THE NEW HEART

Uniting a Divided Campus Through Innovative Green Infrastructure Design

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Abstract

Utah State University is located in Logan, Utah. The original campus buildings surrounded the Quad, a centralized grassy location at the heart of all university activities. Through years of campus expansion to the north, 700 N (Aggie Boulevard) has taken the central position the Quad once held. Aggie Boulevard bisects the campus and is the artery through which students, faculty, and the public frequently travel. This causes congestion far beyond what the road was designed for. This report presents a design to establish Aggie Boulevard as the new heart of campus, as well as reduce current stormwater and transportation inefficiencies.

Currently, Aggie Boulevard produces a high stormwater runoff volume due to the large amounts of impermeable hardscape, nearly 80% of the site area. Large storm gutters on either side of the road channel stormwater runoff to storm drains that convey water to groundwater via shallow drywells without treatment. Vehicles in the area idle for long periods of time, adding to emissions in a location that is frequently out of attainment for $PM_{2.5}$, a secondary pollutant originating from car (NO_x) and agriculture (NH_4) emissions.

The goals of this design are to recharge groundwater with treated runoff, reduce impermeable surfaces, retain design storms as required by local municipalities, eliminate the need for supplemental irrigation in a climate where water is in short supply, emphasize native landscaping, and, create a new cultural center of campus.

Site Selection

Location Description and Aerial View

Situated on Utah State University's campus, Aggie Boulevard (Figure 1) is 80% impermeable hardscape with scattered planting beds and features a two-way asphalt roadway with concrete sidewalks on either side (Figure 1). At present, conventional gutters on either side of the roadway are used to convey stormwater. This area experiences high volumes of pedestrian, bicycle, and slow-moving vehicle traffic during the school day. As the student and faculty population of Utah State University (USU) continue to grow, the site is expected to experience higher volumes of vehicle and foot traffic than ever before. Current discussions among USU facility managers to address these concerns have provided the opportunity to present a design that instills a sense of unity among students and faculty through green infrastructure.

Figure 2. Aggie Boulevard in its current state

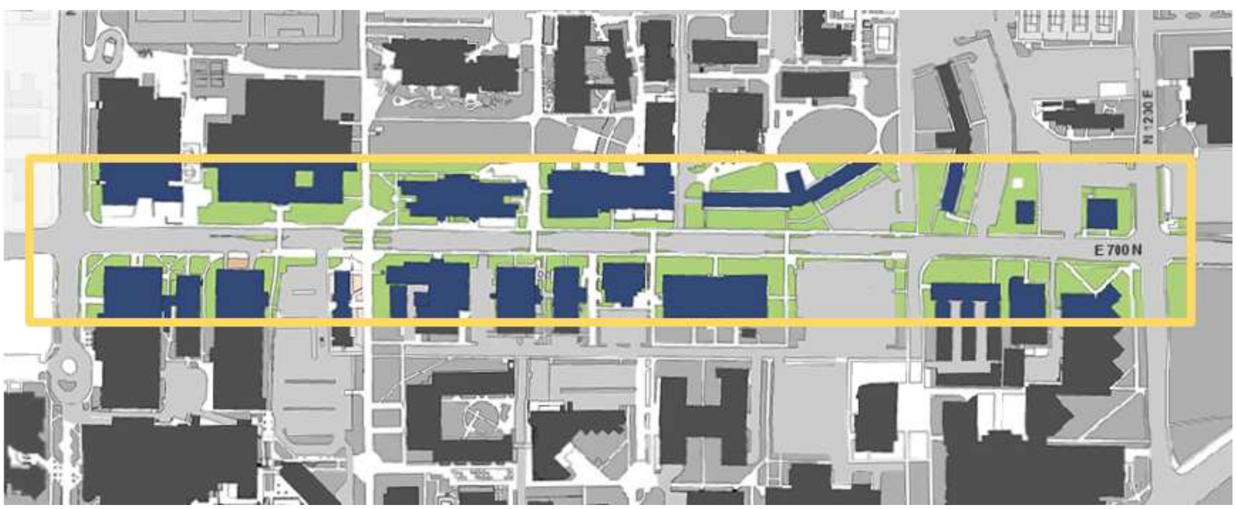

Figure 1. Aerial view of 700 N (Aggie Boulevard) site study area.

Site Analysis

Existing Site Conditions and Improvement Needs

As campus has expanded, it has lost the centralizing element that the Quad once provided. Aggie Boulevard has become the new center for Utah State University, and because of this transition, it experiences high volumes of pedestrian and vehicle traffic. The improvements needed in this area are to reduce impermeable surfaces, retain and treat stormwater, reduce traffic, and create a new aesthetically pleasing green infrastructure-based center of campus.

Because an adjustment to the current site is considered a "new development", the area is subject to new regulations. Logan City, local municipality, requires new developments to retain the 90th percentile storm on site. The 90th percentile storm in this area is 0.66 inches. Additionally, the 100-year, 24-hour storm must be retained so only 0.2 cubic feet per second is discharged from the location. The 100-year, 24-hour storm depth in this area is 3.02 inches. The current Curve Number is 88.2. The runoff depth calculated from the curve number was 0.09 inches for the 90th percentile storm and 1.85 inches for the 100-year, 24-hour storm (NRCS 1986). Presently, stormwater discharges into a gutter and has a potential for contamination due to decaying organic matter and oil and grease from cars. Aggie Boulevard is flat and has a current watershed consisting only of the road area.

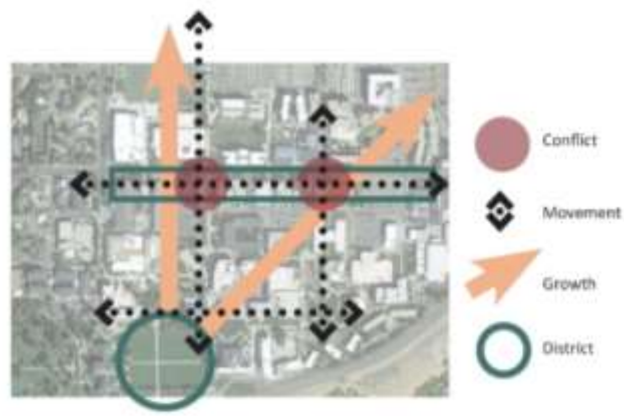

Figure 3. Movement Description Through Site

The movement through Aggie Boulevard is show in Figure 3. The green circle denotes the old center of campus, the Quad. The orange arrows represent the direction of growth of campus infrastructure. The red circles are placed on location on Aggie Boulevard where high pedestrian and vehicle traffic create high congestion. These circles are located on crosswalk areas. The black dotted arrows represent main pedestrian pathways throughout campus.

Design Program

Objective

The objective of this project is to remove vehicle traffic from Aggie Boulevard and replace it with natural landscape that retains the stormwater for use on site. The new landscape will potentially include art features that are accentuated and brought to life by rainfall. A walking path composed of permeable pavers will be available to students walking or biking to class. This will create a more centralized atmosphere on campus while also providing filtration of stormwater through the landscape and soils. To ensure that bus transportation is minimally impacted by the removal of the road, two roundabouts will be placed at the ends of the proposed campus common area. These roundabouts will also allow for vehicle access to all existing parking lots and bus access to campus.

Project Goals

The proposed design aims to meet certain goals and objectives outlined below:

Recharge Groundwater After Treatment - Treat groundwater before discharge by channeling it through soil media and plants.
Reduce Impermeable Surface Area - Replace hardscape that has high runoff potential with permeable surfaces such as permeable pavers and raingardens that allow stormwater to infiltrate the surface.
Retain Design Storms - Retain the 90th percentile and 100-year, 24-hour storms as required by local governments.
Reduce Need for Supplemental Irrigation Past Establishment Period - Store enough water on site to sustain plant life through dry periods after plant establishment.
Emphasize Native, Xeric Landscaping - Reduce irrigation needs by utilizing native plant species requiring minimal water. Native plantings will also highlight the importance of rain in Utah's arid climate.
Improve Circulation and Accessibility - Create a more accessible thoroughfare for pedestrians and bicyclists to reduce congestion during peak commute hours. Reduce emissions from idling cars to help meet current campus-wide goal of producing zero net emissions by 2050.
Create New Cultural Center of Campus - Generate open space for University events and create areas for students to congregate and take advantage of the cultural and aesthetic benefits of green infrastructure. Install art pieces that celebrate the wonder of precipitation in the desert and provide instructional materials on site to educate students and the public about green infrastructure utilized in the design.

Design Methods and Preliminary Analyses

Design Tools

The NRCS runoff curve number will be used to quantify runoff in this location. Physical properties of soil will be used to size the green infrastructure implemented. The CNT National Green Values Stormwater Calculator and various costs found from literature will be used to estimate the cost of the green infrastructure.

The principles of low impact development and best management practices will be used. Additionally, landscape architecture approaches to the project will be used to ensure that the location will be a cultural asset and be functionally and aesthetically pleasing.

Water Retention

In order to create a self-sustaining system, the water falling on the catchment area must be used in the pervious area. Figure 4 demonstrates the average yearly water flow within the site area. The inflow represents precipitation the falls within the catchment area, and the outflow represents the average evapotranspiration rate in Logan, Utah over the previous area (Moller and Gillies 2007). To eliminate the need for supplemental irrigation in the times where evapotranspiration exceeds precipitation, storage of rainwater in excess of evapotranspiration is necessary.

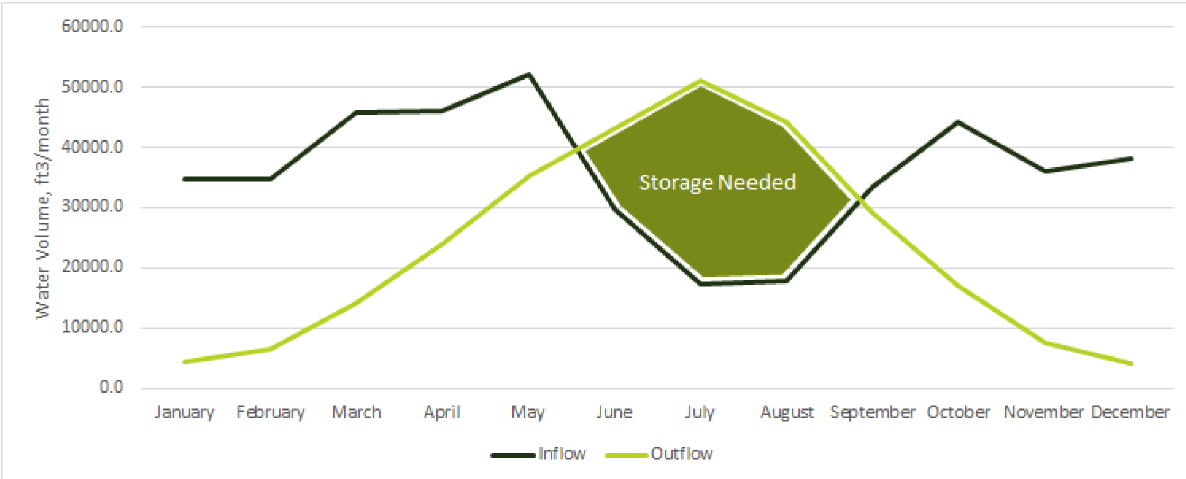

Figure 4. Average Yearly Water Flow

Utah Water Rights laws allow for one 2,500-gallon cistern for every parcel of land. Aggie Boulevard splits two parcels, meaning a total of 5,000 gallons can be stored in cisterns on site. More than 5,000 gallons are needed during the June, July, and August, so water must be stored in the soil. In order to retain the needed water in the soil which has high hydraulic conductivity (60 inches per hour), a geosynthetic clay liner will be placed under the soil media to prevent water from draining out of the site area.

Design Description

Design Overview

To meet the design objective and goals, the asphalt covering Aggie Boulevard will need to be removed. To avoid negatively impacting students who use public transit and people needing to access commuter parking lots, two roundabouts will be installed on the East and West as shown in Figure 5 below. The roundabouts will have bus stops on the inner circle to avoid lines of vehicles waiting to access parking lots, as well as exits leading toward parking lots.

Figure 5. Rendered Plan View of Proposed Redesign.

The pedestrian and bike pathways, made of porous pavers arranged in circular patterns, connect the area between the two roundabouts, as well as provide emergency vehicle access to surrounding buildings. The pathways are angular, broken up by geometric sections of rain gardens. Beneath the porous pavers and intermittent rain gardens lies a geosynthetic clay liner to retain water on site to alleviate the need for supplemental irrigation past the establishment period of the plants. The east wall of the clay liner is 7 ft tall, whereas the west wall of the clay liner is 6 ft tall. This gentle underground slope was added to provide a drain in order to protect water rights of downstream individuals. The western-most rain garden will be unlined to release water that has percolated through the soil media to the groundwater. The water channeled into the area originates from roofs of surrounding buildings as well as nearby parking lots. The water will be channeled via underground downspouts.

Throughout the pedestrian corridor, educational signage and art work will be placed to raise awareness for xeric landscaping, as well as other types of green infrastructure. The location will contain areas for static enjoyment of the surroundings, as well as areas for facilitating pedestrian and bike movement.

The cross section of the design is shown in Figure 6 below. This drawing is not to scale by width for the purpose of highlighting the gravel river which will facilitate water flow from one side of the area to the other. It is, however, to scale by depth. The side view of the design is shown in Figure 7. It shows an underground cistern with a capacity of 2,500 gallons. There will be two of these cisterns on site.

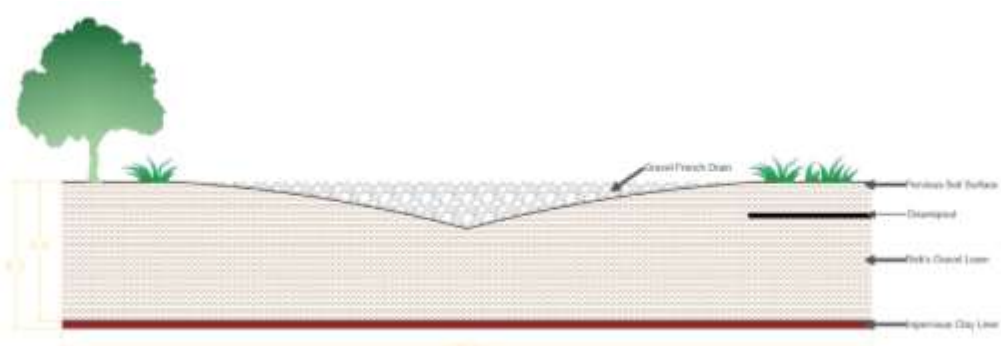

Figure 6. Cross sections of design.

Figure 7. Side View of design.

Retention of Design Storms

In order to retain the 90th percentile storm on the 1.93 ac site (using a 6-acre catchment area), the depth of native soil (porosity 0.185) needed is 0.93 ft (NRCS 2018). Although retention of the 100-year, 24-hour storm is not required by local municipalities, the depth to capture the storm in native soils was calculated and is 4.23 ft.

Because the team would like to have native trees in the landscape which require 5 ft of depth, both storms will be retained in the clay liner. The depth of the soil on top of the clay liner will be 6 ft for safety. Because the location can retain both the 90th percentile storm and the 100-year, 24-hour storm, the runoff from this site has been reduced 100%. This means that 100% of pollutants have been removed from surface water runoff.

Reduction in Impervious Area

The curve number for the existing site (1.93 acres) is 88.2, but the curve number for the proposed site is estimated to be 47. This is a 47% reduction in the curve number, which corresponds to a large reduction in impervious area.

Reduction in Irrigation Water Required

In order to avoid supplemental irrigation, enough water to sustain plants during long dry periods needs to be retained in the pervious area. The soil has a saturated capacity (assuming soil available for storage is 1,200ft by 70 ft by 6 ft and a porosity of 0.185) of 93,240 ft^3 (NRCS 2018). Figure 8 below demonstrates the 6-acre catchment area, consisting of the redesigned Aggie Boulevard (1.93 acre, pervious, shown in red) and surrounding rooftops and parking lots (shown in yellow) which will have drains channeled toward the pervious area. Figure 9 shows a water balance of the yearly precipitation over the 6-acre catchment area, evapotranspiration over the 1.93-acre pervious area, and storage available over time in both cisterns and the ground.

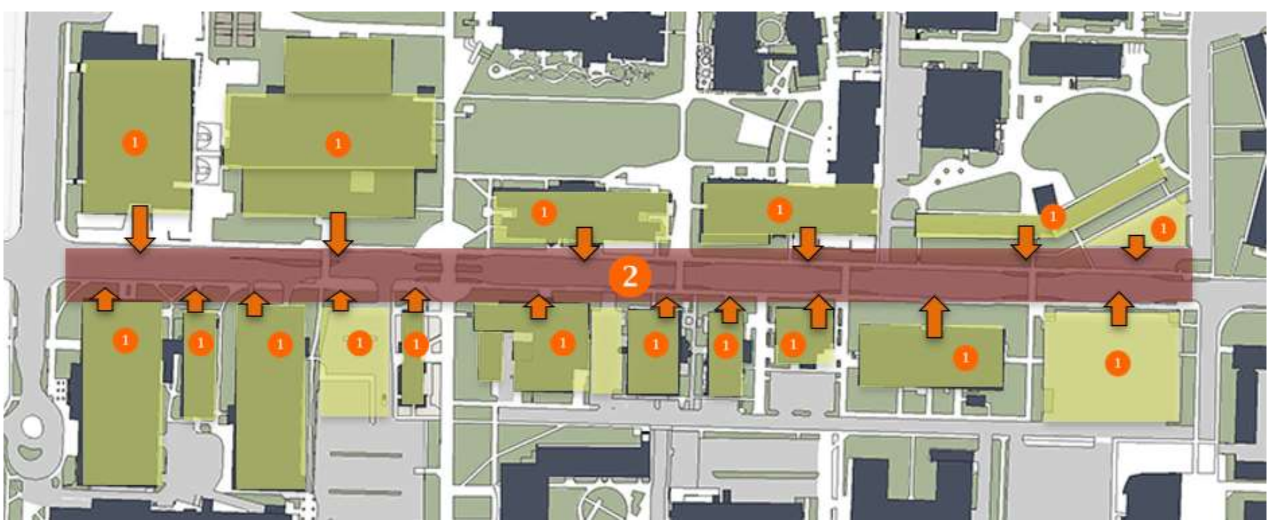

Figure 8. Stormwater Catchment Area

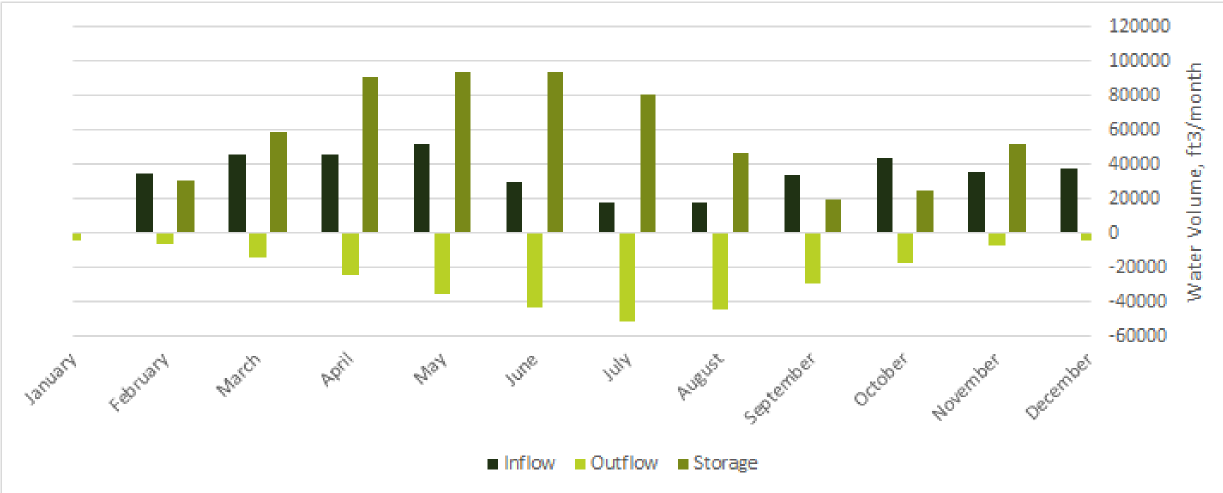

Figure 9. Water Balance of Precipitation, Evapotranspiration, and Storage Available

Based on the water balance above, the months of the year in which evapotranspiration exceeds precipitation are June, July, and August. However, the available stored water (in cisterns and the ground) for those times of year, accounting for those water needs, never drop below 20,000 ft^3 per month, meaning there is more than enough water for average plant needs in Logan's climate. Because no supplemental irrigation will be required past the establishment period for the plants, this design reduces the need for irrigation water by 100%.

Native Landscaping

The team plans to use water-wise, native plants in this area. The plants selected are plants that can survive inundation as well as long dry periods, which a typical precipitation pattern in Utah. The proposed native planting blooming chart and plant palette are shown in Figures 10 and 11. The blooming chart shows the seasons in which the proposed native plantings will bloom, with most blooms happening in the spring, summer, and fall. Some plants continue to bloom into the winter. The aim of choosing these plants is to create an appreciation among the community of native plants in a place where many in the public consider native plants to be weeds. This site will be a demonstration of water-wise landscaping.

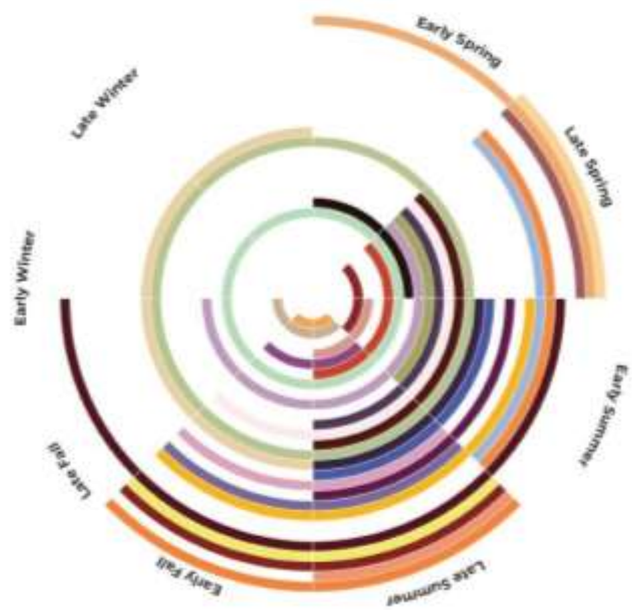

Figure 10. Proposed Blooming Chart for Native Plantings

Figure 11. Proposed Native Plant Palette

The introduction of native trees and vegetation will reduce CO_2 in the area. Carbon sequestration was approximated by assuming each tree would take in 336 lbs CO_2 every year, and 50 trees would be planted (CNT 2010). The carbon sequestration of the area is expected to be 16,800 lbs CO_2 every year.

Treated Groundwater Recharge

The water balance introduced in the "Reduction in Landscape Water Required" section included groundwater recharge. The water used for groundwater recharge flows through the system, getting treatment from native plants and the soil media, and is discharged into an unlined basin with a high hydraulic conductivity. Groundwater recharge was considered to be any precipitation that fell over the catchment area which was not used for evapotranspiration or storage. As shown in Figure 12 below, late spring and late fall are the times of the year where groundwater recharge would be expected. The total yearly treated groundwater recharge for this 6-acre catchment area is projected to be about 55,050 ft^3.

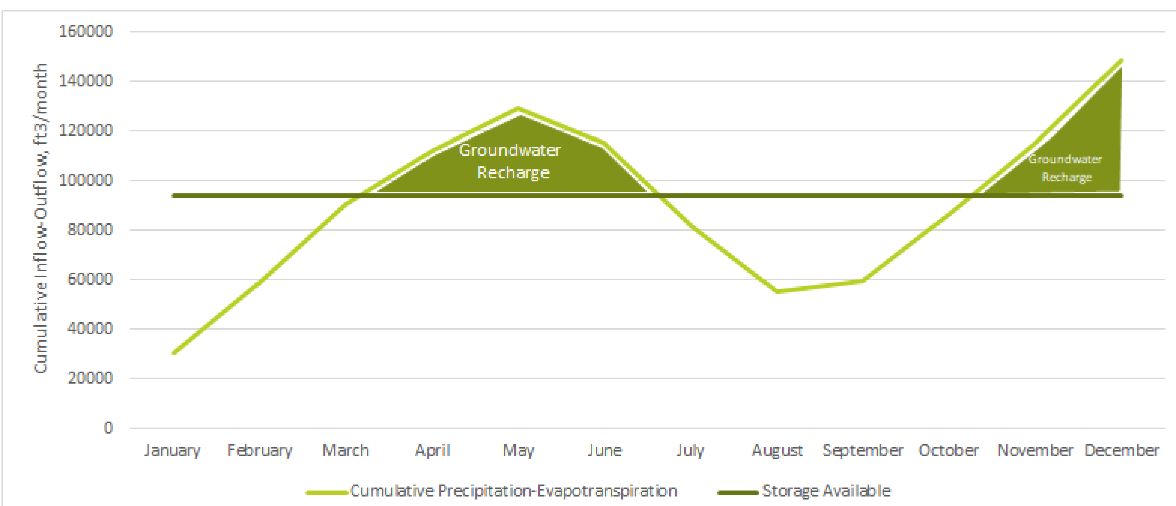

Figure 12. Groundwater Recharge Throughout the Year

Circulation and Accessibility

Vehicle traffic was removed from Aggie Boulevard, thus relieving congestion. The roundabouts placed on the east and west will allow campus and city buses to access the area, as well as allow smaller passenger vehicles to access key parking lots on campus. Figure 13 depicts the traffic flow through these roundabouts. The green arrows indicate small passenger vehicle paths to parking lots, and the blue arrows indicate bus routes.

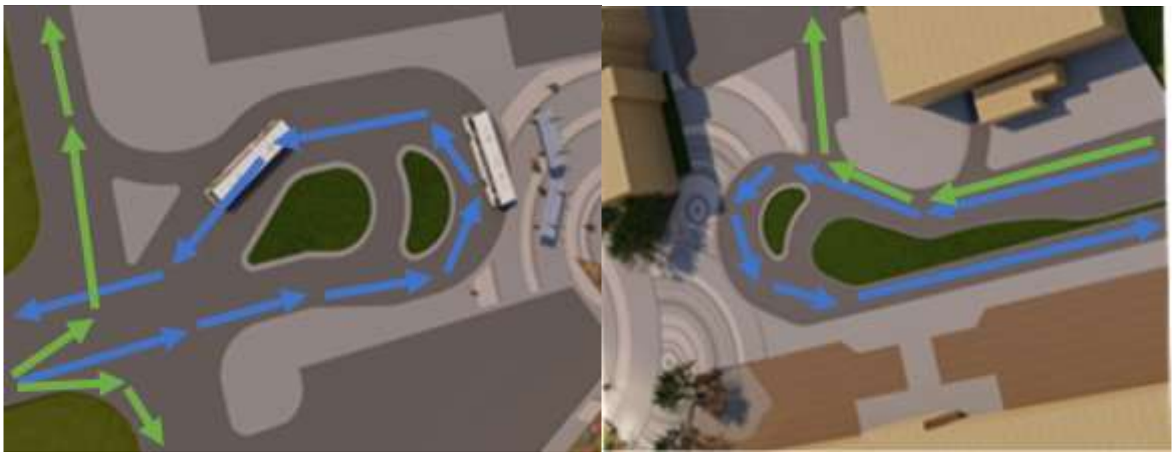

Figure 13. East (left) roundabout traffic flow and West (right) roundabout traffic flow

Decreasing congestion in this area will help meet the greater University goal of producing zero net emissions by 2050. On average, a total of 5,800 cars drive on Aggie Boulevard per day (USU 2016). The design team assumed traffic idles for 15 minutes before the start of every 1-hour class period from 8 a.m. to 3:30 p.m., every car has a standard 2.0 L engine, and each car burns 0.3 gallons per hour while idling (US Energy 2015). The team estimates 562,660 lbs of CO_2 are currently produced on Aggie Boulevard annually (US EIA 2017). The team calculated that removing the road and implementing roundabouts will reduce CO_2 emissions in this area by approximately 62.5%.

Campus Cultural Center

The increased natural space and reduced hardscape will create an atmosphere which will draw people to the area. The landscape will be designed to be a moving space, as well as a space to gather. There will be designated areas along the varying paths for people to congregate. Potential art installations, such as sculptures that move when water is directed onto it, would draw interest to the area during a rainstorm. This would help facilitate a celebration of water in a climate that receives minimal rainfall.

Project Costs

Project Capital Costs

A preliminary economic analysis was performed to estimate the total cost of construction and project implementation. The site survey and other aspects of preconstruction were included. Removal cost of the current asphalt road that overlays Aggie Boulevard was estimated for a 40 ft by 1,200 ft road with a 1 ft thickness. The excavation necessary to install the geosynthetic clay liner was estimated for 10,700 cubic yards of soil material at $16.50 a cubic yard (USDA 2017). The two – 2,500-gallon storage cisterns were priced at $15,000 for each installed cistern (CostHelper 2018). The itemized costs also include the cost of two roundabouts which are to be installed on the east and west exits of Aggie Boulevard. The estimated costs were $386,145.00 for each roundabout (FHA, 2010). Additional cost estimates are presented in Table 1.

Table 1. Itemized Cost of Proposed Project

Itemized Project Cost					
Item #	Item	Quantity	Unit	Unit Price (USD)	Total Amount
1	Mobilization		10%		$ 354,398.20
2	Traffic Control		8%		$ 283,518.56
3	Site and Construction Survey	1	LS	$ 8,900.00	$ 8,900.00
4	Excavation of Asphalt Road	48000	CF	$ 30.00	$ 1,440,000.00
5	Excavation of Soil	10667	CY	$ 16.50	$ 176,000.00
6	Construct Temporary Construction Entrance	300	CY	$ 67.00	$ 20,100.00
7	Storage Cisterns	2	EACH	$ 15,000.00	$ 30,000.00
8	Install Permeable Pavers	84000	SF	$ 12.00	$ 1,008,000.00
9	Geosynthetic Clay Liner	100510	SF	$ 0.60	$ 60,306.00
10	Roundabout	2	EACH	$386,145	$ 772,290.00
11	Downspouts	18	LS	$ 202.00	$ 3,636.00
12	Install Trees	40	EACH	$ 275.00	$ 11,000.00
13	Install Rock and Boulders	100	CY	$ 100.00	$ 10,000.00
14	Native Plants	500	EACH	$ 7.50	$ 3,750.00
TOTAL CONSTRUCTION COST					$3,712,281.10
			ADD 25% CONTINGENCY ON TOTAL		$4,640,351.38

Operation and Maintenance Costs

Operation and Maintenance costs (O&M) associated with the current site include snow removal (November to March), road repair, and upkeep of grass park strips along Aggie Boulevard. The proposed site design will reduce the area of road that is subject to repair by USU facilities while also lessening the amount of area that needs to be plowed during the winter months. If the design is implemented, the site's new maintenance costs will primarily stem from landscaping along the pedestrian corridor, upkeeping the porous pavement, and maintaining the water retention system.

In accordance with the wishes of USU Facilities, our team incorporated native plants that would require minimal maintenance because of their slower growth. The primary maintenance of these landscaped areas would be completed in the spring and fall. Incorporating perennial plants would reduce the cost of installing annual bedding plants every spring, which the University currently does. Removing grass park strips along the pedestrian walkways also eliminates the need for periodic mowing and supplemental irrigation. The O&M cost of upkeeping these native planting areas is estimated to be $1,900 per year.

The porous pavement along the pedestrian corridor will need to be power washed seasonally to alleviate sediment that builds up inside the pores of the pavement. Snow removal on the porous pavement will be done with a rubber tipped plow to increase the longevity of the surface. Estimated annual O&M costs for the porous pavement are $3,000.

The water retention system (including storage cisterns and infiltration areas) was designed to require minimal maintenance. Leaves and other debris will need to be occasionally cleaned from infiltration areas to improve water flow into the porous ground. The storage cisterns will also need to be inspected annually for wear. The estimated annual O&M costs associated with the water retention system are $600.

Valuation of Secondary Benefits

Implementing Green Infrastructure design alternatives in the proposed project provides runoff reduction, but also provides ancillary benefits such as avoided water treatment costs, energy savings, and air quality benefits. Primary and ancillary benefits are quantified in Table 2.

Table 2. Quantified Primary and Ancillary Benefits in the Proposed Site Design

Quantified Valuation of LID Design		
EXPECTED OUTCOME	**AMOUNT**	
Total Runoff Reduction	3,194,605	gallons/year
Avoided Stormwater Treatment Costs [1]	4,280	$/year
Energy Savings from Avoided Treatment[2]	4,373	kWh/year
Avoided Cost of Conventional Infrastructure[3]	2,320,396	$
Quantified Valuation of Air Quality Benefits[4]	1,260	$/year
Reduced NO2 Emissions[5]	8	lbs/year
Reduced SO2 Emissions[5]	23	lbs/year
Source: 1. UDWR, 2010 2. EPRI, 2002 3. Green Values, 2018 4. McPherson, 2006 & Wang and Santii 1995 5. USEPA, 2005		

Project Funding

Discussions with USU Facilities have made it clear that the University Planning Office is actively working to redesign this section of campus, specifically Aggie Boulevard. Because there is a high potential for a renovation, it was assumed that the majority of the funding for this project would be acquired from USU's existing infrastructure budget.

Additional funding could be acquired through Student Sustainability Grants provided by USU's Blue Goes Green initiative, which provides funding for campus sustainability projects. The Utah Department of Environmental Quality also provides funding for innovative, water quality improvement projects through the Utah Clean Water State Revolving Fund (CWSRF). Capital funding could also be acquired through an EPA Source Reduction Assistance Grant.

Summary & Conclusion

The recommended design celebrates and utilizes stormwater in a climate which does not receive much annual rainfall. It creates a new cultural center of campus, which incorporates movement as well as stationary activities. There will be educational signage placed in strategic locations to highlight the benefits of the green infrastructure implemented. The road is removed and replaced with a pervious pedestrian pathway. Vehicle traffic is directed through roundabouts to help traffic flow and reach essential parking lots, which is estimated to reduce carbon emissions from idling by 62.5%. Additionally, the proposed native plant palette will sequester an estimated 16,800 lbs CO_2 every year. This will help the university meet its goal of zero net emissions by 2050.

Rainfall is collected from the surrounded 6 acres and is channeled into a 1.93-acre pervious area, under which two 2,500-gallon cisterns are placed on site to retain water. For additional water storage, a geosynthetic clay liner was placed under the soil to retain additional water without violating water rights. The 1 ft drop in height from East to West of the geosynthetic clay liner is estimated to release an estimated 55,050 ft^3 of treated water for groundwater recharge. The stored water will be used during long dry periods in the summer months and will eliminate the need for supplemental irrigation after plants are established. In addition to removing the need for supplemental irrigation and recharging groundwater, this design also retains 100% of design storms, resulting in a 100% reduction in pollutants discharged to surface water.

This design demonstrates the possibilities of sustainability in a location where drought is common. This design recharges treated groundwater, reduces impermeable surfaces, retains design storms, eliminates need for supplemental irrigation, emphasizes native landscaping, and creates a new cultural center of campus.

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