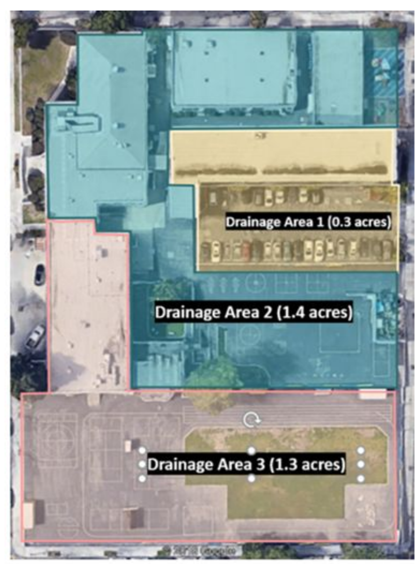

Figure 2 *categorizes the campus into three drainage areas.*

GOALS

We identified six goals for the application of green infrastructure within the geographic and demographic context of Brockton Avenue Elementary School.

1. Capture and treat the complete runoff volume of the 85th percentile, 24-hour storm
2. Educate students and staff on water sustainability through school activities
3. Encourage community involvement and space activation
4. Improve air quality and reduce surface temperatures
5. Revitalize campus aesthetics with green spaces to improve mental health
6. Demonstrate awareness of precipitation seasonality

The limited space at Brockton Avenue Elementary School demands creative and efficient solutions; we propose the use of a variety of green infrastructure interventions and educational initiatives to accomplish these goals. Throughout the planning, implementation, and maintenance phases, these goals will continually guide and inspire our efforts, measuring the extent of success of each goal with a performance matrix at each phase to quantify how users respond to the green infrastructure.

DESIGN SOLUTION

The proposed applications of green infrastructure designed to address these goals include 7,600 sq ft of green roof area, 4,800 sq ft of permeable pavement that drains to a 2,650 cubic foot (cb ft) underground cistern, three bioretention areas, and four drought-tolerant rain gardens hosting fourteen native trees, four benches and six educational signs, as shown in **Figure 3**.

Green Roof

Green roofs will play a critical role in reducing stormwater pollution, air pollution, and surface temperature problems that plague Southern California. These roofs lower the temperature of the surrounding area through evapotranspiration, thereby reducing money spent on cooling and improving energy efficiency for the building. The plants on green roofs use rooftop runoff from stormwater events and improve air quality by filtering greenhouse gases and particulate matter, addressing Goals 1 and 4.

With approximately 23,000 sq ft of flat roof space exposed to sunlight, 21 percent of the total area of Brockton Elementary is potentially usable for green roofs. We have considered the structural stability and roof obstructions of the various buildings on campus before deciding to install a green roof on the main entrance building in Drainage Area 1, labeled as Location 1 on **Figure 3**. We plan to cover the 7,600 sq ft of this area with Dune Sedge, a drought resistant, evergreen grass species that saves 50-70 percent more water than a traditional lawn[17], addressing Goal 6 of our design objectives. Additionally, a drip irrigation system will be installed in order to provide ample water supply in the drier months of the year.

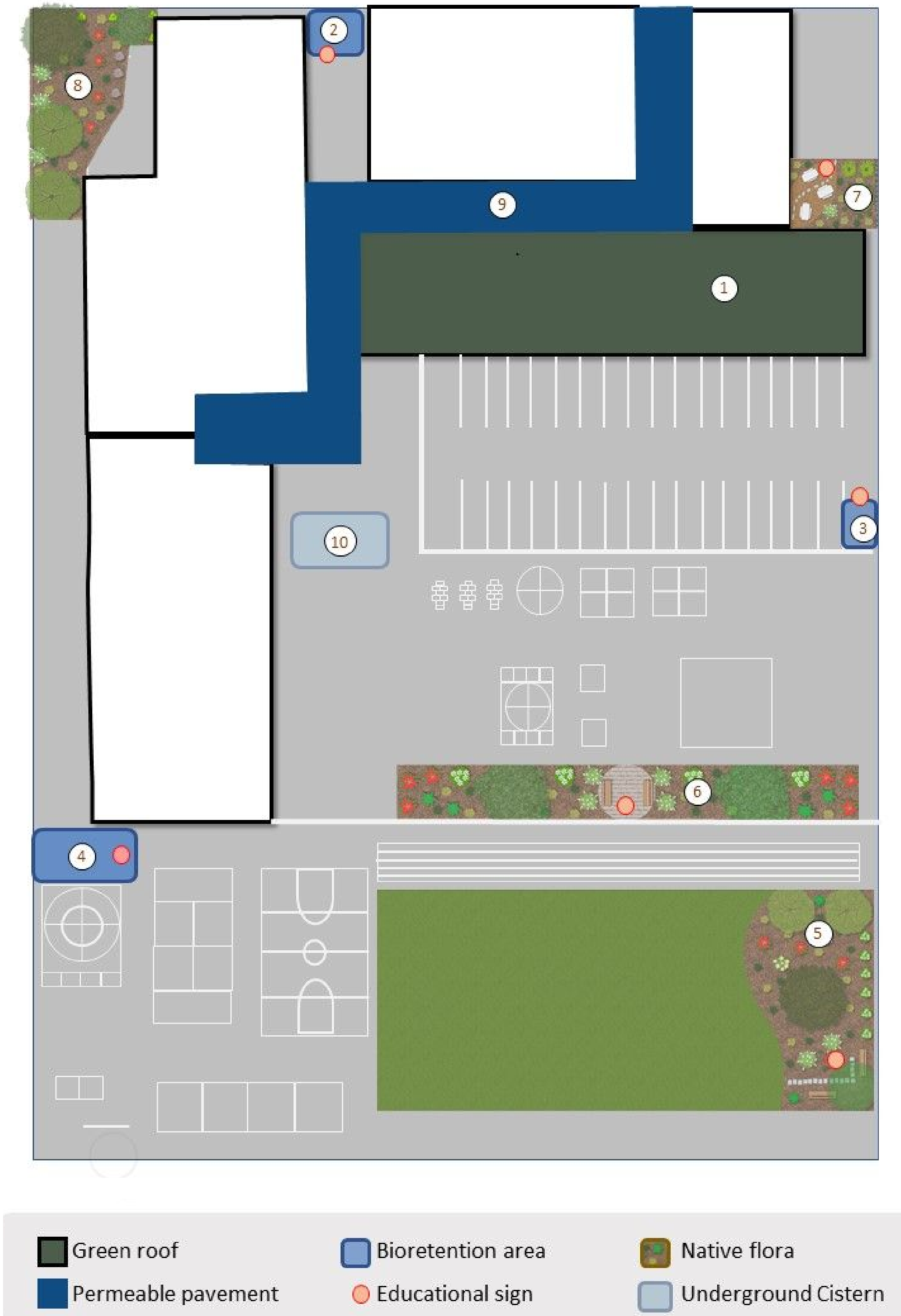

Figure 3 *lays out the proposed additions of green infrastructure to the elementary school.*

Permeable Pavement

The terrain at Brockton elementary is predominantly pavement, which contributes to pollutant runoff and small-scale flooding where rainwater stagnates. To tackle this, we will install 4,800 sq ft of permeable pavement in the exposed corridor on the northern portion of the school (Location 9, **Figure 3**), addressing Goal 1 by reducing runoff and increasing infiltration. Recognizing the moderately slow permeability of the soil, we will also add an underdrain below the soil to direct the infiltrated water to the underground cistern discussed in the following section.

In addition to its potential for stormwater capture and filtration, a secondary benefit of permeable pavement is that it will decrease surface temperatures during rain events. When water is absorbed by permeable pavement, the surface temperature is regulated better than it is by plain black asphalt due to the high specific heat of water. Regular asphalt also has a low albedo, meaning more solar radiation is absorbed upon heating. Adding permeable pavement means less solar radiation will be absorbed and more water will saturate the surface, making warm days more manageable for students. Implementing permeable pavement will therefore address Goals 1 and 4.

Underground Cistern

Cisterns are artificial reservoirs used to capture runoff from paved areas. The stored rainwater can be used for irrigation, thereby reducing water demand and water bills for the school. We will install an underground cistern at Location 10 on **Figure 3** to collect and store runoff from the proposed permeable pavement through the underdrain. The proposed underground cistern can hold 2,650 cb ft of runoff. A small sedimentation unit will remove trash and sediment from runoff to prevent large contaminants from entering the storage unit. Before being used for surface irrigation, the water stored in the cistern will undergo UV disinfection to remove biological pathogens.

Bioretention area

Bioretention areas are designed to remove silt, trash, metals, bacteria, oils, grease, and organic materials from surface runoff. Effective bioretention areas are designed with gently sloped sides filled with vegetation and compost and a flow path designed to maximize the time spent in the swale, which enhances water quality through gradual infiltration. We propose to implement bioretention areas at Locations 2, 3, and 4 in **Figure 3** to capture 540, 720, and 900 cb ft of runoff respectively. These locations are currently either pre-existing points of drainage or unused paved sections. Runoff can be directed into these bioretention areas with curb cuts at Location 3 and with slight regrades if necessary. These bioretention areas will be designed with an impermeable layer at the bottom of the excavated area, 12 inches of gravel, 4 inches of pea stone, 24-48 inches of bioretention soil media (composed of 40 percent sand, 20-30 percent topsoil, and 30-40 percent compost), 3 inches of fine-shredded hardwood mulch, and 6-9 inches to account for ponding depth[18]. The sloped sides will also hold the small tree Western Redbud, the large shrub Toyon, and the perennial California Goldenrod. Blue Rush will populate the flat bottom of the bioretention area. These plants are all native to Southern California and are suitable for bioretention areas because they tolerate a variety of soils and can provide good drainage in seasonal inundation and drought alike[19], addressing Goals 1 and 7 by reducing runoff with plants that tolerate precipitation variability.

Drought Tolerant Rain Gardens

Locations 5, 6, 7, and 8 in **Figure 3** will be transformed into walkable drought tolerant gardens compatible with the arid LA climate. Drought tolerant plants or native plants decrease the need for irrigation, conserve imported fresh water, and lower the overall cost for the school, which addresses Goal 6. A variety of plants were chosen because each plant provides unique benefits, enhances biodiversity, and increases the overall aesthetic, addressing Goal 5. All of our proposed plants were chosen according to the suggestions for the Los Angeles climate denoted in "The Drought Tolerant Garden, Los Angeles County Handbook"[20].

- **Mulch** helps to retain moisture, keep the ground cool, and suppress weeds. This allows for less watering, lower maintenance, and a beneficial impact on the urban heat island effect[21]. We propose the implementation of mulch in all proposed drought tolerant gardens.
- **Benches** cultivate a welcoming and natural learning environment for the students.
- **Trees** are interchangeable between the Tipuana Tipu, Coast Live Oak, and Chitalpa Tree in the design solution; they are all drought tolerant and provide shade.
- **Perennials** used are the California Buttercup and Scarlet Monkeyflower to provide attractive flowers during any season.
- **Grass** options include Common Rush or Blue Wildrye. These are very versatile and can be combined with any plant.
- **Vines** cover vertical spaces for privacy; We propose the use of the Virgin's Bower vine.
- **The California Tree Poppy** will serve as the focal point to these gardens. Native to southern California, this plant has stunning flowers that add visual interest to any space.

At Location 5, we propose the addition of a Coast Live Oak with surrounding vegetation to provide shade to the students during recess. Two benches and a path are also integrated into this area to allow students to interact with the garden. This location is proposed to capture 2,520 cb ft of surface runoff from Drainage Area 3. At Location 6, we propose one bench surrounded by California Tree Poppies and two Tipuana Tipu with a lively scattering of grass and perennials. This garden is designed to capture 1,620 cb ft of surface runoff. Location 7, adjacent to the playground, is currently a point of drainage into the street. We propose a small tree, surrounded by grass and benches, and the addition of a Virgin's Bower vine on the fence to the right for more privacy. This location is designed to capture 810 cb ft of runoff. The walking area will be made of dirt instead of mulch to accommodate foot traffic without disrupting the garden. Location 8, at the western corner of campus, is currently underutilized . This garden will harbor California Tree Poppies and a variety of grass and trees to increase biodiversity. By placing a drought tolerant garden in this area, the aesthetic value of both the school and the neighborhood improves.

Community Engagement and Education

We propose the incorporation of bilingual educational signs, live sensor readings, community volunteer days, and collaborative college visits to supplement our green infrastructure interventions. Through these measures, Brockton students and community will gain a greater understanding of the purpose and processes of green infrastructure.

There will be six educational signs, each located adjacent to an application of green infrastructure to educate readers on the significance of each type of green infrastructure applied, addressing Goal 2. Since 36 percent of students at Brockton Avenue Elementary are English-language learners with Spanish as their first home language, these signs will have both English and Spanish translations, as shown in **Figure 4**. In addition, we will implement various sensors to monitor the water usage. Flow sensors will be used to determine the amount of rainwater collected and used and supplemental city water needed[22]. Water temperature and pH sensors will be paired with LED lights in stormwater drains and inlets. The information gathered will be posted so that the public can view accumulated historical data.

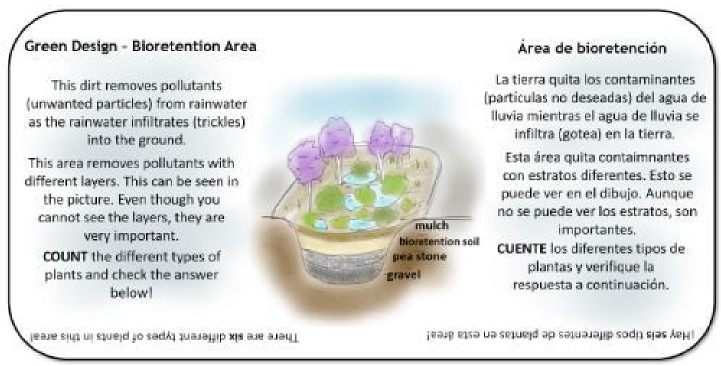

***Figure 4** gives an example of an educational sign by a bioretention area that would educate the students about its purpose and engage the students with an activity.*

We also propose a Volunteer Day to engage the community in planting native flora in the drought tolerant gardens and in the bioretention areas. Brockton Avenue Elementary has previously coordinated community days for mural painting, harvest festivals, and celebrations. Similarly, the community could learn about the importance of green infrastructure and stormwater management on campus in a Volunteer Day, satisfying Goal 3. The success of these Volunteer Days was previously demonstrated by the application of a rain garden and a bioswale to Braddock Drive Elementary School and Gifted Magnet, described as a case study in the Introduction. The school hosted a volunteer day where 150 volunteers completed soil distribution and planted 380 plants alongside representatives from LAUSD[9].

Members of our team went to K-5th grade classes to demonstrate the filtration processes of bioretention areas, and we were met with a great interest in water systems and environmental issues by both the students and the teachers. We propose integrating class garden visits into the curriculum and implementing a volunteer program in which UCLA students visit classrooms to encourage learning about water conservation and green practices with small-scale demonstrations, addressing Goal 2. We hope to cultivate a stronger partnership between Brockton Avenue Elementary School and UCLA, where Brockton students can also attend field trips to UCLA, to help empower them to pursue higher education and make a lasting impact on their world.

Design Performance

Runoff Volume Calculation using HydroCalc

The Los Angeles County LID Manual suggests sizing Best Management Practices (BMPs) to capture and treat the complete runoff volume of the 85th percentile, 24-hour storm. Capturing the water quality design storm allows for a significant reduction in effluent pollutant load due to consistent capture of what is commonly known as the "first flush." First flush describes the high concentration of pollutant load present within the initial parts of a rain event. For areas such as LA that experience infrequent rain events, capturing and treating the first flush is key as urban impervious areas are allowed more time to build up pollutants between storms. These BMPs are identified in their respective drainage areas in **Figure 5**.

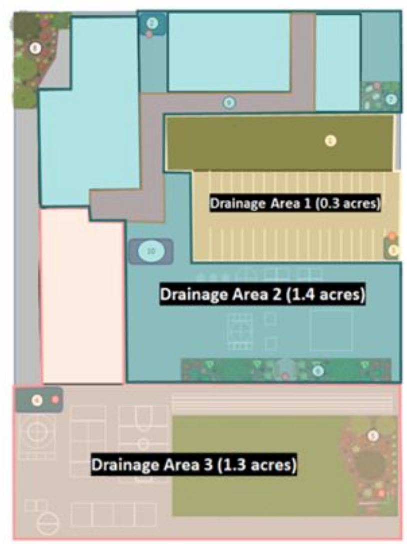

Figure 5 *isolates the three Drainage Areas and depicts the BMPs utilized within them.*

The runoff volume calculations shown in **Table 1** were performed using "HydroCalc", a software produced and made public by the LA County Department of Public Works. The software uses the modified rational method to calculate various parameters including total runoff volume and peak flow rate. For proper function, the software requires a user input of the drainage area, flow path length/slope, design storm frequency/depth, and soil type. The results for each drainage area are displayed below. Refer to **Appendix** for the complete inputs and outputs. Using LA County isohyets, the 85th percentile 24-hour rainfall depth for the project area is 1.1 inches.

Drainage Area	Area (ac)	Current Impervious	Current Runoff (cb ft)	Proposed Capture (cb ft)	TSS Removal (%)	Bacterial Removal (%)	Metal Removal (%)
1	0.3	0.95	1,020	1,230	85	5	2
2	1.4	0.95	4,770	5,370	76	19	7
3	1.3	0.65	3,190	3,420	85	95	35

Table 1 *lays out the HydroCalc runoff volume calculations for the campus, categorized by drainage area. TSS, bacterial, and metal removal percentages are calculated from BMP pollutant removal efficiencies by drainage area*[24].

Tree Benefits from i-Tree Design

The additional 14 trees added to the campus will provide a variety of ecological services to the Brockton Avenue Elementary students and the facility. The online application "i-Tree Design" was used to calculate the tree benefits related to greenhouse gas mitigation, other air quality improvements, and stormwater interception[23]. The trees have projected total-to-date benefits of $24,327 within their lifetime.

These trees are projected to intercept 21,281 gallons of stormwater annually by retaining rain on leaves, branches and bark, increasing infiltration through their root systems, and reducing soil erosion. These trees will conserve 432.1 Kilowatt-hours of electricity and will reduce consumption of heating fuel by 54.2 therms through shading and evapotranspiration in their lifetime. The trees selected for planting will sequester 15,055 pounds of atmospheric carbon dioxide annually, and decrease heating and air conditioning demands, which further reduces greenhouse gas emissions associated with power production. These savings are compounded annually, as shown in **Figure 6**.

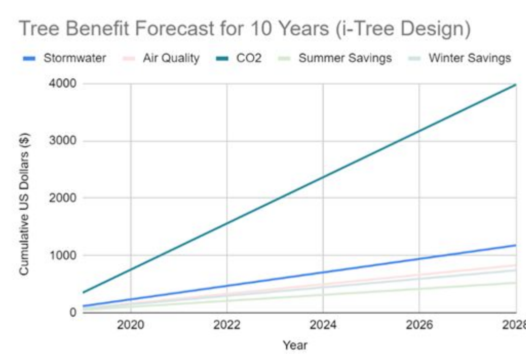

Figure 6 *plots the projected benefits of the 14 newly planted trees over the next 10 years by type of ecological benefits.*

PROJECT PHASING

The project phasing is modeled after previous case studies in the West Los Angeles area and is shown in **Table 2**. Planting will occur in the early fall so plants may acclimate over the wetter months before experiencing the lack of rain and intense heat typical of summer in Los Angeles.

YEAR IN PROGRESS	SEP - DEC	JAN - MAY	JUN - AUG
YEAR ONE	Create student involvement programs on campus. Incorporate sustainability and water conservation concepts in school activities with UCLA collaboration.		Install educational signs to explain future green infrastructure additions.
	Obtain necessary grants and permits.		
			LAUSD removes asphalt for drought tolerant rain gardens.
YEAR TWO	Classes visit and water gardens once every other month, scheduled such that the garden is watered twice a week and students can interact with the garden.		Install permeable pavement and underground cistern when school is out of session.
	Brockton Volunteer Day; community plants drought tolerant rain gardens.	Install educational signs about drought tolerant rain gardens.	LAUSD removes asphalt for bioretention areas.
YEAR THREE	Classes visit and water gardens once every other month, scheduled such that the garden is watered twice a week and students can interact with the garden.		Install green roof infrastructure when school is out of session.
	Brockton Volunteer Day; community installs bioretention areas.	Install educational signs about bioretention areas.	
YEAR FOUR	Classes visit and water gardens once every other month, scheduled such that the garden is watered twice a week and students can interact with the garden.		Check with LAUSD for repairs.
	Brockton hosts Volunteer Day; community installs soil and plants on green roof.		

Table 2 *lays out the four-year plan for implementing the proposed green infrastructure to the elementary school.*

COST AND MAINTENANCE

Development in Los Angeles can be expensive, but Brockton Avenue Elementary School will benefit from the recent push for green infrastructure in Los Angeles urban development. The expected costs are tabulated below in **Table 3** by category, along with a 15 percent contingency to account for unforeseen costs, adding up to $143,670.36 to implement this design.

Main Feature	Components	Cost per Unit	Quantity	Cost
Green Roof	Dune Sedge[29]	$4 per sf	7500 sf	$30,000
	Installation[30]	$1.66 per sf	7500 sf	$12,450
Permeable Pavement	Permeable Asphalt[31]	$1.00 per sf	4800 sf	$4,800
	Underdrain[31]	$20 per foot	400 ft	$8,000
Underground Cistern	2650 CF Cistern[32]	$5000 per unit	1	$5,000
	Sand & Cartridge Filter[31]	$560 per unit	1	$560
	UV Disinfection[33]	$760 per unit	1	$760
	Cistern Installation Cost[31]	$7,000	1	$7,000

Bioretention area	Engineered Soil[34]	$32 per cy	89 cy	$2,848
	Mulch[35]	$60 per cy	12 cy	$720
	Pea Stones[35]	$30-35 per cy	15 cy	$525
	Western Redbud[36]	$69.50 per tree	3	$208.50
	Toyon[37]	$190 per shrub	5	$950
	California Goldenrod[38]	$1.22 per plant	10	$122
	Blue Rush[48]	$6.50 per plant	17	$110.50
	Filter fabric[31]	$5 per sy	134 sy	$670
	Gravel[31]	$35 per cy	45 cy	$1575
	Underdrain[31]	$20 per foot	1000 ft	$20,000
Drought Tolerant Rain Gardens	Engineered Soil[34]	$32 per cy	204 cy	$6,528
	Gravel[31]	$35 per cy	102 cy	$3,570
	Tipuana Tipu[37]	$450 per tree	4	$1,800
	Coast Live Oak[39]	$330 per tree	2	$660
	Chitalpa Tree[40]	$72.98 per tree	5	$364.90
	California Buttercup[38]	$0.43 per plant	10	$43
	Scarlet Monkeyflower[38]	$0.91 per plant	15	$13.65
	Common Rush[41]	$2 per plant	25	$50
	Virgin's Bower[42]	$7 per plant	5	$35
	Blue Wildrye[43]	$0.29 per 1 pound	4 lb	$92
	California Tree Poppy[38]	$4 per plant	10	$40
Benches	Bench[44]	$500 per unit	4	$2,000
Sensors	Flow Sensor[45]	$160.65 per unit	8	$1,285.20
	pH Meter and Thermometer with Bluetooth[46]	$165 per unit	4	$660
Educational Signs	Signpost[47]	$50 per unit	6	$300
			Predicted cost	$124,930.75
			15% contingency	$18,739.61
			Total cost	$143,670.36

Table 3 *identifies the cost of the components within the proposed applications of green infrastructure. When prices were given as a range of prices, these calculations were made using the larger price to produce a conservative cost.*

The maintenance of these applications of green infrastructure can be incorporated into semi-annual volunteer days and into the existing LAUSD maintenance routines. The green roof will require little attention aside from regular fertilizing during the growing season. Permeable pavements should be inspected regularly and power washed two to four times a year to prevent clogging. The bioretention areas and drought tolerant rain gardens can be maintained through regular weeding, mowing, fertilizing, and trash removal to reduce clogging. These activities can be performed by students, classes, and volunteers through coordinated campus events for educational purposes and community inclusion. After heavy rain events, the bioretention areas should be inspected for structural integrity. Sensors and monitors will be applied to the underground cistern to determine if leaks or hazards are generated and to ensure the pH of the captured stormwater remains neutral within the cistern. Annual maintenance fees price at $17,147.88 as shown in **Table 4**.

Main Feature	Components	Cost per Unit	Quantity	Cost
Green Roof	Maintenance[30]	$1.50 per sf	7500 sf	$11,250
Permeable Pavement	Power Washing[49]	$1.60 per sy per washing	533 sy, 4 washings	$3,411.20
Underground Cistern	Inspection	$25 per hour	4	$100
Bioretention Area, Drought Tolerant Rain Gardens	Weeding and Cleaning	$25 per hour	6	$150
			Predicted cost	$14,911.20
			15% contingency	$2,236.68
			Total annual cost	$17,147.88

Table 4 *identifies the annual cost of maintaining each proposed application of green infrastructure.*

FUNDING

Measure W, or the Safe, Clean Water Act, was passed in 2018 as a citywide investment into green projects in Los Angeles County that collect and clean stormwater before it enters the ocean[25]. This measure places a tax of 2.5 cents per sq ft of impermeable surface areas on private properties, generating up to $285 million annually to fund green infrastructure projects. These projects may fall under one of three categories: infrastructure, technical, and scientific studies programs. The RainWorks project falls into the category of scientific studies, which funds projects focused on stormwater capture or urban runoff capture. This project qualifies for an estimated $890,000 from this fund source[26,27], which is over six times the amount required to fund the proposed site redesign.

Proposition 1 sets aside $900 million worth of grants and loans for projects involved with the prevention or cleanup of contaminated groundwater that has served or currently serves as a source of drinking water[28]. Of that $900 million, $160 million is dedicated to disadvantaged communities, and $74 million is designated for activities which treat, prevent, or remediate contaminated groundwater used for a source of drinking water. The activities planned for the RainWorks program, specifically the restoration of native landscape, should fall under the multi-benefit restoration category for Proposition 1, which would allow us to request up to the maximum allocation of the overall $37 million given for the whole program[28].

These sources alone will provide ample funding for installation and annual maintenance fees, demonstrating the feasibility in bringing this design plan to fruition.

APPENDIX: CALCULATIONS AND OUTPUTS

Bioretention Areas								
Layer	Depth (in)	Porosity	DA-1		DA-2		DA-3	
			Area (sq ft)	Volume (cb ft)	Area (sq ft)	Volume (cb ft)	Area (sq ft)	Volume (cb ft)
Freeboard	6	1	400	200	300	150	500	250
Ponding	6	1	400	200	300	150	500	250
Eng. Soil	24	0.2	400	160	300	120	500	200
Gravel	12	0.4	400	160	300	120	500	200
				720		**540**		**900**

Rain Gardens								
Layer	Depth (in)	Porosity	Location 8		DA-2		DA-3	
			Area (sq ft)	Volume (cb ft)	Area (sq ft)	Volume (cb ft)	Area (sq ft)	Volume (cb ft)
Freeboard	6	1	450	225	900	450	1400	700
Ponding	6	1	450	225	900	450	1400	700
Eng. Soil	24	0.2	450	180	900	360	1400	560
Gravel	12	0.4	450	180	900	360	1400	560
				810		**1620**		**2520**

***Table 5** identifies the soil moisture volume of the various bioretention areas and rain gardens by drainage area.*

REFERENCES

1. Engemann et al. (2019). “Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood”, *PNAS,* 116(11), 5188-5193. doi.org/10.1073/pnas.1807504116
2. “Los Angeles Depends on Imported Water,” *Sierra Club, Angeles Chapter* angeles.sierraclub.org/los_angeles_depends_on_imported_water
3. (2019) “Mayor Garcetti Launches L.A.’s Green New Deal” *lamayor.org*
4. “Westwood, Los Angeles, California (UCLA Campus) 1933-2019,” *Los Angeles Almanac.* www.laalmanac.com/weather/we135aa.php
5. Frank, Richard (2016). “The Clean Water Act, Federalism, Big Money and the California Supreme Court,” *Legal Planet*.
6. Clean LA. “Frequently Asked Questions,” *Public Works of Los Angeles County*. dpw.lacounty.gov/prg/stormwater/Page_01.cfm
7. Coutts, Christopher; Hahn, Micah (2015). “Green Infrastructure, Ecosystem Services, and Human Health”, *Int. J. Environ. Res. Public Health*, 12(8), 9768-9798.
8. Friends of Braddock Drive. “The Campus,” *Braddock Drive Gifted Magnet Elementary School*.
9. American Society of Landscape Architects. “Braddock Drive Elementary School and Gifted Magnet: Learning/Walking/Reading Garden,” *Green Infrastructure & Stormwater Management Case Study*.
10. Clark, Laura (2019). “What Are Title 1 Schools,” *Student Debt Relief*.

11. California School Directory. "Brockton Avenue Elementary School," *California Department of Education*.
12. Google Earth Pro V 7.3.2.5776. (November 19, 2018). Brockton Avenue Elementary School, Los Angeles, California, United States of America. 33° 02' 38.09" N, 118° 27' 46.02" W, eye alt 538 ft. Google, 2019.
13. Los Angeles County Department of Public Works, Water Resources Division (2015). "LA County Soil Types" *County of Los Angeles Open Data.* data.lacounty.gov/Shape-Files/LA-County-Soil-Types/sz94-meiu/data
14. National Cooperative Soil Survey (2003). "Ramona Series".
15. Fram, Miranda S; Belitz, Kenneth (2012). "Groundwater Quality in the Coastal Los Angeles Basin, California", *U.S. Geological Survey and the California State Water Resources Control Board.*
16. Los Angeles County Department of Public Works. "Los Angeles County Storm Drain System". pw.lacounty.gov/fcd/StormDrain/index.cfm
17. "Sand Dune Sedge", *California Native Plant Society.* calscape.org
18. "Bioretention Areas & Rain Gardens," *Massachusetts Clean Water Toolkit*.
19. Central Coast Water Board. "LID Plant Guidance for Bioretention", *Central California Coast Technical Assistance Memo*.
20. BKi and G3 (2012). "The Drought Tolerant Garden, Los Angeles County Handbook" *The County of Los Angeles.*
21. Yamamoto, Yoshika (2006). "Measures to Mitigate Urban Heat Islands," *Science and Technology Trends* 18(2), 65-83.
22. Hair, Lisa; Kramer, Melissa (2016). "City Green: Innovative Green Solutions for Downtowns and Infill Locations", *United States Environmental Protection Agency.*
23. i-Tree Design design.itreetools.org
24. "Stormwater pollutant removal, stormwater credits", *Minnesota Stormwater Manual.* https://stormwater.pca.state.mn.us/index.php?title=Stormwater_pollutant_removal,_stormwater_credits
25. SCCAWeb (2019). "Measure W in Los Angeles County Impacts Social Construction Industry," *SCCA*.
26. (2019) "Estimated Annual Regional Program Funds by Watershed Area", *Safe Clean Water LA.*
27. DPW-SafeCleanWaterLA (2019). Personal correspondence.
28. (2019) "Frequently Asked Questions; Propositions 1 and 68; Grant Opportunities Proposal Solicitation Notice". nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=174751&inline
29. "Hey, California, you can still have a lawn! Here are five water-wise alternatives" (2015). *Los Angeles Times*. https://www.latimes.com/home/la-hm-drought-grass-html-20150723-htmlstory.html
30. "Green Roofs" (2014). *Reducing Urban Heat Islands: Compendium of Strategies*. 10
31. "Cost-Estimation Tool for Low-Impact Development Stormwater Best Management Practices" (2014). *Public Works Technical Bulletin 200-1-135*. C-6,7.
32. "2650 Gallon Norwesco Underground Water Tank" (2019). *National Tank Outlet*.
33. "Pelican Basic Ultra Violet (UV) Disinfection System" (2019). *Pelican Water Systems*.
34. "Specially Blended Engineered Topsoil" (2019). *Atlantic Mulch*.
35. "Landscape Cost Guides" (2019). *True Cost Guide*. HomeAdvisor.
36. "Western Oklahoma Redbud Tree" (2019). *The Tree Center Plant Supply Co.*
37. "Alphabetical Plant Catalog - Wholesale Pricing" (2019). *Evergreen Nursery.*
38. "California Native PLants" (2019). *Las Pilitas Nursery.*
39. "Quercus Agrifolia - Coast Live Oak" (2019). *Moosa Creek Nursery*.
40. "10.25-Gallon Purple Chitalpa Flowering Tree in Pot (With Soil)" (2019). *Lowe's.*
41. "Juncus effusus Soft Rush, Common Rush" (2019). *Mid Atlantic Native Plant Farm*.
42. "Virgin's Bower - Clematis Virginiana" (2019). *Prairie Nursery Native Plants & Seeds*.
43. "Wildrye - Blue" (2019). *Silver Falls Seed Company*.
44. "Park Benches" (2019). *The Home Depot*.
45. "Turbine Flow Rate Sensor, 8300 Pulses per Gallon" (2019). *Grainger.*
46. "HALO Wireless Field pH Meter" (2019). *Hanna Instruments*.
47. "U-Channel Posts - Green Enamel and Galvanized" (2019). *SafetySign.com*
48. "Blue Rush" (2019). *Pond Plants R Us*.
49. Tosomeen, Craig (2003). "Porous Concrete Sidewalk Cleaning Trial Using a Pressure Washer," *City of Olympia.*