REVITALIZING NATURAL TREATMENT

HARVESTING RESILIENCY AT COLORADO STATE UNIVERSITY'S VETERINARY TEACHING HOSPITAL.

Project Location
Colorado State University South Campus
Registration Number: D40

Faculty Advisor
Dr. Kimberly Catton, Environmental Engineering

Team Members
Griffin Cullen, Environmental Engineering
Jessica Doig, Landscape Architecture
Caroline Michael, Ecological Engineering
Liting Tao, Environmental Engineering
Natalie Thompson, Environmental Engineering

PROJECT ABSTRACT

Our project, Veterinary Teaching Hospital: Revitalizing Natural Treatment aims to create an innovative new solution to treat stormwater runoff from Colorado State University's esteemed Veterinary Teaching Hospital. Our new solution will replace an outdated drainage ditch with a more environmentally beneficial, sustainable, and aesthetically pleasing meandering bioswale. The new design will consist of a 1750 foot long sawle along with three new detention ponds and vegetated buffers. Our proposed area contains numerous animal pens used to house large animals for treatment at the veterinary hospital and large amounts of animal manure are produced as a consequence of this. The pens themselves along with a large manure holding area exist within the boundaries of our project area, making phosphorus and nitrogen treatment critical. Added plant density and diversity will greatly improve the existing area's capacity to retain and partially treat outgoing storm runoff, which will reduce the amount of nutrients received by the outlet source, Spring Creek. Additionally, we aim to create a more resilient design to accommodate Colorado's stronger storm events that have started as a consequence of climate change. Finally, the area as it exists adds little visual interest to an area of such prestige and importance to the school and our design aims to create a more student- friendly educational space.

EXISTING CONDITIONS

The area in question for the project is a 1750 foot long drainage ditch that captures stormwater runoff from the area indicated in Figure 1. The current ditch has steeply sloped sides and consists solely of short grass, as shown in Figure 2.

Figure 1. Drainage area

Figure 2. Drainage ditch

The drainage ditch is located next to Colorado State University's Veterinary Teaching Hospital, which results in runoff from large animal pens and a manure holding facility (shown in Figure 3).

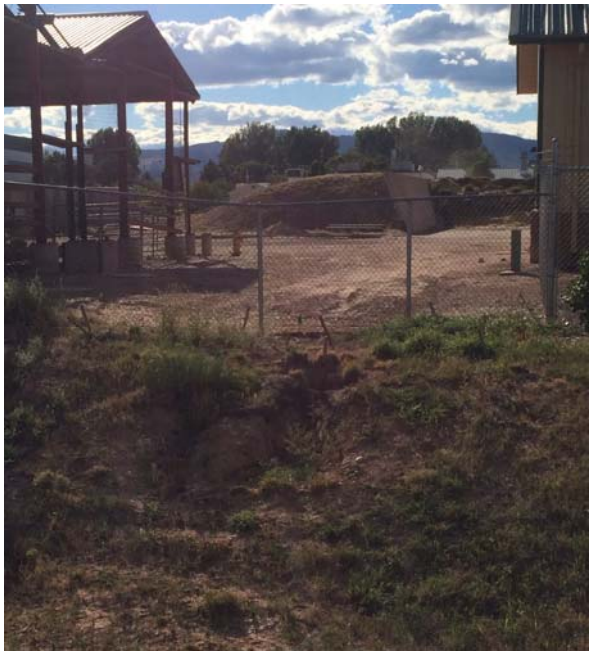


Figure 3. Manure holding area

PROJECT GOALS

Currently, the project site poses three main challenges to our team: excessive nitrogen and phosphorus loading from animal manure runoff, a structure that is poorly adapted to the stronger storm events predicted to be a consequence of climate change in Colorado, and the

lack of visual interest or educational value for visitors to the Veterinary Teaching Hospital. Therefore, the design's primary objective will be to reduce the amount of nutrient output created by the existing ditch, as there are no barriers to excess nitrogen and phosphorus entering local freshwater systems, such as Spring Creek, where the ditch eventually drains. Second, we will plant new species to increase the biodiversity of the area and increase its climate resiliency capabilities. Thirdly, the design will focus on creating an aesthetically enhanced environment with an educational walking trail to stimulate interest in the area and in the importance of stormwater management. Finally, while not part of a technical design, the team strives to continue Colorado State University's green legacy and set a precedent for sustainable designs in the future on campus.

APPROACH

When deciding how to approach the project site, there were three main considerations at the forefront of the decision-making process: stormwater treatment potential, the new project's climate resiliency, and the aesthetic and innovative value the new design would have to campus. After considering multiple treatment options, a bioswale was determined to be a beneficial and feasible design to implement.

The rational method and Manning's equation were used to determine the size of the bioswale using design criteria from King County, WA's Department of Natural Resources and Parks. The rational method was further used to determine the storm return period the bioswale would be able to accommodate. Currently, "projections of future precipitation change [in Colorado] do not agree about whether Colorado's annual precipitation will increase or decrease" (Colorado Water Conservation Board). This makes climate change in Colorado difficult to predict, which in turn creates a conundrum for designing a bioswale. To compensate for this, plants were selected to be drought resistant, while the return period storm was designed to a 100-year storm, to account for possible and more frequent flood events that could also result from climate change in Colorado.

In general, the bioswale was designed to have short grasses along its bottom trench, long grasses to line the sides of the main trench and shrubs along the border. Plants were broken into three categories: treatment plants, drought resistant plants, and aesthetic plants. Table 1 shows the removal efficiencies for the selected treatment grasses in the bioswale. Drought resistant, "Colorado-friendly" plants include *Agastache* (a perennial also known as Colorado Red Hyssop), *Yucca filamentosa*, *Agave parryi*, *Chamaebatiaria millefolium* (fernbush), *Berberis thunbergii* (crimson barberry), *Nepeta x faassenii* (catmint), *Cytisus purgans* (Spanish gold bloom), *Helictotrichon sempervirens* (blue avena grass), *Achillea* (moonshine yarrow), *Nassella tenuissima* (Mexican feather grass), and *Buchloe dactyloides* (buffalo grass). All other plants were selected purely for aesthetic purposes. Figure 4 shows the assortment of plants that will be used in the bioswale.

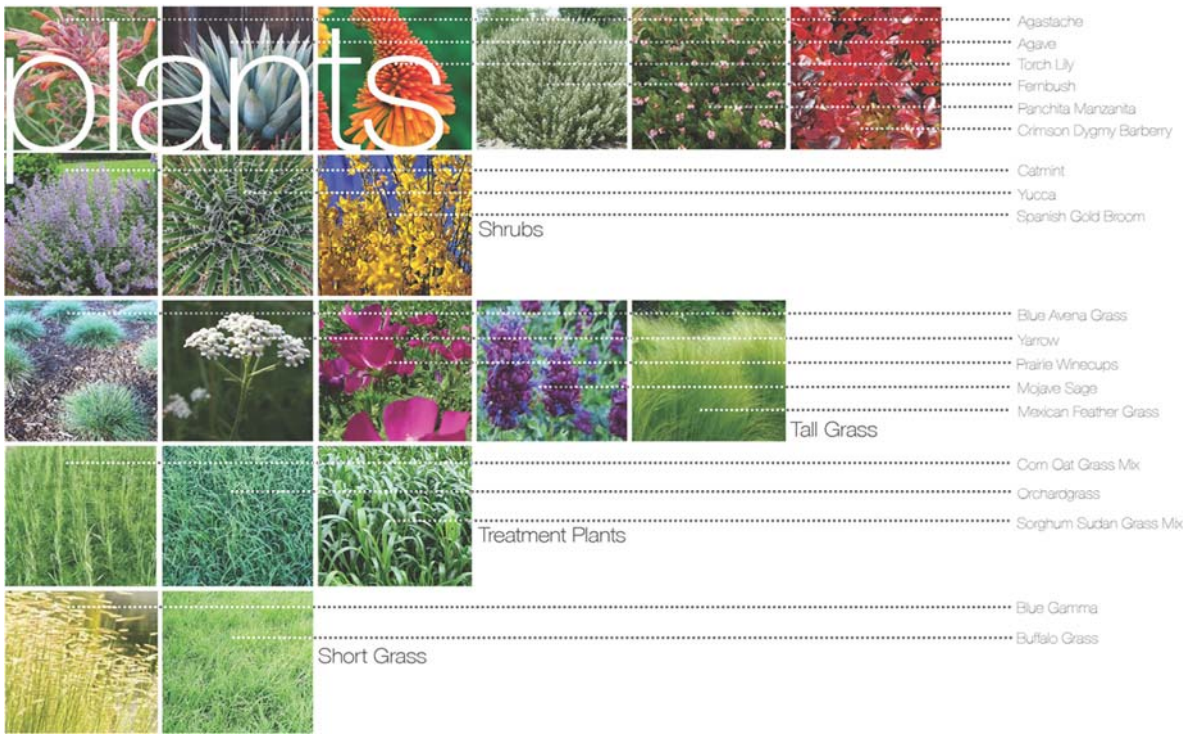


Figure 4. Plants used in the bioswale (Grismer 2006) (Young 1980)

PERFORMANCE

During a flood event, stormwater from animal pens, manure collection system, side road, and bike trail will flow over the vegetated buffers of the bioswale. A portion of water will be held on-site through infiltration, while the rest of the water will be collected in the ditch and then discharged into Spring Creek. For infiltration, according to a USDA survey, the soil makeup of the site is classified as type B which has medium permeability of 1 in/hr (USDA,1986). The infiltration area combines vegetated buffers, the bioswale, and a grassy ditch, with a total area of 78,750 ft^2. Based on the removal efficiencies of selected plants, the estimated removal rate for nitrogen and phosphorous is 50% for the entire area. Removal rates for the current and proposed plants can be seen in Table 1. Other benefits within the designed bioswale include the added 6.18 acres of native plant community and an increase in 9 species of pollinators as seen in Table 2.

Table 1: Nitrogen and Phosphorus Removal Rates For Existing and Proposed Plants

Plant	**Nitrogen Removal**	**Phosphorus Removal**	**Source**
Corn-oat or orchard grass mixture	88%	87%	Young et al. (1980)
Orchardgrass	52%	52%	Dillaha et al. (1988)
Sorghum-Sudan-grass mix	81%	84%	Young et al. (1980)
Average of Bioswale (Proposed)	**74%**	**74%**	
Grass swale	38%	9%	EPA (1994)
Average of Grass Swale (Current)	**38%**	**9%**	

Table 2: List of Pollinators For Each Plant

Plant	**Pollinators**	**Source**
Fernbush	Bees, Tarantula Hawk Wasp (Pepsis formosa)	Whealen & Sperlich (2013)
Panchito Manzanita	Bees, hummingbirds, painted lady butterflies	Camp (2010)
Agastache	Honeybees, bees, hummingbirds	Garden Mentors (2012)
Spanish Gold Broom	Bees	Nilsen (2000)
Catmint	Hummingbirds, moths, butterflies and bees	Extension (2013)
Yucca	Yucca moth	Proctor et al. (1996)
Torch Lily	Hummingbirds	Peck (2015)
Crimson Pygmy Barberry	Small and large bee species	Lebuhn et al. (1994)
Agave	Bats, hawkmoths	Kline (2011)

Also, three new detention ponds are designed to collect additional stormwater and mitigate flooding during a strong storm event. An educational trail with signs will demonstrate the function of vegetated buffers, bioswales, and detention ponds in collecting and treating stormwater that not only provides information about stormwater management, but also underlines the importance of protecting water resources. In addition, the College of Engineering at Colorado State University holds an annual Engineering Days event to showcase students' design projects and the event draws visitors from the community and industry, as well as prospective students interested in exploring engineering. The new design at the Veterinary Teaching Hospital is believed to be an ideal educational place to showcase water resources engineering for visitors during Engineering Days.

Multiple water resources goals are addressed in the design. By applying the National Green Values Calculator, the added green infrastructure (vegetated buffers and bioswale) is calculated to create a 23.3% reduction in runoff depth from the existing condition for a 10-year storm event. Also, our new design is estimated to have a 38% reduction in stormwater peak flow (as determined by assessing the differences in runoff coefficients as applied to the rational formula), and 1.76 in of annual groundwater recharge (calculated by applying runoff coefficients to annual rainfall data). Under Colorado Water Law, water harvesting and water reuse are illegal for individuals without an appropriate permit. (Colorado Division of Water Resources)

CLIMATE RESILIENCY

The James L. Voss Veterinary Teaching Hospital, Diagnostic Medical Center, and other facilities in the College of Veterinary Medicine and Biomedical Sciences (CVMBS) located on Colorado State University's south campus is covered under the university's main campus general Stormwater Discharges Associated with Non-Standard Municipal Separate Storm Sewer

Systems (MS4s) permit. Colorado Department of Public Health and Environment (CDPHE) regulates MS4 permits based on the Colorado Water Quality Control Act and the Federal Water Pollution Control Act. Currently at Colorado State's south campus, there is a grassy channel that carries stormwater runoff from the site to Spring Creek. This grassy channel is comparable to a grass swale, but the channel sides are too steep for proper treatment. Colorado State's south campus has a wide array of stormwater runoff pollutants. Because Colorado State is in an urban area with an expansion project that proposes more impervious surfaces, pollutants from automobiles such as oil, grease, salt, etc. are a prominent contaminant. In addition, there are several animal pens that are on property which contribute nitrogen and phosphorus. During rain events stormwater reaches the channel from over 38 acres of Colorado State's south campus. Climate change poses the risk of increased frequency and magnitude of storms, this grassy channel or swale will not be able to remove pollutants that may be discharged from the site. This increased stormwater runoff, caused by both urban development and climate change needs to be more resilient to prepare for such events.

The proposed bioswale, detention ponds, and vegetated buffers will increase resiliency to Colorado's State's south campus by reducing stormwater runoff by 23.3% and decreasing the peak flow rate by 38%. By increasing vegetation and preparing detention ponds, there will be an increase of over 50% of pollutant loads from the new design. In addition, instead of using a 1-year, 24-hour design storm to calculate stormwater runoff, a 100-year storm was used to account for the unpredictability of climate change (EPA, Grassed Swales 2014). By over designing by today's standards, the bioswale is more resilient for the future and magnified storm events. A bioswale is a stormwater management technique that will build resiliency to the site as shown by the performance rates of the technology. This increased vegetation will not only provide aesthetic value to Colorado State's south campus, but also build the resiliency of the site.

MAINTENANCE PLAN

Due to the large number of new plants required by the bioswale, there will need to be considerably more maintenance around the area than what currently exists. Colorado State University Facilities protocol ensures that there will be a scheduled maintenance on the area once every year. However, considering the density of plants in the area and its function as an educational tool, there will need to be more maintenance of the bioswale than what facilities would generally cover. To combat this problem, the bioswale can be integrated into Colorado State University's annual Fall Clean-Up event, where student volunteers perform landscaping tasks for the local community. This would also increase student interest and enhance the bioswale's desired educational value. Table 3 covers an example two-year maintenance plan for the bioswale. (Minimal treatments such as mowing grass are expected to take place on a more routine basis outside of the one-year maintenance plan set by facilities.)

Table 3. Proposed maintenance plan

Date	Maintenance	Crew
March 2017	Trimming shrubs, weeding, trash pick-up	CSU Facilities Employees
October 2017	Raking leaves, weeding, trash pick-up, removal of excess sediment deposits	CSU Fall Clean-Up volunteers
March 2018	Trimming shrubs, weeding, trash pick-up	CSU Facilities Employees
October 2018	Raking leaves, weeding, trash pick-up, addition of new plantings	CSU Fall Clean-Up volunteers

INNOVATION AND VALUE TO CAMPUS

Colorado State University's south campus is located along Bay Road in Fort Collins and is adjacent to the City's Mason corridor bus route, MAX, and Mason Bike Trail which increases visibility to members of the community and CSU students, faculty, and staff. The development of the bioswale, vegetated buffer, and detention ponds would provide atheistic upgrades to the community bikers along the Mason Bike Trail. Since Fort Collins is a platinum biking community, there is a significant amount of biker traffic next to CSU's south campus, which will be improved as seen in Figure 5. As noted in Figure 6, there is no aesthetic appeal to the current design for pedestrians. Implementing the meandering bioswale, vegetative buffers, and detention ponds the community and CSU affiliates will be able to enjoy an increase of 6.2 acres of native plant communities, as seen in Figure 4. The proposed bioswale will increase plant diversity by 19 species and pollinator diversity by 9 species, as seen in Table 2. In addition, groundwater recharge will be increased by 1.76 inches per year from the bioswale.

Figure 5. Cross-Section View of Bioswale Next to Mason Bike Trail

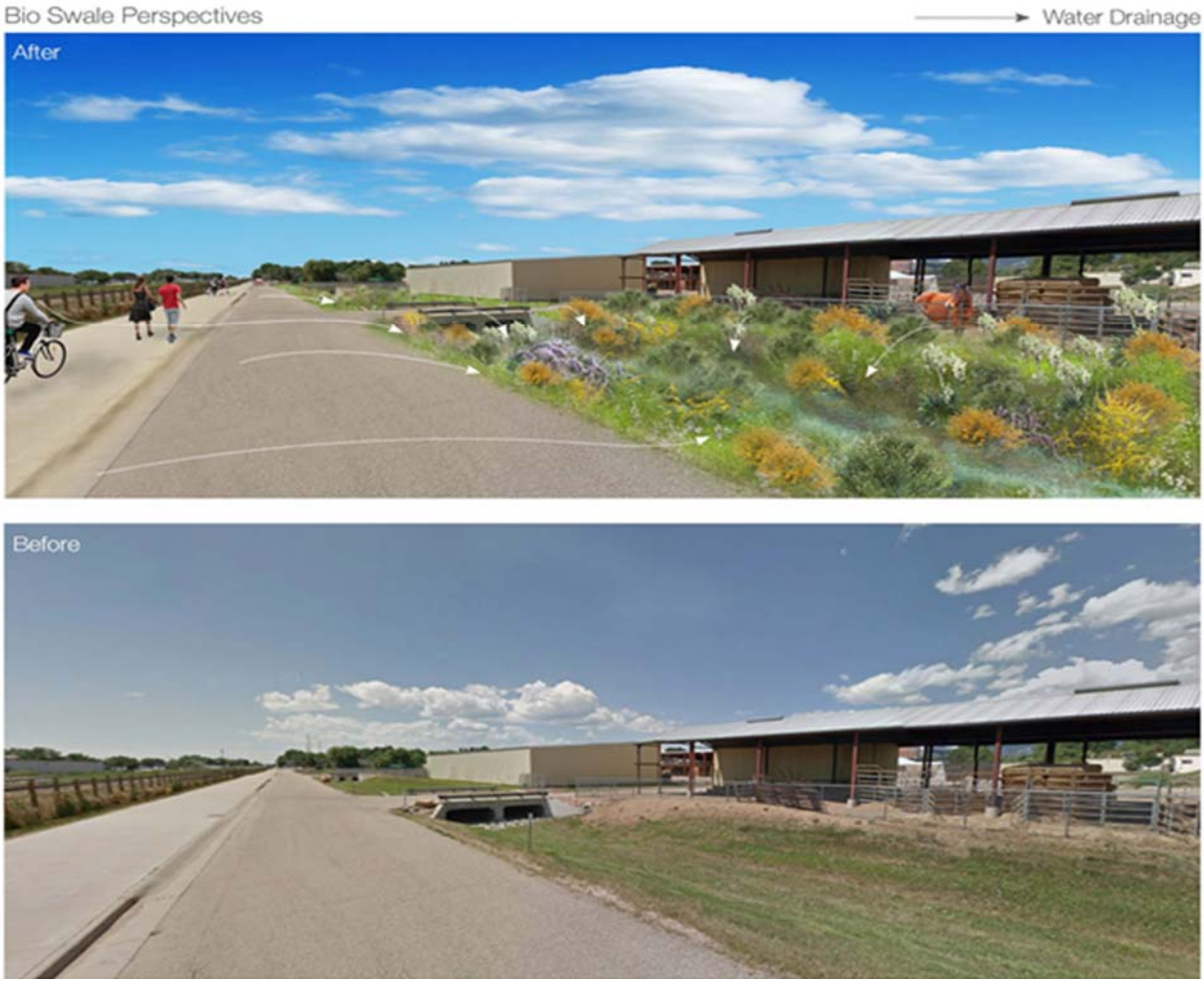


Figure 6. Before and After Implementation

As seen in Figure 7, along the bioswale, an educational trail will have signs conveying the importance of green infrastructure and stormwater management. Because CSU's south campus is so close to pedestrian transportation, like the MAX bus and Mason Bike Trail, an addition of Colorado native plants will be accepted by community. With the expansion of CSU's south campus, funding has been set aside by CSU's Facility's Management to increase the stormwater management capacity at the south campus. Because addition facilities, like an equine teaching hospital, will increase both the imperviousness and number of animals on the site, CSU recognizes the need to improve stormwater management on south campus (Physical Development Master Plan "Road Map for the 21st Century" 2014). CSU Facilities has already contacted their stormwater master planning consulting to review stormwater conditions for the expansion project. CSU is dedicated to improving the stormwater conditions at south campus because CSU is a land grant university and aims to set standards for the community on innovative green infrastructure (Physical Development Master Plan "Road Map for the 21st Century" 2014). The implementation of the bioswale, vegetated buffers, and detention ponds will not only be accepted by the community, but also the CSU campus. Economic objects have not been solidified, so Green Innovators estimated costs based on native plants and local hardware stores.

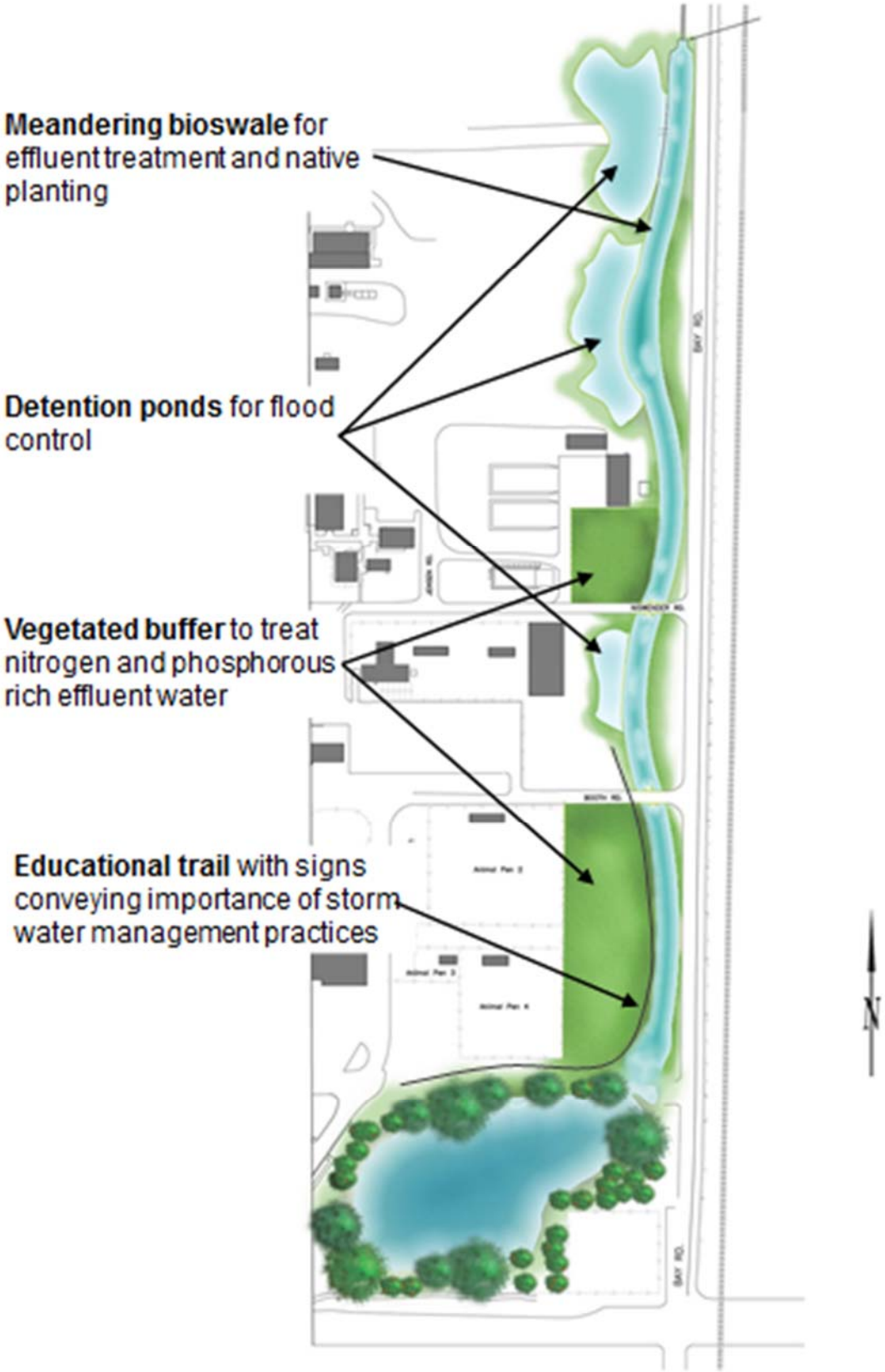


Figure 7. Outline of Proposed Design

COST ANALYSIS

Table 3. Estimated Cost of Project Implementation

Material	Cost per Unit	Number		Cumulative Cost
Sorghum Sundangrass Seeds	$64.95 per 50 lb	40	lb	$ 51.96
Blue Gamma Seeds	$117.00 per 5lb	120	lb	$ 2,808.00
Native Shrubs	$50.00 per plant	50	plants	$ 2,500.00
Soil and Compost	$25 per y^3	500	y^3	$ 12,500
Gravel	$0.25 per ft^2	30,000	Ft^2	$ 7,500.00
Washed rock	$38 per yard	50	Yard	$ 1,900.00
Excavation (includes labor)	$0.15 per ft^2	78,750	Ft^2	$ 11,812.50
		Total Estimated Cost:		$ 39,072.46

CONCLUSION

Veterinary Teaching Hospital: Revitalizing Natural Treatment is believed to be the most feasible design option for stormwater management on CSU's South Campus. This multifaceted design offers an innovative solution to treat the stormwater runoff from a complex area. The Veterinary Teaching Hospital contains elements of both urban runoff and agricultural runoff. The meandering bioswale, vegetated buffers, and detention ponds are all specifically designed to treat the unique runoff from this area. Implementing better stormwater management practices was identified as one of the many problems to address in the 2014 Colorado State University Master Plan. This Master Plan established that the Veterinary Teaching Hospital is within the Spring Creek drainage and little to no water quality infrastructure is currently in place. As another part to the CSU master plan, the Veterinary Teaching Hospital is planned to receive new buildings, roads, and other facilities (CSU 2014). With the implementation of new facilities, additional precautions must be made to storm water management. According to the CSU Facilities Department, Olsson Associates was contracted to evaluate the stormwater impacts of the proposed new layout of South Campus. In August of 2015, the evaluation revealed that four detention ponds should be implemented for better stormwater management.

We believe that with the addition of vegetated buffers and a meandering bioswale, this project will take on a new light. Not only will the design meet the stormwater management needs of the area, but it will also add aesthetic, educational, and recreational opportunities in a cost effective way. Overall, our design is estimated to cost just under $40,000 as seen in Table 5. Because funding has already been established for this project area, the addition of our design features would only benefit the design and offer aesthetically pleasing solutions to an existing proposal.

REFERENCES

Camp Laura (2010). Feeding Frenzy-Manzanita and Friends. *California Native Plant Society.*

Castelle, A. J., A. W. Johnson, and C. Conolly (1994). Wetland and Stream Buffer Size Requirements—A Review. *Journal of Environment Quality* 23.5: 878.

Colorado Division of Water Resources. (n.d.). *Rainwater, Graywater, and Stormwater.* Retrieved from http://water.state.co.us/SurfaceWater/SWRights/Pages/RainwaterGraywater.aspx

Colorado Water Conservation Board. (2015). *Colorado climate plan: state level policies and strategies to mitigate and adapt*. Retrieved from http://cwcbweblink.state.co.us/WebLink/ElectronicFile.aspx?docid=196541&searchid=243b8969-739b-448c-bd2d-699af9b7aea0&dbid=0

Department of Natural Resources and Parks (2009). King County, Washington Surface Water Design Manual. Seattle, WA.

Dillaha, T.A., J.H. Sherrard, D. Lee, S. Mostaghimi, and V.O. Shanholz (1988). Evaluation of vegetative filter strips as a best management practice for for feed lots. *Journal of Water Pollution Control Fed.* 60(7): 1231-1238.

Extension (2013). Plants for Water Wise Pollinator Gardens: Catmint (Nepeta faassinii and hybrids) N. x fassenii, N. mussinii. *eXtension.org*.

Garden Mentors (2012). Agastache - A Pollinator Magnet.

Grismer, Mark E., Anthony T. O'Green, and David Lewisn (2006). Vegetative Filter Strips for Nonpoint Source Pollution Control in Agriculture. *University of California Division of Agriculture and Natural Resources*. Publication 8195.

Groves, W. W., P. E. Hammer, K. L. Knutsen, S. M. Ryan, and R. A. Schlipf (2010). Analysis of Bioswale Efficiency for Treating Surface Runoff. *University of California, Santa Barbara* 1-174.

Hickenlooper, John W., King, Mike, and Wolfe, Dick (2011). Administrative Approach for Storm Water Management. *Division of Water Resources.*

Hunt, William F., and Nancy White (2001). Designing Rain Gardens. *Urban Waterways Stormwater Publication Files*. North Carolina State University.

Jurries, Dennis (2003). BIOFILTERS (Bioswales, Vegetative Buffers, & Constructed Wetlands) For Storm Water Discharge Pollution Removal. *Department of Environmental Quality*. State of Oregon.

Kline, Katie (2011). Pollination from the plant's perspective. *Ecological Society of American.*

Knight, R.L., Payne, V.W.E., Borer, R.E., Clarke, R.A., and Pries, J.H. (2000). Constructed wetlands for livestock wastewater management. *Ecological Engineering, 15*, 41-55.

Lebuhn, Gretchen; Anderson, Gregory J. (1994). Anther tripping and pollen dispensing in Berberis thunbergii. The American Midland Naturalist. 131(2): 257-265. [65336]

Mazer, Greg, Derek Booth, and Kern Ewing (2001). Limitations to Vegetation Establishment and Growth in Biofiltration Swales*. Ecological Engineering* 17.4, 429-43. doi: TU984.18

National Stormwater Management Calculator. (2009). *Green values: Lot information*. Retrieved from http://greenvalues.cnt.org/national/calculator.php

New Jersey Stormwater Best Management Practices Manual. (2004). *Chapter 9.9: Standard for sand filters.* Retreived from http://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.9.pdf

Nilsen, Erik Tallak (2000). Spartium junceum L. In: Bossard, Carla C.; Randall, John M.; Hoshovsky, Marc C., eds. Invasive plants of California's wildlands. Berkeley, CA: University of California Press: 306-309. [53172]

Northern Water's Conservation Gardens (2014). Xeriscape Plaza Plant List

Peck, Alison (2015). Pollinators Paradise Garden. *Center for ReSource Conservation.*

Physical Development Master Plan "Road Map for the 21st Century" (2014). *Colorado State University.*

Proctor, M., Yeo, P. & Lack, A. (1996). *The Natural History of Pollination. Timber Press,* Portland, OR. ISBN: 0-88192-352-4.

Richard B. Alexander, Richard A. Smith, Gregory E. Schwarz, Elizabeth W. Boyer, Jacqueline V. Nolan, John W. Brakebill (2008). Differences in Phosphorus and Nitrogen Delivery to The Gulf ofMexico from the Mississippi River Basin. *Environmental Science and Technology.* 42, 822–830. doi: 10.1021/es0716103

Stoner, Nancy (2011). Working in Partnership with States to Address Phosphorus and Nitrogen Pollution through Use of a Framework for State Nutrient Reductions. *United State Environmental Protection Agency, Office of Water*. Washington, D.C.

Urban Drainage and Flood Control District (2011). Stormwater Management and Planning. *Urban Storm Drainage Criteria Manual* 3, 1-17. *Fort Collins Government*. Stormwater Criteria.

USDA. "Technical Release 55." *Urban Hydrology for Small Watersheds (1986).*

United State Environmental Protection Agency (2014). Grassed Swales.*Water: Best Management Practices*. Washignton, D.C.

United State Environmental Protection Agency (2009). Surface Water Design Manual. Seattle, WA: Division.

United State Environmental Protection Agency (2014). U.S. Environmental Protection Agency: Climate Change Adaptation Plan. Washignton, D.C.

Vandersande, Matthew W., Edward P. Glenn, and James L. Walworth (2001). Tolerance of Five Riparian Plants from the Lower Colorado River to Salinity Drought and Inundation. *Journal of Arid Environments* 49, 147-59. doi:10.1006/jare.2001.0839

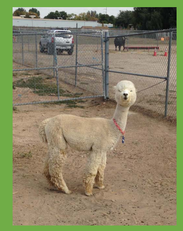
Whealen, Kate & Sperlich, Betty (2013). Pollinator Plant of the Month. *Santa Fe Master Gardener Association.*

Wolfe, Dick and Grantham, Joseph (2011). Synopsis of Colorado Water Law. *Colorado Division of Water Resources: Department of Natural Resources.* Denver, Colorado.

Young, R. A., Terry Huntrods, and Wayne Anderson (1980). Effectiveness of Vegetated Buffer Strips in Controlling Pollution from Feedlot Runoff. *Journal of Environment Quality* 9; 483-487

REVITALIZING NATURAL TREATMENT

HARVESTING RESILIENCY AT COLORADO STATE UNIVERSITY'S VETERINARY TEACHING HOSPITAL. . . . . REGISTRATION NUMBER D40



PROBLEM:

GOALS AND OBJECTIVES:

- Implement biologic **treatment** of effluent runoff from animal pens
- Increase biodiversity through **native planting**
- Provide **educational** opportunities emphasizing the importance of storm water treatment
- Enhance **aesthetic appeal** through design complexity and diversity
- Improve project resiliency through designing for **100 year** storm event

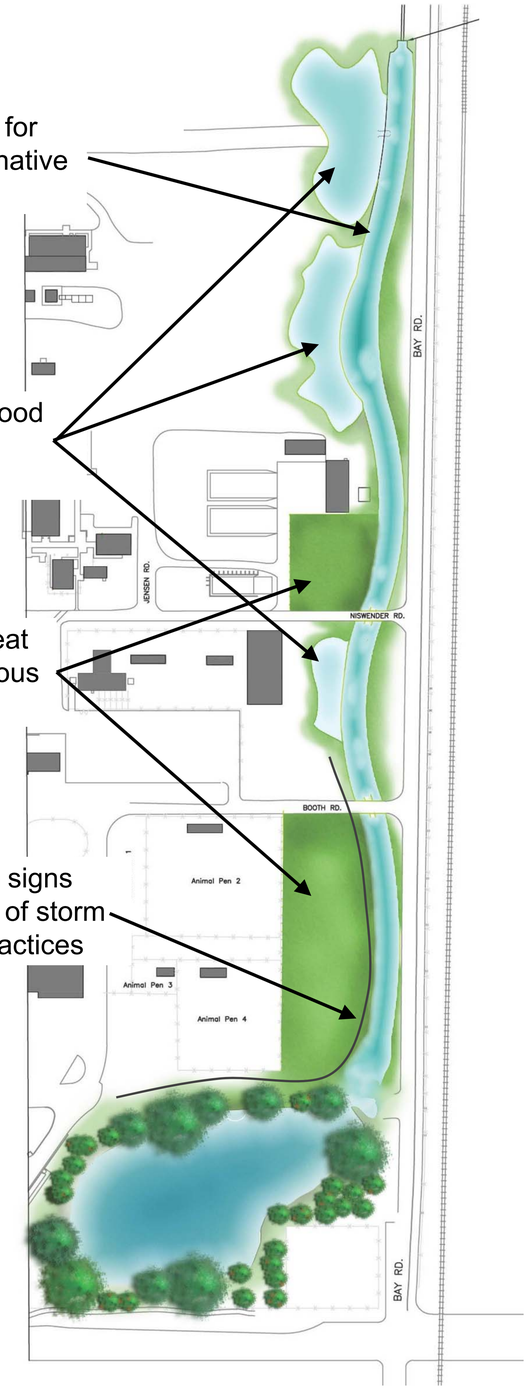
SOLUTION:

Meandering bioswale for effluent treatment and native planting

Detention ponds for flood control

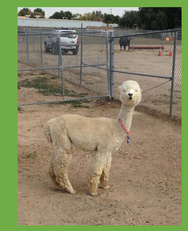
Vegetated buffer to treat nitrogen and phosphorous rich effluent water

Educational trail with signs conveying importance of storm water management practices



REVITALIZING NATURAL TREATMENT

HARVESTING RESILIENCY AT COLORADO STATE UNIVERSITY'S VETERINARY TEACHING HOSPITAL. . . . . REGISTRATION NUMBER D40

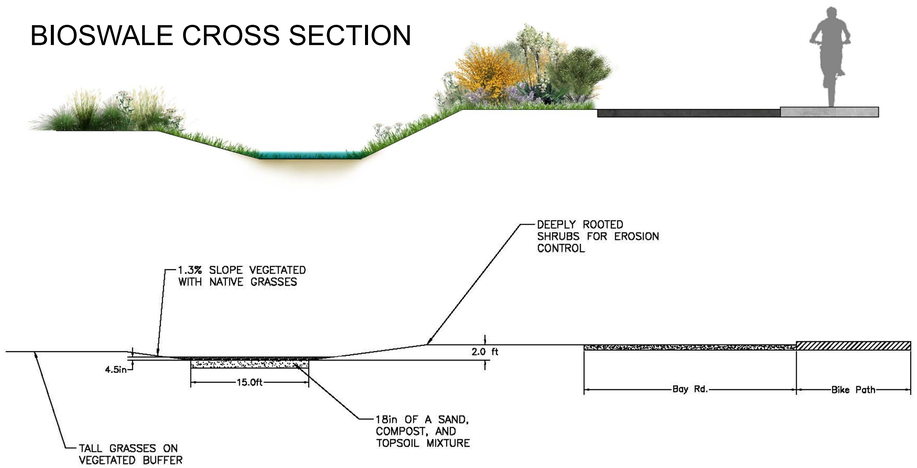


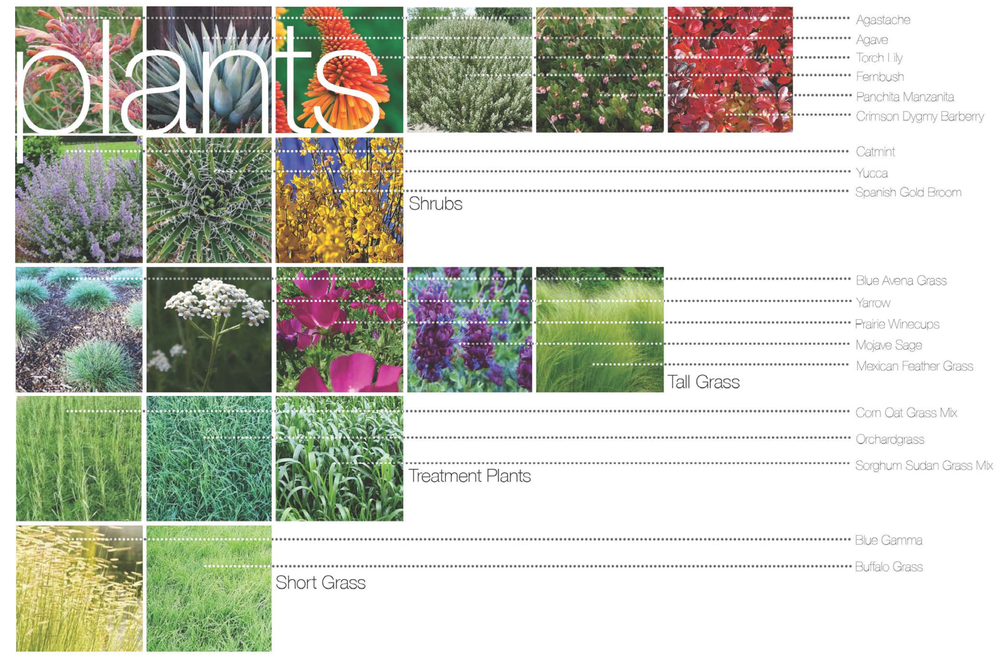
BENEFITS:

- Reduce **runoff depth** and decrease total runoff by 23%
- Reduce peak storm flow by 38%
- Reduce annual storm water **pollutant load** by more than 50%
- Increase annual **groundwater recharge** by 1.76 in/yr
- Restore **6.2 acres** to native plant communities
- Increase **plant diversity** by 19 species and **pollinator diversity** by 9 species

DESIGN DETAILS:

BIOSWALE CROSS SECTION





Bio Swale Perspectives — Water Drainage

PROFILE