GREEN GATEWAYS

Revitalizing key entry points on the UC Berkeley campus with Green Infrastructure

University of California, Berkeley
Team Registration #021

ABSTRACT

As a forward-thinking university, UC Berkeley is committed to advancing innovative, campus-wide climate initiatives in its latest master plan. The Green Gateways team expanded upon these initiatives, aiming to further animate the master plan through experiential and educational green infrastructure. We saw opportunities at three campus entry points situated near Strawberry Creek to improve stormwater infrastructure while simultaneously revitalizing social nodes and educating the community about their connection to the greater Strawberry Creek watershed.

We recognize that decades of conventional gray infrastructure conveying urban runoff to the creek has left a damaged ecosystem and an inaccessible creek interface with campus life. A revitalized Strawberry Creek holds the potential for climate resilience in the future. Our designs aim to harness this potential and implement green infrastructure around the creek to mitigate peak flows, control bank erosion, bolster local ecology, and reduce urban heat. We present specific site designs of the campus' three main entrances and a master plan of how these design strategies can be scaled across the campus. We aim to enhance the experience of arrival on campus and educate a wide audience about stormwater management strategies that enrich natural resources and bring beauty to public spaces.

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INTRODUCTION

The two forks of Strawberry Creek are the heart of the UC Berkeley campus. The creek offers educational opportunities and gives the campus landscape its distinct character, as mentioned in the UC Berkeley Campus Master Plan 2022 (CMP). Similarly, the UC Berkeley Resilient Water Plan 2023 (RWP) calls for "bolstering the resilience of infrastructure and natural systems, including Strawberry Creek's ecological functions." The RWP further calls to "integrate stormwater facilities with the campus experience and create a multi-benefit amenity for the campus community and broader public to engage with the natural environment for interaction and academics." Guided by the wealth of university-led research and planning documents, we pursued the EPA Rainworks challenge to showcase how socially and educationally engaging green infrastructure for stormwater management could revitalize Strawberry Creek.

We worked closely with our faculty advisor, Professor of Landscape Architecture and Environmental Planning, Matt Kondolf, who specializes in river restoration and has extensive knowledge of Strawberry Creek. He met with us regularly to illuminate how our current stormwater management system degrades the creek and to advise us on appropriate creek revitalization strategies. Sharon Harichandran, an Environmental Specialist in the Environmental Health and Services Department (EH&S) and a contributor to the RWP, was another essential correspondent whose input was crucial to our decision-making.

After leading multiple tours of stormwater concerns and infrastructure projects on campus, Sharon encouraged us to avoid management interventions with high maintenance costs, such as below-grade cisterns, mechanical rainwater harvesting systems, and rooftop gardens. She emphasized the importance of having scalable green infrastructure projects with opportunities for banking stormwater credits to offset future campus densification. Sharon also informed us that the campus architect had informally identified the university's North Gate and West Gate as underexplored areas in planning documents and needed better experiential design and wayfinding.

Noticing that these two gates, as well as the Sather Gate in the south of campus, are situated beside Strawberry Creek, we identified a unique opportunity to use the three existing campus entry points or "gateways" as sites to explore our goal of combining green infrastructure with creek revitalization. Siting our interventions at entrances connecting to active pedestrian corridors would ensure high visibility and diverse social and educational interaction with our designs. Based on recommendations from Matt, Sharon, and the RWP we explored how different scalable and low-maintenance green infrastructure strategies apply to the social, ecological, and hydrological contexts of each gateway site. Our Green Gateways team presents site designs featuring strategies such as permeable paving, floodplain expansion, channel restoration, and conveyance of rooftop runoff to rain gardens. We outline how these interventions can be scaled across campus on a master plan level.

CAMPUS AND WATERSHED CONTEXT

UC Berkeley is a biodiversity hotspot on the eastern shore of the San Francisco Bay Area. Strawberry Creek drains a steep watershed and passes through a range of microclimates and ecosystems as it drops from 900 ft elevation in the Berkeley Hills, through the campus (built on the Strawberry Creek alluvial fan), down to 200 ft at the west edge of campus. On campus, the creek is delineated into three main segments: The North Fork, the South Fork, and the mainstem below the confluence of the two forks. As it leaves the campus, the creek enters an underground concrete culvert and is conveyed under the City of Berkeley and ultimately into the San Francisco Bay (Figure 1). Today, the UC Berkeley Campus is the only principal location where the creek flows above ground along a natural channel.

The Strawberry Creek watershed receives runoff from a drainage area of approximately 1,163 acres, 40% of which is urbanized (Charbonneau, 1987). UC Berkeley's main campus of 190 acres is currently estimated to be nearly 60% impervious with most of its runoff directed to the creek (UC Berkeley, 2023).

Strawberry Creek is a valuable natural resource to the campus community and visitors, serving as a much-needed natural respite and educational study site. However, due to the creek banks becoming incised over time and overgrown with invasive vegetation, it often goes unnoticed by those navigating through campus. Furthermore, urbanization has altered the hydrological dynamics of the creek, leading to increased peak flows, streambed degradation, bank erosion, destruction of aquatic habitats, and heightened flood potential. In response, UC Berkeley has established a goal to restore Strawberry Creek's health and natural hydrology.

CURRENT CONDITIONS AND FUTURE PLANS

Aging Gray Infrastructure

Our existing gray infrastructure (concrete storm drains fed by curb and gutter drainage from roads and pipes from rooftops) is strained during major storm events. According to the 2023 hydraulic modeling by EH&S, the stormwater pipe infrastructure is undersized for a 10-year storm event in segments (UC Berkeley, 2023). With increasingly frequent and extreme storm events and an aging stormwater pipe network subject to leaks and root intrusion, the risk and impact of localized flooding in those areas is increased. Green infrastructure projects that reduce flow to these pipes are required to help improve functionality until they are eventually replaced.

High Impervious Surface Percentage

As noted above, the main campus is estimated to be 60% impervious surfaces with building roofs contributing 33% and site hardscapes contributing 29% (UC Berkeley, 2023). The most recent Campus Master Plan proposes substantial new construction and an ultimately denser built environment on campus. Anticipating further expansion of impervious surfaces into existing open spaces, the RWP recommends implementing large-scale, low-maintenance green infrastructure projects elsewhere to offset new construction and help UC Berkeley earn stormwater credits from the City of Berkeley.

Strawberry Creek Health

The RWP recommends creek restoration and floodplain expansion as long-term resilience strategies and advocates for weaving creek 'living labs' into these projects. These educational creek access points involve students in studying and monitoring flow rates, water quality, and ecological diversity. Active monitoring is crucial to understanding how well green infrastructure is working. This high-quality data helps support future green infrastructure project planning. The Campus Master Plan and the RWP advocate for ongoing restoration to improve soil health, increase infiltration rates, reduce erosion through native planting, and slow flow with check dams.

THREE GATEWAYS

Site 1: Sather Gate – Permeate, Shade, Socialize

<u>Site Context and Stormwater Issues:</u>

Figure 1: Sather Gate in front of bridge over Strawberry Creek.

This gateway is the most iconic entrance on campus and serves as the backdrop for countless graduation photos (Figure 1). Part of a crucial North-South corridor, it is used by students to get to and from classes and is a popular tourist destination en route to the Campanile Tower. Also, a bridge, thousands of pedestrians unknowingly cross over Strawberry Creek daily. It is the most impervious of the three sites, as it is adjacent to the bustling paved Sproul Plaza—a historic and present-day hub for free speech gatherings, protests, and campus events. As outlined by the RWP, objectives for projects on North-South circulation corridors should aim to slow and infiltrate stormwater moving downhill by increasing permeable surfaces and mitigate heat island effects by redirecting stormwater to irrigate trees and vegetation.

<u>Proposed Interventions:</u>

Detention and Infiltration in Underutilized Lawn Space

Currently, 1272 square feet of underutilized lawns adjacent to Sproul Plaza and Sather Gate are transitioned by our design into rain gardens and swales featuring native vegetation listed in (Table 1 on page 6). These upgraded vegetation patches will detain and infiltrate stormwater conveyed from rooftops (Figure 2). The vegetation, once established, could save 62,000 gallons of potable water per year. The combination of permeable pavers and native vegetation in this site would reduce the annual surface runoff into Strawberry Creek by 37%, from 9.78 inches to 6.12 inches, as estimated using the EPA National Stormwater Calculator tool under current annual rainfall scenarios of 16.2 inches (Latham 2017).

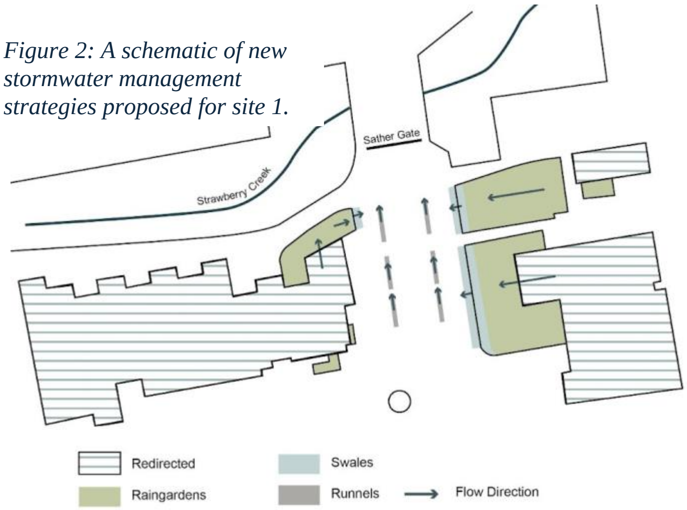

Figure 2: A schematic of new stormwater management strategies proposed for site 1.

Permeable Paving

A strategic partial replacement of the impervious plaza surface with permeable interlocking concrete pavement will increase on-site stormwater infiltration. Strong impermeable surfaces will selectively remain to facilitate the high traffic of two-wheelers and wheelchairs. In our intervention, we replace 10086 sq ft. of impervious pavement with permeable pavers for an overall 27% reduction of existing impervious surfaces.

Runnels, Tree-Wells and Creek Viewing

A series of runnels in the plaza collects runoff from pavements and overflow from swales via subterranean pipes. Strategically placed bridges allow for accessible crossing. Rain or shine, the runnels create visual wayfinding towards the creek, where permeable seating platforms oriented towards the creek encourage pause in a busy environment. The runnels have permeable gravel floors and penetrate tree wells built around existing flood-tolerant London plane trees on Sproul Plaza. Any excess runoff is directed into Strawberry Creek, but this runoff will reach the creek more slowly, reducing stream energy and thus contributing less to channel erosion.

Site 2: West Gate – Restore, Educate, Monitor

<u>Site Context and Stormwater Issues:</u>

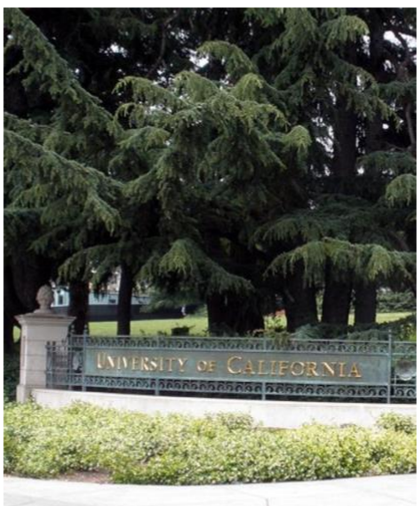

Figure 3: West 'Gate' entrance from Oxford Street

Figure 4: View of the incised strawberry creek and exposed banks with the Eucalyptus Grove to the right

The West Gate is not a true gate but still a major entrance for pedestrians that commute to and from campus using the Berkeley BART station. The confluence of Strawberry Creek's North and South forks, situated just east of the West Gate is the focus of our intervention. The floodplain between the two forks is occupied by a grove of non-native Eucalyptus trees (*Eucalyptus globulus*). These trees are impressive specimens, having grown to heights of over 200 ft. However, nearing the end of their lifespans, they have been increasingly toppling during windstorms. The dense shade they cast and their allelopathic characteristics preclude the establishment of a ground story of riparian vegetation, leaving exposed soils in the stream banks and negative effects on other species due to released chemicals. The channel itself suffers from ongoing incision due to increased peak flows generated by runoff from impermeable surfaces upstream in the watershed (Figures 4 & 5). Peak flows carry debris produced by the bark and branches of Eucalyptus, often clogging the channel. The confluence holds great potential as a space for informal gatherings and organized educational activities, but the current conditions make the site inaccessible, and uninviting, and lead many to feel unsafe here.

Proposed Interventions:

Floodplain Expansion + Successional Replacement of Invasives with Natives

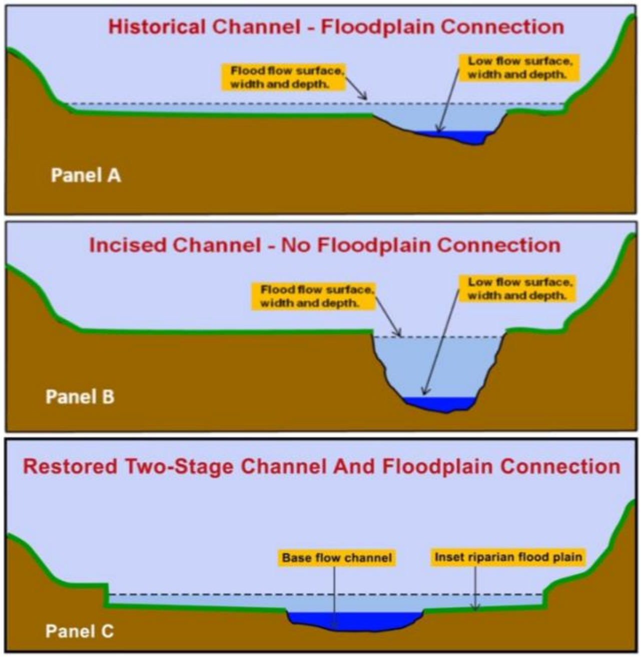

Figure 5: The evolution of the Strawberry Creek channel from its historic form with the stream flooding into its floodplain during highflows (Panel A), to an incised channel disconnected from its floodplain due to extreme erosion caused by peak flows (Panel B), and the proposed restoration to a two-stage channel form featuring a baseflow channel and a inset floodplain flooded during high flows (Panel C) adapted from ANR, Vermont website

Riparian vegtation			
Scientific name	**Common name**	**Type**	**Plant Community**
Salix Nigra	Black Willow	Tree	Riparian
Umbellularia californica	California Bay Laurel	Tree	Riparian
Aesculus californica	California Buck eye	Tree	Riparian
Cornus californica	Creek dogwood	Tree	Riparian
Polystichum munitum	Sword fern	Shrub	Riparian
Elymus Triticoides	Creeping wild rye	Grass	Riparian
Bioswale			
Scientific name	**Common name**	**Type**	**Plant Community**
Iris douglasiana	Douglas iris	Shrub	Riparian / Mountain Meadow
Elymus Triticoides	Creeping wild rye	Grass	Riparian
Carex barbarae	Whiteroot	Grass	Riaparian / Mountain Meadow
Juncus spp and cvs	Gray rush	Grass	Mountain meadow
Lonicera involucrata	Twinberry	Shrub	Mountain meadow
Raingarden			
Scientific name	**Common name**	**Type**	**Plant Community**
Scrophylaria Californica	Bee plant	Shrub	Coastal Sage Scrub / Riparian
Heteromeles arbutifolis	Toyon	Shrub	Coastal sage scrub / Chapparal
Rhamnus californica	Coffeeberry	Tree	Coastal Sage Scrub
Lonicera involucrata	Twinberry	Shrub	Mountain meadow
Mimukus aurantiacus	Sticky monkeyflower	Shrub	Coastal sage scrub / Chapparal
Salix Nigra	Black Willow	Tree	Riparian

Table 1: Native vegetation for each project type.

The Campus Master Plan recommends planting native riparian species to restore Strawberry Creek with the successional removal of the aging Eucalyptus Grove. However, the need to reconnect the creek to its floodplain is currently overlooked. Restoring lateral connectivity to the historical floodplain is crucial for supporting ecosystem development, to increase biodiversity, and infiltrate stormwater. This strategy is suitable for this location at the confluence, due to its downstream position within the UC campus, with the greatest stream discharge. Creating more fluvial space here for water during storm events will help reduce erosion on the currently incised channel and steep banks. Following the failure of a check dam within the last decade, a large reach of the North Fork was restored with a series of boulder steps, and its channel is now reasonably close to the elevation of floodplain. However, the South Fork remains incised 6-10 ft below the floodplain surface. We propose to lower the floodplain surface adjacent to the channel to create an inset floodplain that would flood every 1-2 years (figure 5). As this surface will be hydrologically connected to the stream, it can support native riparian vegetation (Table 1) after reworking the bank-full dimensions of this channel to 20 ft wide and 1.2 ft high, based on regression equations developed for the San Francisco Bay area region (Dunne & Leopold, 1978, Beiger et al 2015, Gotvald et al 2012). As with the expanded floodplain at the North Gate site, the new channel dimensions will not be fixed with hard structures, but the banks will be allowed to self-adjust, unless engineers encounter infrastructure that must be protected, in which case hard protection can be buried behind a natural bank.

Living Lab + Universal Accessibility to the Creek

Restoring the confluence is a time-intensive process which requires monitoring and maintenance. Coupling restoration with ‘living lab’ programming will involve students in active learning on-site while ensuring consistent care and research. We designed perforated steel steps in addition to a wheelchair-accessible ramp to facilitate educational activities such as sampling exercises along the creek. In addition to increasing access, we propose repurposing tree stumps of the Eucalyptus trees marked for felling as seating in the upper terrace of the floodplain for an outdoor classroom experience.

Site 3: North Gate – Slow, Detain, Filter

Site Context and Stormwater Issues:

This gateway is situated on a quieter, secluded portion of campus where the North Fork transitions from a buried culvert to an open stream. A dense understory of vegetation, steep topography, and fencing separating the chancellor's residence from the rest of campus currently limits interaction with the creek. Stormwater issues include high surface flows from connected downspouts of nearby rooftops, and increased pollutant-laden runoff and stream velocity during major storms.

Proposed Interventions:

Rooftops to Rain Garden
The design collects and redirects rainwater from two rooftops (North Gate Hall and McCone Hall) into a new 3,500-square-foot rain garden (Figure 6). The rain garden, situated in a currently underutilized lawn space adjacent to the creek, will detain 95% percent of the rooftop runoff to the creek and greet those at North Gate. A rain-activated viewing platform will be a temporary installation to mark and celebrate this momentous overhaul of the North Gate and encourage outdoor use in all weather. Educational signage will explain these interventions.

Check Dams and Floodplain Expansion
Below the rain garden, at the entrance of the North Fork, we propose to regrade the stream's west bank to create a floodplain that is hydrologically connected to the channel, and to lengthen the channel with a meander bend, in place of the existing, artificially straightened channel. This inset floodplain would be set at an elevation such that it would be inundated in the 2-year return interval flood. This would involve a redesign of the Chancellor's 11,800 square foot underutilized lawn and irrigated garden into a new expanded flood plain - an emphatic but feasible intervention according to our topographical analysis. On the north side, backing up to Hearst Street, the sloping bank will be graded to offer amphitheater-style seating looking down to the creek and the floodplain, on which a temporary stage could be set up for performances and other events, and the seating could be used as informal gathering space at other times. The fence protecting the Chancellor's residence would be moved back 110 ft westward, strengthened, and densely vegetated to preserve the separation of the residence from public uses. Transitioning the private grass lawn into a native vegetated floodplain coupled with the rain garden design will save a potential 741,000 gallons/year of potable water once the vegetation has been established. The detention and infiltration of surface-runoff into the soil, as well as biofiltration of toxic

substances by plants in these upgraded vegetation patches, will reduce the pollutant-loads currently flowing directly into the creek. Site will be revegetated with the same plant palette as West Gate.

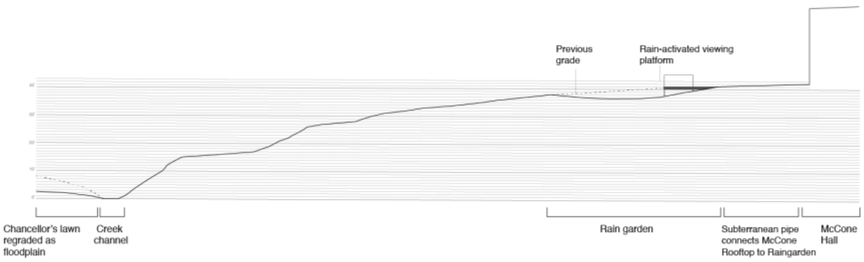

Figure 6:A technical section view of interventions in North Fork, including floodplain expansion (left), rooftop rain redirection and rain garden establishment (right)

The channel will be constructed with an initial width of 4 ft and height of 1 ft, based on regional relations of bankfull discharge for a given drainage area (Dunne & Leopold 1978, Gotvald et al 2012, Bieger et al 2015). But these dimensions provide only a starting point: the banks will not be hardened, as to allow the channel to adjust. Where infrastructure is potentially at risk from bank erosion, hardened protection will be installed behind a vegetated earthen bank, serving as a last resort if the biotechnical bank protection proves insufficient and the hardened bank is exposed. In the lengthened channel, we propose to install a series of low check dams (1 ft in height) along this reach to dissipate energy and provide more heterogeneous habitat, and a These interventions reduce the slope of Strawberry Creek from 6% to 3% in this reach, which reduces the shear stress on the creek bed (the erosive force per unit area) in this reach by 55% from 0.18 kilo-newtons per square foot to 0.08 kilo-newtons per square foot.

PHASING, FUNDING AND MAINTENANCE

When assessing financial feasibility and maintenance costs, we sought the expertise of our landscape operations manager, Lydia Woltjer, and our irrigation coordinator Nick Cole. Sharon Harichandran directed us toward the right grants and partnerships for budgeting and phasing out these large projects. The Sather Gate project is the fastest and least expensive due to its minimal changes in topography and landscaping; West Gate would require more funds for earthwork and tree removal; North Gate will also require earthwork and is of intermediate cost. We've outlined a phasing plan, budgeted costs and identified grants for potential funding below:

	PHASE ONE (roughly years 1-2)	PHASE TWO (roughly years 2-4)	PHASE THREE (roughly years 4+)
SITE 1: Sather Gate	1) replace plaza surfaces with permeable paving. 2) construct runnels. 3) partially clear creek-side vegetation and install viewing platform.	1) regrading and planting to make swales and rain gardens. 2) place pipes connecting rooftops to rain gardens.	
SITE 2: West Gate	1) Removal of unhealthy/fall-prone Eucalyptus and other non-natives. 2) Creation of tree stump seating.	3) Regrading of channel and banks for floodplain expansion. 4) install stairs and ramp for creek access.	1) Replant with native vegetation. 2) Long-term: Ongoing monitoring and maintenance by students and professors.
SITE 3: North Gate	1) Plant and regrade lawn into native rain garden. 2) Daylight and redirect stormwater runoff. 3) Build bridge over daylit storm drain. 4) Build rain activated viewing platform. 5) Create runnel for rain garden overflow into Strawberry Creek.	1) Move current fence line 110 ft from creek bank. 2) Regrade a portion of the Chancellor's lawn to height of flood plain. 3) Cut down invasive trees. 4) Plant native riparian trees. 5) Revegetate new flood plain.	1) Mill felled redwoods from North Gate site for amphitheater seating above the entrance of creek.

COSTS	Site 1 (SATHER GATE)	Site 2 (WEST GATE)	Site 3 (NORTH GATE)
Project design and specifications	$40,000.00	$52,000.00	$62,000.00
Planning and community review	$14,000.00	$15,000.00	$15,000.00
Engineering, surveying	$7,500.00	$50,000.00	$25,000.00
Permitting approval	$15,000.00	$50,000.00	$52,000.00
Construction admin	$15,000.00	$64,000.00	$32,000.00
Contract work	$150,000.00	$645,000.00	$425,000.00
Inspection services	$10,000.00	$13,000.00	$15,000.00
Completion of notification	$5,000.00	$12,000.00	$10,000.00
Grand total *Excluding Maintenance	$256,500.00	$901,000.00	$636,000.00

Potential Grants

Federal Grants: Climate resilience grants

National Wildlife Federation Climate Resilience Regional Challenge Grant

State Grants:

CA Dept of Fish and Wildlife "Addressing Climate Impacts"
Dept of Water Resources "Riverine Stewardship Program"
Dept of Fish and Wildlife "Wildlife Corridors – Nature Based Solutions"

School:

The Green Initiative Fund

Applying for this fund is especially important to our maintenance strategy for our native plantings and creek restoration. The Green Initiative Fund (TGIF) is a funding program specifically designed for green campus-related projects, funding ranges from 5-6k per semester, this would be able to cover maintenance and upkeep costs for each site, as well as allow students to work through the use of work-study program. TGIF funded the restoration project on the North Fork at the confluence site, attracting matching funds from campus. The success of the North Fork project should make a future creek-related project rank highly for TGIF support.

Mitigation stormwater funds for ongoing/proposed projects.

The stormwater mitigation fund is incentivized by UC Berkeley to offset future construction.

CONCLUSION

The UC Berkeley campus offers exceptional opportunities to implement stormwater infrastructure in a highly visible environment, with educational opportunities for local K-12 schools through graduate student training. Running through the heart of campus, the two forks of Strawberry Creek have been used extensively for teaching and research. Through some simple interventions, the ecological value, visibility, and public use of the creek can be greatly improved, and the role of the creek in receiving stormwater runoff from the campus can be highlighted, and stormwater can undergo increased infiltration, detention of peak flows, and filtering before it reaches the creek. The time for intervention is ideal: the Campus is now implementing the 2022 Master Plan and the 2023 Resilient Water Plan. One specific project now in the planning phase is the West Oval biodetention facility, which will include many elements proposed in Berkeley's 2019 EPA Rainworks competition entry.

We focus our proposed interventions on the three principal gateways to campus: all highly visible sites, all ripe for improvements in stormwater management and stream restoration. Working closely with campus Environment, Health and Safety, these sites were selected based on relevance to ongoing campus planning efforts and to address some of the more urgent infrastructural needs currently on the table, while also offering the most compelling opportunities to engage members of the public who might not otherwise be exposed to concepts of stormwater and its management.

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