SOCIO HYDROLOGY

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A FRAME FOR AN INTEGRATED GREEN INFRASTRUCTURE MASTER PLAN

Abstract

The 2nd Street corridor is a major pedestrian and vehicular thoroughfare running along an historic border of the University of Arizona (U of A). Adjacent to the roadway are several dormitories, academic and research buildings and one of the most prominent entrances to the University, the Student Union Memorial Center. 2nd Street, its surrounding buildings and historic landscapes are at the confluence of 66 acres of sub-watersheds on this urban campus. Flooding and circulation issues across the 15.3 acre site stem from poor stormwater management practices and are compounded by a growing student body population and climate change.

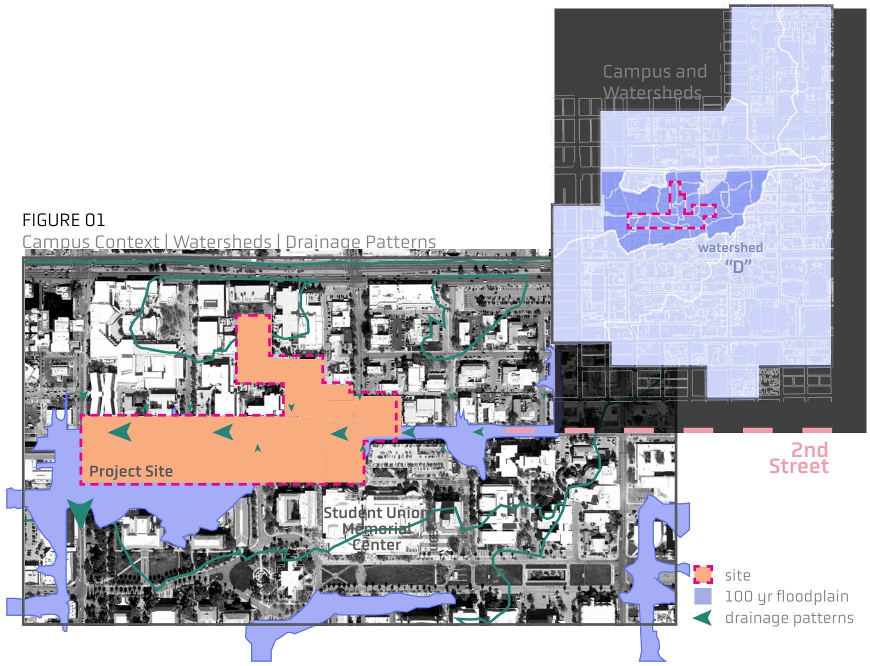
Socio-Hydrology reevaluates the heavily trafficked 2nd Street corridor introducing green infrastructure (GI) practices to better utilize water as a resource in the arid Sonoran Desert, improve safety and comfort for the campus community, create spaces for multi-disciplinary collaboration, and establish broader campus GI literacy. The design manages a 10-year storm on site and reduces runoff by 17.2% during a one-year/24hr storm. Further phasing allows the site to manage flows from a 25-year storm and generates water that can be used as irrigation in the landscape.

Given the U of A campus' continuing population growth, the design responds with layered social and ecological GI strategies that maximize functionality and usability of the limited campus space. Socio-Hydrology also demonstrates GI strategies intended to serve as a precedent for the broader campus context whose implementation will effectively reduce downstream impacts.

SITE CONTEXT & SELECTION

MAJOR CONSIDERATIONS

FIGURE 01
Campus Context | Watersheds | Drainage Patterns



Tucson is a city prone to flooding, with an average of 12 inches of rain occurring annually in two short rainy seasons. Heavy downpours flood roadways making them impassable, creating dangerous conditions for vehicles, pedestrians cyclist and neighboring buildings. The city uses street infrastructure for stormwater management moving water quickly along roadways to larger washes and the neighboring Rillito and Santa Cruz Rivers. Little attention is given to slowing water and harnessing runoff as a resource.

The U of A campus uses a similar strategy for managing stormwater, with drainage from many watersheds relying on street conveyance. Flooding and safety issues are further compounded by the campus' high level of impervious coverage at 73% (U of A Stormwater Management Plan, p.6). Storm water runoff flows across these impervious surfaces and drains to city streets that surround and move through campus, giving rise to a variety of flooding and safety issues.

A LOT OF WATER, A LOT OF WASTE

The 15.3 acre project site **(Fig. 01)** lies along the 2nd Street corridor and within watershed D, one of five distinct watersheds across the campus of the University of Arizona. The street itself is a primary conduit for water during storm events and becomes the downstream confluence of 17 contributing sub-basins spanning 66 acres. A one year/24 hr storm generates over 4.3 ac-ft of runoff from these contributing sub-basins, a majority of which moves directly through the site by means of street conveyance leading to dangerous conditions for the heavily trafficked corridor **(Fig. 02)**.

FIGURE 02
Challenges of the site are characterized primarily by stormwater management and missed opportunities for water resources. These situations are further complicated by heavy street and pedestrian traffic.

A BIT OF HISTORY

The southern portion of the site has multiple, historically significant elements that the team strove to respect through subtle GI design interventions. Historic features include: a lava rock wall built in 1916, which functioned as an old campus boundary, grass berms, shaped in 1901, to hold flood irrigation and heritage trees, part of the University Arboretum collection which has been accumulating diverse plants and arid-adapted trees since the 1950s (University of Arizona Historic Preservation Plan, 2006, p.24-29).

In order to ensure preservation of historic features through the design process, the team consulted with Professor of Heritage Conservation Gina Chorover. Consultations informed the decision to preserve the historic lava rock wall and propose sub-grade infiltration tanks underneath historic grading. Sub-grade storage can also be explored for its potential as supplemental irrigation for turf and adjacent landscapes. While aligning with current Campus Planning and Design Standards for “preservation of the campus historic district,” the team’s proposal also creates precedents for retrofitting other historic areas on campus with GI features (The University of Arizona Manual of Design and Specification Standards, 2011, Tab C2-5). Conversations with Arboretum Director Dr. Quist focused the team on prioritizing a palette of native and drought tolerant trees that would offer social and ecological benefit to the site. The team developed a list of structurally and ecologically diverse trees that honors the arboretum’s “experimental and eclectic” mission and biodiversity goals.

BUILDING OFF THE PAST

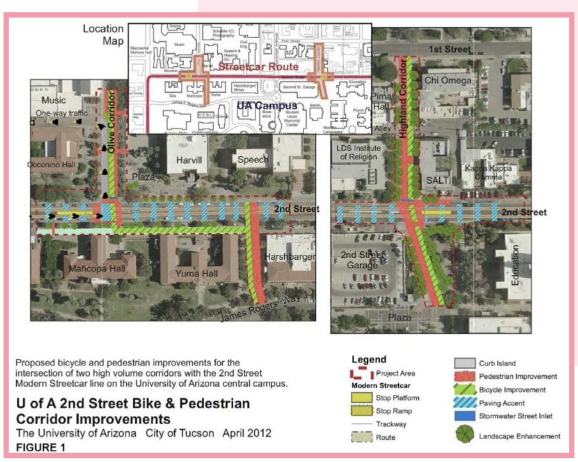


FIGURE 03
A 2011 proposal from University Planning, Design and Construction at time of current street car installation.

In 2011, University Planning, Design and Construction (PDC) prepared a proposal for the 2nd Street corridor calling to improve safety and wayfinding for pedestrians and cyclists, enhance vegetation along the street and adjacent alley, as well as install underground storage tanks and infiltration chambers underneath sidewalks **(Fig. 03)**. This master plan proposal builds off of PDC’s previous initiative while maintaining alignment with the University’s Stormwater Management Plan goals to “...integrate surface water into site design, promote proactive solutions to stormwater runoff, integrate works of art in high-use common areas, and encourage people into open space and corridors while implementing stormwater management strategies at various scales and in various locations across the site...” (Manual of Design and Specification Standards, Tab C2-2 -Tab C2-5, 2011 and Stormwater Management Plan, p.5, 2017).

SITE ASSESSMENT

A CLOSER LOOK

Fig. 04 highlights conditions across the project site that are compounded by the effects of heavy stormwater flows but are also independently problematic in regards to circulation, water quality, Urban Heat Island effect and general user comfort and experience. There are multiple points of pedestrian and vehicular conflict that need to be addressed, given that over 6,000 users pass through the corridor daily (Pima Association of Governments - PAG).

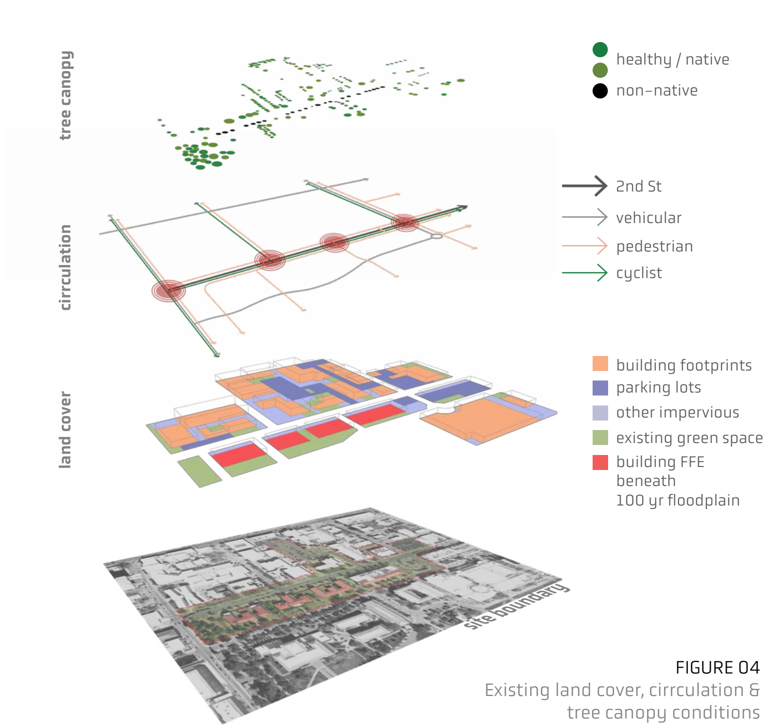


FIGURE 04
Existing land cover, cirrculation & tree canopy conditions

According to PAG's GI Prioritization Tool, tree canopy on site is above average for respective canopy density goals (over 20%), however many trees are non-native and in poor health. Consultations with the Arboretum Director verified support for the team's proposal to replace struggling trees with native and arid-adapted tree species that offer increased shade canopy and ecological services while minimizing irrigation.

DON'T CROWD ME

Crowded conditions on 2nd St. lead to uncomfortable and problematic circulation (**Fig. 05**). Underutilized areas north and south of the street corridor present opportunities to disperse pedestrian flows and establish new social space alongside GI improvements.

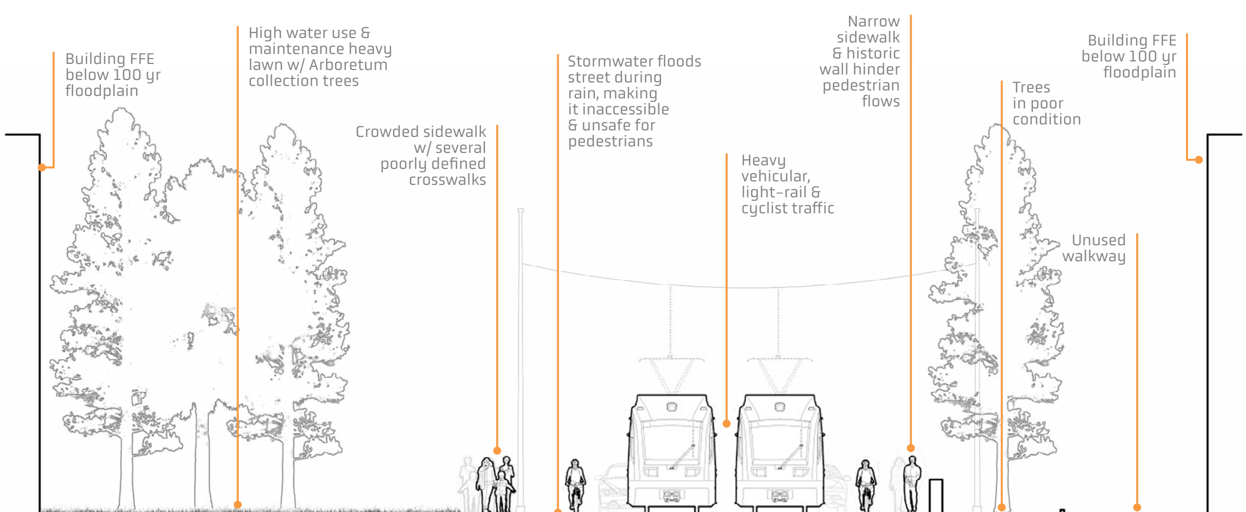


FIGURE 05 2nd St Corridor | Existing Conditions | Looking East

FEEDBACK & DEVELOPMENT

TABLE 01
To further inform the master plan proposal the team initiated cross-disciplinary collaborative research in areas from stormwater quality & soil infiltration to maintenance & planting strategies.

Design Features	Cross-disciplinary Advisory Team
1. Soil Strategies	Shawn Kelley (President, National American Society of Landscape Architects)
2. Historic Preservation	Gina Chorover (Professor of Heritage Conservation, University of Arizona)
3. Water Harvesting	Grant McCormick (Campus Planner, Soil, Water and Environment Professor)
4. Circulation and Planning	Dr. Philip Stoker (Professor of Planning, University of Arizona)
5. Tree Canopy	Dr. Tanya Quist (Arboretum Director, University of Arizona)
6. Water Quality	Arizona Laboratory for Emerging Contaminants
7. Bioswales	Nichole Casebeer (Watershed Management Group, Tucson non-profit)
8. Planting Strategies	Rodney Swink (Professor of Landscape Architecture, North Carolina State University)
9. Maintenance Strategies	Woodford Remencus (Facilities Management Landscape Manager, University of Arizona)
10. Soil Infiltration and Stormwater Pollutants	Dr. Thomas Meixner, Samantha Swartz and Jack Anderson (Department of Hydrology and Water Resources, University of Arizona)
11. Campus alignment	Mark Novak, Campus Landscape Architect, (University of Arizona)
12. Artwork and GI	Penelope Cotrell-Crawford (Art History major)

WATER QUALITY

Water quality test results **(Tab. 02)** from the Arizona Laboratory for Emerging Contaminants showed that concentration levels of heavy metals were below those typically found in urban stormwater runoff according to research by Dames and Moore (Dames, 1990). The team attributes this to heavy rains before the water samples were taken, but it does not negate the need to improve water quality and lower the incidence of suspended solids in stormwater runoff.

TABLE 02
Water Quality Tests
(comparisons with typical concentrations)

Pollutants	Typical (mg/l)	Parking Lot	2nd Street
Iron	8.7	.1011	.04354
Nickel	.022	.00138	.00419
Cadmium	.0015	.00017	.0001
Zinc	.2 (.01-2.9)	.0238	.0925
Copper	.05 (.01-.4)	.017	.0393
Lead	.18 (.01-1.2)	.00014	.00043

SOILS

The dominant soil on site, hydrological soil group D, is composed mostly of clay which has relatively slow infiltration rates. To further understand the site's soil characteristics, team members from the Department of Hydrology and Atmospheric Sciences assisted with site-specific, soil infiltration tests. The results **(Fig. 06)** informed the team's proposal to improve infiltration in the 2nd Street corridor by combining biofiltration systems, bioswales, infiltration chambers and dense planting strategies that are proven to effectively mitigate stormwater pollutants and retain stormwater runoff.

FIGURE 06
Infiltration Tests
(centimeters/hr)

FOSTER
RETROFIT
ADAPT
MANAGE
ESTABLISH

PROCESS

PROGRAMMING & CONCEPT

To ensure likelihood of implementation the team discussed design strategies and existing campus GI practices with Facilities Management manager Woodford Remencus. He believes "as you integrate water harvesting into landscape, the more mainstream it becomes" which supports the overarching goal of the master plan to develop a collaborative GI strategy that integrates social, ecological and educational function. To further explore existing GI projects on campus the team studied the College of Landscape Architecture's Sonoran Desert Underwood Garden Laboratory. The garden is an interpretive oasis with GI features including bioswales, cisterns, dense native plantings, and retention areas designed as social spaces. These strategies improve ecological function while framing stormwater management as beautiful campus space.

> "Rather than simply designing to enhance ecological quality . . . we must first design to frame ecological function within a recognizable form."
>
> Nassauer (1995, p.162)

Inspired by the writing and works of ecologist and landscape architect Joan Nassauer, the team saw the Underwood Garden as an excellent example of ecological function framed within a recognizable form. Structured architectural elements like seat walls and steel coupled with artistic features aid in the public perception of the sometimes 'messy ecology' as a beautiful and inspiring space. Our proposal seeks to frame high functioning GI spaces through the incorporation of artistic and architectural features layered with social and ecological benefits. This approach will further develop the campus GI design language while aligning with broader campus strategic plan goals of encouraging a cross disciplinary approach to stormwater management and GI research (University Strategic Plan, Pillar 2, 2018).

GOALS & OBJECTIVES

F•oster cross disciplinary collaboration in GI application and research
- campus collaborations in GI research and education
- community engagement and public education
- art as a means to expand GI literacy

R•etrofit University of Arizona campus with innovative GI strategies
- streetscapes and plazas with GI and layered social benefits
- historic district to improve stormwater management
- parking lots to minimize runoff, pollution and urban heat island

A•dapt to a changing climate and growing campus population
- flexible stormwater management approach for campus
- planting and maintenance strategies for climate resilience
- strategies that align with comprehensive campus plan

M•anage stormwater flows on site while accommodating upstream conveyance
- rainfall from a 10-year/24hr storm event on site
- 2nd Street conveyance to prioritize pedestrian safety
- harvested rainwater for re-use or recharge

E•stablish University of Arizona as a leader in GI strategies
- campus gateways that highlight GI
- scalable GI strategies for broader campus application
- social and ecological value through integrated GI

SOCIO–HYDROLOGY

Master Plan Key

1 GI Plazas
2 Green Parking Lots
3 Northern GI Network
4 Southern Bioswale
5 Green Pedestrian Corridor
6 Historic Landscape GI Retrofit
7 Green Street
8 Detention Basin/ Social Space (P1/board)
9 Seating/Research Station (P2/board)
10 GI Gateway (P3/board)
* GI Art Feature

A NEW VISION

Socio-Hydrology creates both a frame and a framework for an integrated GI campus master plan. Working in collaboration with campus Landscape Architect Mark Novak, campus planner and GI expert Grant McCormick and Facilities Management Landscape Manager Woodford Remencus, our plan promotes; a multi-disciplinary collaborative approach to GI that will engage a broad and diverse audience, holistic and layered GI strategies to address the existing campus as well as plans for future growth, and the establishment of a new U of A campus design language that is synonymous with GI.

Specific GI strategies are highlighted below **(Tab. 03)** and have been prioritized within the master plan proposal based on a combination of appropriateness, impact and success on campus and in case studies within similar climates at similar scales.

TABLE 03
GI Case Studies

Strategy	Application	Performance	Case Study
Permeable Paving	Parking Lots, Plazas, Pedestrian Areas	Minimize runoff, increase solar reflective index (SRI)	City of Glendale Park and Ride (Glendale, AZ)
Bioswales	Parking Lots, Streetscapes	Runoff retention, irrigate vegetation, minimize UHI	Scottsdale Museum of the West (Scottsdale, AZ)
Detention / Social Space	Plazas, Social Spaces	Runoff retention, biofiltration	Underwood Sonoran Laboratory (Tucson, AZ)
Biofiltration System	Streetscapes	Runoff retention, improved tree health	Bagby Street Reconstruction (Houston, TX)
Urban Tree Canopy	Parking Lots, Streetscapes, Pedestrian Areas	Minimize UHI, carbon sequestration, rainfall interception	Phoenix Civic Space Park (Phoenix, AZ)
Downspout Disconnect	Building Exteriors	Water harvesting, reduce irrigation	Dominici Courthouse (Albuquerque, NM)
Underground Cisterns	Historic Landscapes	Minimize runoff, reduce irrigation	University of Texas, Dallas (Richardson, TX)

SMALL STEPS, BIG STRIDES

SCALABLE STRATEGIES

The master plan proposal balances the need for a grand campus GI vision while also generating a typology of smaller scalable strategies **(Fig. 07)**. These strategies when installed will demonstrate GI solutions that can be implemented on a broader scale within the neighboring and upstream campus landscape. Typologies propose integrated GI solutions to address campus plazas, historic landscapes, parking lots and streetscapes.

FIGURE 07
Typologies for various land used meant as reference for future design across campus
• see poster for more detail

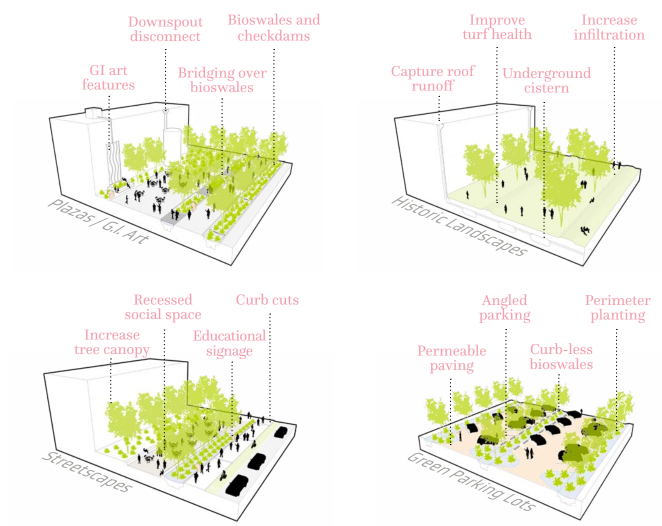


FIGURE 08
Typical design details for north & south sides of 2nd St
• see poster for more detail

LARGE-SCALE INTERVENTIONS

A network of GI features running along 2nd St. **(Fig. 08)** are designed to direct water away from heavy circulation taking advantage of stormwater as a resource for new native plantings. To the south of 2nd St. run densely planted bioswales which protect a new pedestrian permeable paver walkway. Seating areas double as collaborative research stations and can be equipped with bioswale monitoring sensors to collect performance data. To the north, water moves through curb cuts to shallow planting beds. During larger rain events water overflows to recessed detention basins that infiltrate over 24 hours. Detention basins double as social space the majority of the year during dry weather.

A variety of cost saving measures were considered (i.e. soil catchment drains and concrete weirs could be replaced by simple curb cuts and rip-rap weirs).

PERFORMANCE

HYDROLOGY

Performance measurements were an important aspect of Socio-Hydrology's master plan in order to provide value to campus and generate support through quantifiable results. Utilizing the Ration Method which is widely used for small urban watersheds, the team calculated stormwater runoff reduction for 1-year, 10-year, 25-year and 100-year storm events to better understand site water volumes **(See Calculations, p. 16)**. With the introduction of permeable paving, linear networks of bioswales, native plantings, and decomposed granite detention basins, the site's impervious surface was reduced by 37% **(Fig. 09)**. These changes alone reduce runoff from a one-year storm on site by 17.2%. Furthermore, GI elements in the proposed design have the capacity to hold 2.13 acre-ft which is the equivalent to a 10-year storm event **(Tab. 04)**.

Additional performance measurements take the form of water savings and reduction in irrigation costs. Applying the EPA's Resource Conserving Landscape Cost Calculator to a proposed native planting re-design for 5,200 S.F. of underutilized turf, expected water-related costs are reduced by 76% and maintenance costs are reduced by as much as 46% (Tools: Greenscapes). Decomposed granite retention areas also double as social space in dry weather adding 3,000 S.F. of accessible, functional space for pedestrian use.

FIGURE 09
Land use pre & post design

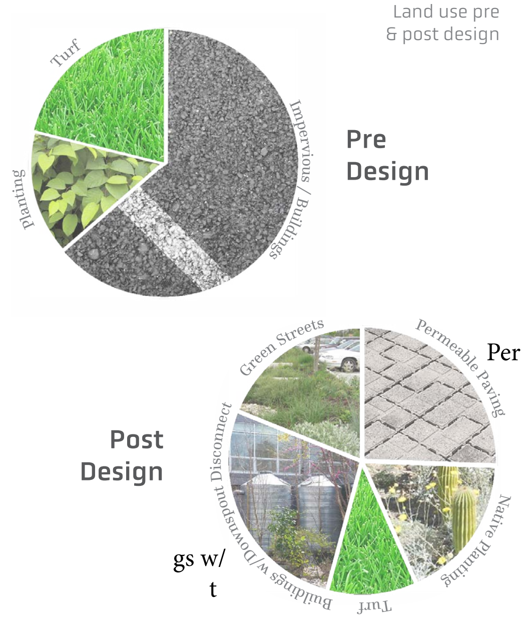


TABLE 04
Storage capacity post design

G.I. Type	Footprint	Storage Capacity
Detention Basins @ 20" deep	6,343 S.F.	10,530 C. F.
Swales @ 18" deep	13,725 S.F.	27,450 C.F.
Microbasins @ 12" deep	55,352 S.F.	55,350 C.F.
Above Ground Cisterns (15 new)	10,600 GAL (ea)	21,225 C.F.
Subsurface Infiltration Chambers	Phase 4	Based on storage needs

WATER HARVESTING

Additional storage capacity **(Tab. 04)** can be achieved through the application of new above and below ground cisterns that tie into the 2nd Street GI network. Cistern storage can provide irrigation resources while increasing the site's capacity to store the equivalent of a 25-year storm.

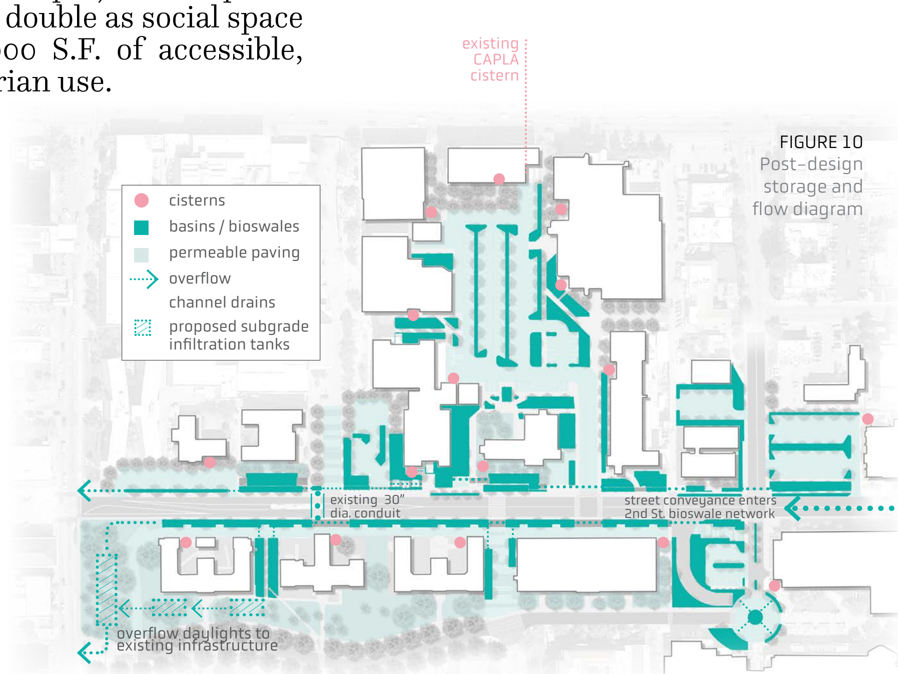


FIGURE 10
Post-design storage and flow diagram

GROW NATIVE

TREE CANOPY

The plan expects to increase native and arid-adapted trees of various sizes and forms to create structural, ecological and aesthetic diversity across 2.5 acres of proposed bioswales and retention basins **(Tab. 05)**. Within 10 years these trees will shade over 30,000 S.F., increasing human comfort, reducing surface temperature and sequestering and decreasing the emission of almost 160,000 pounds of CO2 (i-Tree. org). Trees will intercept over 4,010 cu. ft. of rainwater and provide other benefits as seen in **(Tab. 06)** tree canopy value. Research from 2015, in Tempe, Arizona, found that shade in the desert was the most important factor in increasing user comfort in regard to air temperature (City of Tempe, Urban Forestry Master Plan, 2017). Neighborhood studies found decreased temperatures of up to 7.9 degrees Fahrenheit in areas that increased tree canopy by about 35% (City of Tempe, Urban Forestry Master Plan, 2017).

TABLE 05
Proposed tree species

Botanical Name	Origin	Size
Acacia anuera	Australia	15 x 15
Ugnadia speciosa	Mexico	12 x 12
Chilopsis linearis	Mexico	20 x 30
Senegalia berlandieri	Texas	15 x 20
Prosopis velutina	Desert Southwest	35 x 35
Fraxinus greggii	Desert Southwest	12 x 12
Parkinsonia florida	Desert Southwest	30 x 30

TABLE 06
Tree value over 10 years

Number Added	134
Stormwater Intercepted	325,643 Gallons
Shade Created (after 10 years)	31,651 Square feet
Energy Conserved	68, 176.4 Kilowatt-hours
*CO2 Reduced	159,836 Pounds
Dollars Saved over 10 years	$13,234

*Combined number from sequestered CO2 and decreased energy production needs and emissions from buildings around site.

UNDERSTORY

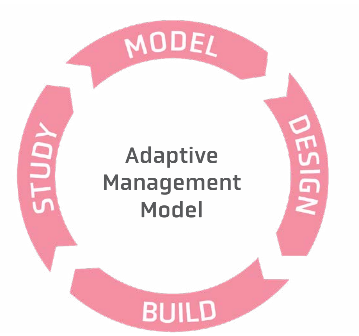
1.3 acres of restored native plantings take the form of dense, understory vegetation to mitigate pollutants, increase infiltration, decrease erosion and improve habitat. The team referenced studies conducted at the University of Utah on the effectiveness of vegetation treatments in bioswales in semi-arid environments. These studies concluded that desert upland vegetation planted at 2-3 times its natural density would sustainably and effectively retain stormwater and mitigate pollutants (Houdeshel et al. 2015).

The team also referred to Pima County's Riparian Protection and Restoration document adopted by the Science Technical Advisory Team to inform native planting strategies (Pima County Regional Flood Control District, 2000). Applying Pima County's formula to determine xeroriparian plant density, (Xeroriparian A = $1.26\ m^3/m^2$) the team proposes a 'Xeroriparian A' habitat model in bioswales. 'Xeroriparian A' classified habitats have layers of plants to prevent erosion and increase infiltration, include diversity of plant species and structure and leaf litter to hold in moisture (Pima County Regional Flood Control District, pg 7). This strategy will increase plant biodiversity while having the additional benefit of creating habitat.

WATER SAVINGS

According to Pima County, native trees use between 0.5 and 1.5 acre-feet of water, where as turf can use over 4 acre-feet (Pima County, 2000). Mature citrus, which is widely used on campus, can use up to 135 gallons of water per day (Wright, 2011). Replacing existing turf, pine and citrus trees with arid adapted and native species would reduce irrigation costs and conserve water by 2.5-3.5 acre-feet in some areas of the design.

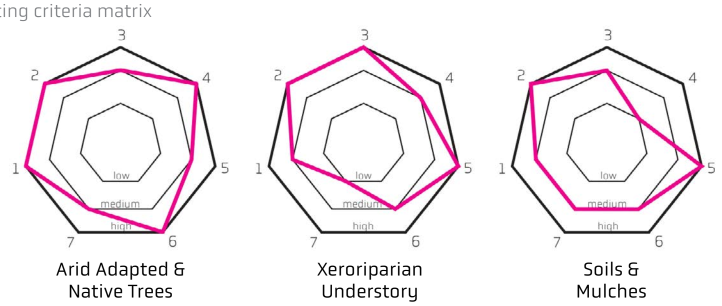
INNOVATION & CAMPUS VALUE



COLLABORATIONS IN ADAPTIVE MANAGEMENT

The team proposes an Adaptive Management strategy for implementation and maintenance phases of the master plan. This circular approach involves cross-disciplinary collaboration, modeling, research informed design, and periodic performance measurements, all of which feed evolving maintenance and planting strategies. This model for landscape management builds resiliency into the design in the face of climate change (Hunter, p.174). Shoemaker Green on the University of Pennsylvania campus is one case study of a green infrastructure project that successfully incorporates monitoring and research as a part of its maintenance plan (Shoemaker Green, 2016). Adaptive management of urban landscapes was also the basis for the team's development of a criteria matrix for selecting plants and soils that prioritize resilience to disturbances, increased aesthetics, and structural diversity among other criteria **(Fig. 11)**.

FIGURE 11
Planting criteria matrix

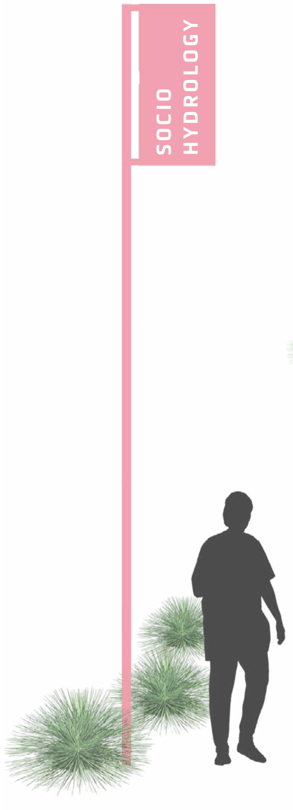


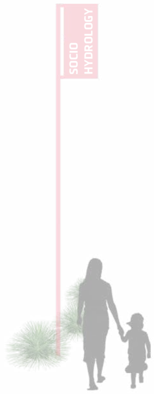
1. PLASTICITY – performance across a range of environmental conditions
2. WATER WISE – evapo-traspiration, water storage, infiltration
3. BIORETENTION – capacity to retain / treat nutrients and environmental pollutants
4. ECOLOGICAL RESILIENCE – the ability of an ecosystem to maintain function in the face of environmental disturbance
5. STRUCTURAL DIVERSITY – spacial complexity and diversity of physical form
6. AESTHETICS – form, texture and seasonality
7. MAINTENANCE – pruning, ranking, replacement

Collaborative efforts within various U of A departments would inform how the design's performance gets measured and evolves over time. For instance, Hydrology and Atmospheric Sciences partners would collect data on hydraulic conductivity, water quality and infiltration to feed Facilities Management's maintenance strategies. Then students from Natural Resources and Landscape Architecture would monitor plant health to inform the University's future plantings and Arboretum maintenance. Lastly, traffic/ pedestrian counters taken on social media platforms could provide data collection for U of A Parking and Transportation. This adaptive management strategy will not only encourage cross-disciplinary collaboration between various departments on campus but will also aid in building a responsive, resilient and engaging campus landscape.

SOCIAL VALUE

Many GI projects on campus have largely focused on stormwater management strategies, not accounting for human or social dimensions. Socio-Hydrology creates visible and integrated social spaces that double as stormwater management systems increasing student access to green space which is associated with improved psychological and physiological performance (Lau, p.56). Apart from emphasizing the benefits GI offers campus, the master plan improves safety for users through highlighted crosswalks and bike lanes. All of this comes together in a master plan that seamlessly weaves social components with GI applications into the campus fabric.





GI IS ART

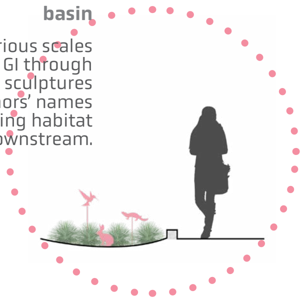
Working in collaboration with the campus and broader Tucson community is a critical component designed into the master plan proposal. Beyond engagement through applied-research and adaptive management strategies, an additional layer of engagement is achieved through subtle, artistic details and site elements. Designed to educate, engage and generate funding revenues, this typology package reflects the team's belief that art and GI can overlap in promoting new campus collaborations and branding for the U of A.

GI District

A bold branding element for the 2nd St corridor that aids in building campus engagement and literacy regarding GI practices.

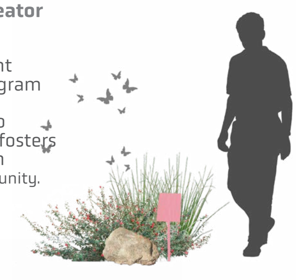
Donation basin

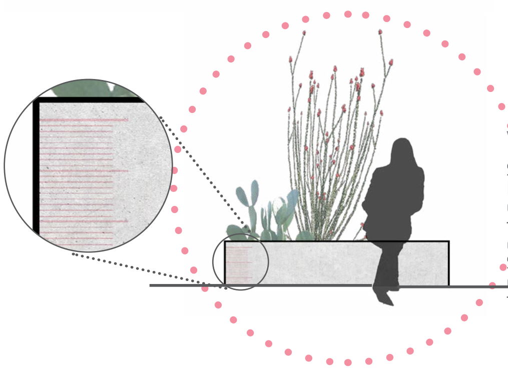
Funding various scales of campus GI through donations, wildlife sculptures highlight donors' names while referencing habitat connectivity downstream.



Pollinator creator

A student pollinator plant adoption-program encouraging connections to nature and GI fosters stewardship in campus community.





Visual cues

Subtle details in the landscape aid in connecting site users to GI while providing an educational opportunity. Seat walls within detention basins contain flood level markings

Interpretive signage

Provides public education and community engagement.

THOUGHTS ABOUT PHASING

TABLE 07
Proposed phasing options

Phase	Timing	Description/Reasoning
1) 2nd St, South Side	Year 1-5	GI corridor, research stations, and gateway features begin to solve some flooding issues while providing continuity from east to west and protecting pedestrian movement.
2) 2nd St, North Side	Year 5-10	More expensive/design intensive detention basins significantly control flooding while providing much needed social space and restoring native plantings.
3) Parking Lots / Plazas	Year 10-15	Once 2nd St. systems can handle more stormwater, retrofits to parking lots (i.e. angled parking, perimeter planting, etc.) further mitigate water entering system from on site.
4) Historic Landscapes / Cisterns	Year 15-20	Site is now able to handle 10-yr storm event. Additional cisterns and sub-grade infiltration tanks will allow GI systems to accommodate upstream conveyance.

IMPLEMENTATION STRATEGIES

REDUCED PARKING | ALTERNATIVE TRANSPORTATION

Consultations with Facilities Management and references to plans for future growth (U of A Capital Improvement Plan, 2018), informed the team's understanding that many campus spaces, often parking lots, are slated for future development. The master plan responds by prioritizing forward-thinking GI strategies that give preference to environmental and social benefits while planning for a campus that is less reliant on cars. Parking is minimized by 25% and smaller lots are retrofitted with permeable pavers that can be recycled for use in future campus projects. The University Parking Transportation Services is "committed to reducing congestion and increasing air quality through its promotion of alternative transportation programs and expanding the use of commuter options" (University of Arizona Parking and Transportation Services). There are many existing campus alternatives, with new or subsidized programs being initiated every year at the University.

FUNDING OPPORTUNITIES

The team explored many avenues for funding within the university, across-college projects and external funding options. For example, an initiative in the 2018 Strategic Plan includes "seed funding to incentivize and initiate multidisciplinary research focused on the built environment" (University Strategic, Plan Pillar 2). The U of A is one of the first higher-education institutions in the U.S. to list the built environment as a university-level priority, which demonstrates its strong commitment to sustainability issues and a potential for major financial investments to this area in the future.

External grants are another opportunity for funding **(Tab. 08)**. The U of A already prioritizes this as represented by the internationally recognized Southwest Climate Adaptation and Science Center (CASC) which focuses on "climate science, climate adaptation and environmental health in U.S. Southwest" (UA News, Oct. 2018, UA CASC Receives $4.5M for Continued Research). Capital construction projects also set aside funding for art project installations which are integral part of the master plan (University of Arizona Facilities and Safety, 2005).

TABLE 08
Funding opportunities

Funding / Source	Eligibility / Focus
1. $400,000, UA Green Fund	Student-initiative projects on the U of campus that have a focus on G.I. and community outreach
2. EPA Section 319 Grant	Grant For non-point source water quality improvement
3. EPA Science to Achieve Results (STAR)	Grant supports graduate student training
4. $1.5M, (CAPLA)	Funding for construction surrounding future development at CAPLA
5. $.5M U of A Provost's Office	Additional funding to support CAPLA construction project
6. $4,000 State Garden Club Scholarship	Grant for environmental education and student training
7. $10,000, Landscape Architecture Foundation	Grant program for faculty and students to examine landscape performance
8. $200,000 National Science Foundation (RAPID)	Grant for quick-response research on natural or human-made unanticipated events.
9. $90,000 EPA P3 Grant	Research and design projects addressing environmental and public health challenges

IN CONCLUSION

Through an iterative process involving campus collaborations, outside consultations, literature reviews, case studies and precedents of successful campus GI projects our team has developed a master plan proposal that balances aspiration, innovation and true project feasibility. Building off of previous campus plans, Socio-Hydrology establishes a framework and new campus model for stormwater management within the 2nd St. corridor that demonstrates integrated GI strategies layered with social, ecological and educational benefits for the broader campus context. Adaptive management strategies solidify campus collaborations throughout the design, implementation and maintenance process while building resilience and ongoing research into the design. Enhanced campus gateways develop new partnerships and establish U of A as a leader in GI. Interpretive GI art aids in developing community literacy in GI while providing education, storytelling and celebration around the importance of water in the desert.

A LONG RELATIONSHIP WITH WATER

Rain Responsive GI Centerpiece

ABOVE
Exploded fruit of the Saguaro cactus

Tucson, Arizona, has a long relationship with water, with over 4,000 years of agricultural history and 12,000 years of human habitation. Native cultures were drawn to the area for water that once flowed in the Santa Cruz River. The icon of Tucson is the Saguaro cactus. This iconic indigenous plant has served as an important food resource for the native cultures of Tucson. Saguaro fruit ripens at the onset of the monsoon season and traditionally native cultures harvested this food resource, but out of respect and reverence left some fruit behind on the plant. When hit by the monsoon rains the fruit explodes revealing a stunning red interior. Taking inspiration from this, a proposed GI gateway at the prominent student union entrance to campus incorporates permeable pavements, bioswale networks, basins and an interpretive GI centerpiece. This sculptural element takes inspiration from the exploded Saguaro fruit and is a symbol of U of A's respect and reverence for the important resource of water in the desert. As the sculpture fills with rain, it opens revealing a bright red interior, creating excitement and celebration around rain and GI on campus.

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CALCULATIONS

Before	**SF**	**CN**
Buildings / Parking	305,610	98
Streets / Sidewalks	172,730	95
Open Space	74,245	84
Turf	100,258	84

After	**SF**	**CN**
Buildings	176,410	98
Streets / Sidewalks	122,730	95
Permeable Paving	167,059	94
Open Space	116,919	80
Turf	69,725	80

Total Area....................................652,843 S.F.
Composite CN (before)..................93.46
Composite CN (after)......................91.27

$$S = \frac{(1000)}{(CN)} - 10$$

S = potential maximum storage of the site (inches)

Pot. Max Storage (before)..........0.70 in
Pot. Max Storage (after).............0.96 in

$P_1 = 1.38$
$P_2 = 1.73$
$P_5 = 2.16$
$P_{10} = 2.51$
$P_{25} = 3.00$
$P_{100} = 3.80$

P = 24 hour rainfall depth for a storm selected frequency (inches)

$$Q = \frac{(P-0.2S)^2}{(P+0.8S)}$$

Q = the total runoff depth (inches)

V = the total runoff volume

Runoff Curve Method

	1 year / 24 hr	10 year / 24 hr	25 year / 24 hr	100 year / 24 hr
Before:	$Q = \frac{(1.38 - 0.2\,(0.70))^2}{(1.38 - 0.8\,(0.70))}$	$Q = \frac{(2.51 - 0.2\,(0.70))^2}{(2.51 - 0.8\,(0.70))}$	$Q = \frac{(3.00 - 0.2\,(0.70))^2}{(3.00 - 0.8\,(0.70))}$	$Q = \frac{(3.80 - 0.2\,(0.70))^2}{(3.80 - 0.8\,(0.70))}$
	Q = 0.79 in runoff **V = 0.99 ac / ft**	**Q = 1.83 in runoff** **V = 2.29 ac / ft**	**Q = 2.29 in runoff** **V = 2.86 ac / ft**	**Q = 3.07 in runoff** **V = 3.83 ac / ft**
After:	$Q = \frac{(1.38 - 0.2\,(0.96))^2}{(1.38 - 0.8\,(0.96))}$	$Q = \frac{(2.51 - 0.2\,(0.96))^2}{(2.51 - 0.8\,(0.96))}$	$Q = \frac{(3.00 - 0.2\,(0.96))^2}{(3.00 - 0.8\,(0.96))}$	$Q = \frac{(3.80 - 0.2\,(0.96))^2}{(3.80 - 0.8\,(0.96))}$
	Q = 0.66 in runoff **V = 0.82 ac – ft**	**Q = 1.64 in runoff** **V = 2.05 ac – ft**	**Q = 2.09 in runoff** **V = 2.61 ac – ft**	**Q = 2.85 in runoff** **V = 3.56 ac – ft**
Runoff Volume Reduction	17.2 %	10.5 %	8.7 %	7.0 %

Additional Storage

GI Type	S.F.	Cu. Ft.
Detention Basins @ 20”	6,343	10,530
Swales @ 18”	13,725	27,450
Microbasins @ 12”	55,352	55,350
Cisterns (15 new)	10,600 Gal (ea)	21,225
Infiltration Chambers	Phase 4	Based on storage needs

Total Additional Volume.....................93,110 Cu. Ft.
★ before the addition of above or below ground cisterns

or

2.14 ac – ft