Investigating the Effect of Bioswales on Water Quality and Flooding in Shoal Creek Watershed, Austin, TX

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Introduction

Shoal Creek, as an urban watershed with low flow and 55% impervious cover, has experienced rapid development in recent years, and therefore is extremely flood-prone and susceptible to water quality issues. Millions of dollars have been spent on various green infrastructures, such as rain gardens, infiltration-based bioswales, and permeable pavements, as well as flood mitigation projects. In particular, in the Allandale neighborhood in the northern half of the watershed, there is a 2013 City of Austin project to implement two swales along Shoal Creek. These swales were built by excavating small pools at the end of storm pipes, lining the bottom with large rock and vegetating with native plants. Swales have great potential in collecting, holding, and infiltrating water that contains sediment and dissolved pollutants. Retaining water allows for gradual introduction into the creek, feeding it more naturally.

Research Question & Hypothesis

Do swales on Shoal Creek have a measurable positive impact on water quality and flow rates by retaining and infiltrating stormwater during rainfall events?

Infiltration-based swales on the Shoal Creek watershed can impact water quality and flow rates during rainfall events.

Objective

Investigate hydrological and water quality effects of bioswales during rainfall events using the Shoal Creek Allandale project as an example. We expected that during a rainfall event, the swales would retain, absorb, and infiltrate water, mitigating the flood impact and improving the water quality of the creek.

Materials & Methods

Water quality and hydrology analysis using historical datasets

We statistically characterized City of Austin water quality test results since 1994 at 7 selected sites in the Shoal Creek and Bear Creek watersheds. Analyses included:

- Narrowing test parameters from hundreds available to conductivity, turbidity, and *E. coli*.
- Systematic quality differences between sites and watersheds
- Trend analysis
- Pre-/post- analysis using Allandale bioswale construction dates

We then connected this data to NOAA Camp Mabry rainfall data and 3 USGS flow gages on Shoal Creek and Bear Creek dating back to 2007. These investigations focused on differences in discharge and depth responses to rainfall between the more developed, less vegetated Shoal Creek watershed and the more natural Bear Creek watershed, as well as an attempt to connect water quality to hydrology.

Runoff, retention, and infiltration analysis

We also gathered geospatial data for soil, impervious cover, digital elevation, and the municipal stormwater network. This enabled us to calculate the full channel network, sub-basins, and runoff direction of the stream channels along with the impervious cover percentage and soil hydrologic group of the catchment area that feeds the swales. Additionally, by dividing the catchment inlets into Voronoi Polygons, we were able to estimate the runoff volume that could flow into each inlet and swale and the maximum rainfall depth.

Field sample collection and testing

Using field data collection software we then mapped out sampling locations in the study area and were able to input the water quality measurements digitally in the field and the lab. We collected water samples from bioswale intakes, retention pools, storm sewer and upstream, midstream, and downstream creek locations, before, during, and after the April 20th rainfall event. Field data was also collected by measuring the swale channel segments in order to determine their maximum discharge and volume capacity.

Effects on water quality:

Testing of *E. coli*:

- Test fecal coliform (specifically, *E. coli*) & general coliform by using Coliscan Easygel:
  - Collect water samples from different study sites in sterile containers and keep them on ice.
  - Transfer the water samples into the bottles of Coliscan Easygel.
  - Pour 5 mL of the inoculum mixtures into labeled petri dishes.
  - Incubate the petri dishes at 35°C (95°F) for 24 hours.

Testing of Conductivity:

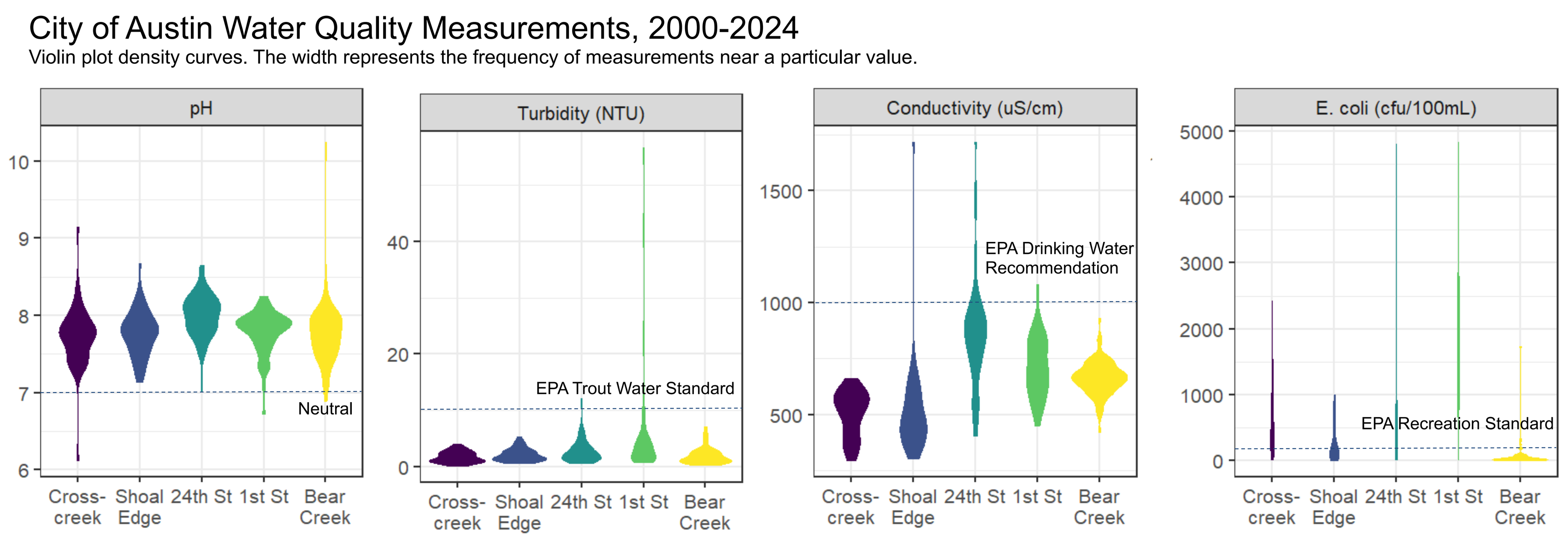
- Determine the conductivity of the water samples by using a probe and multimeter.

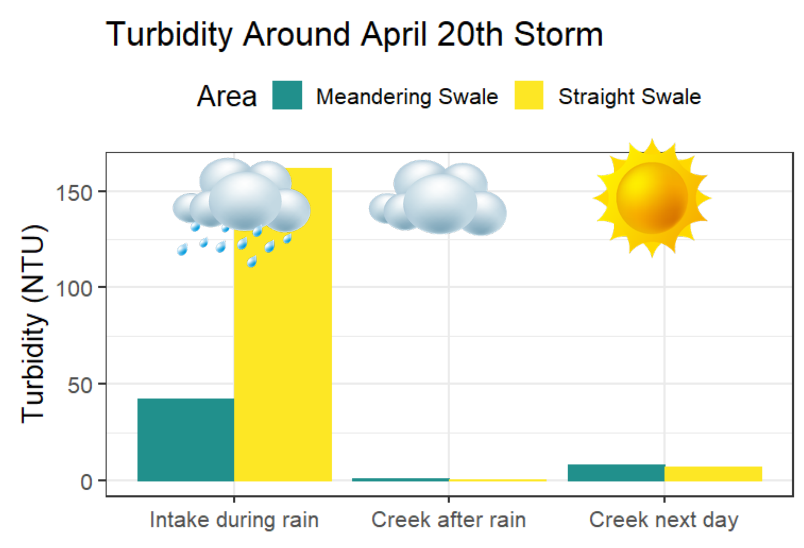
Testing of Turbidity:

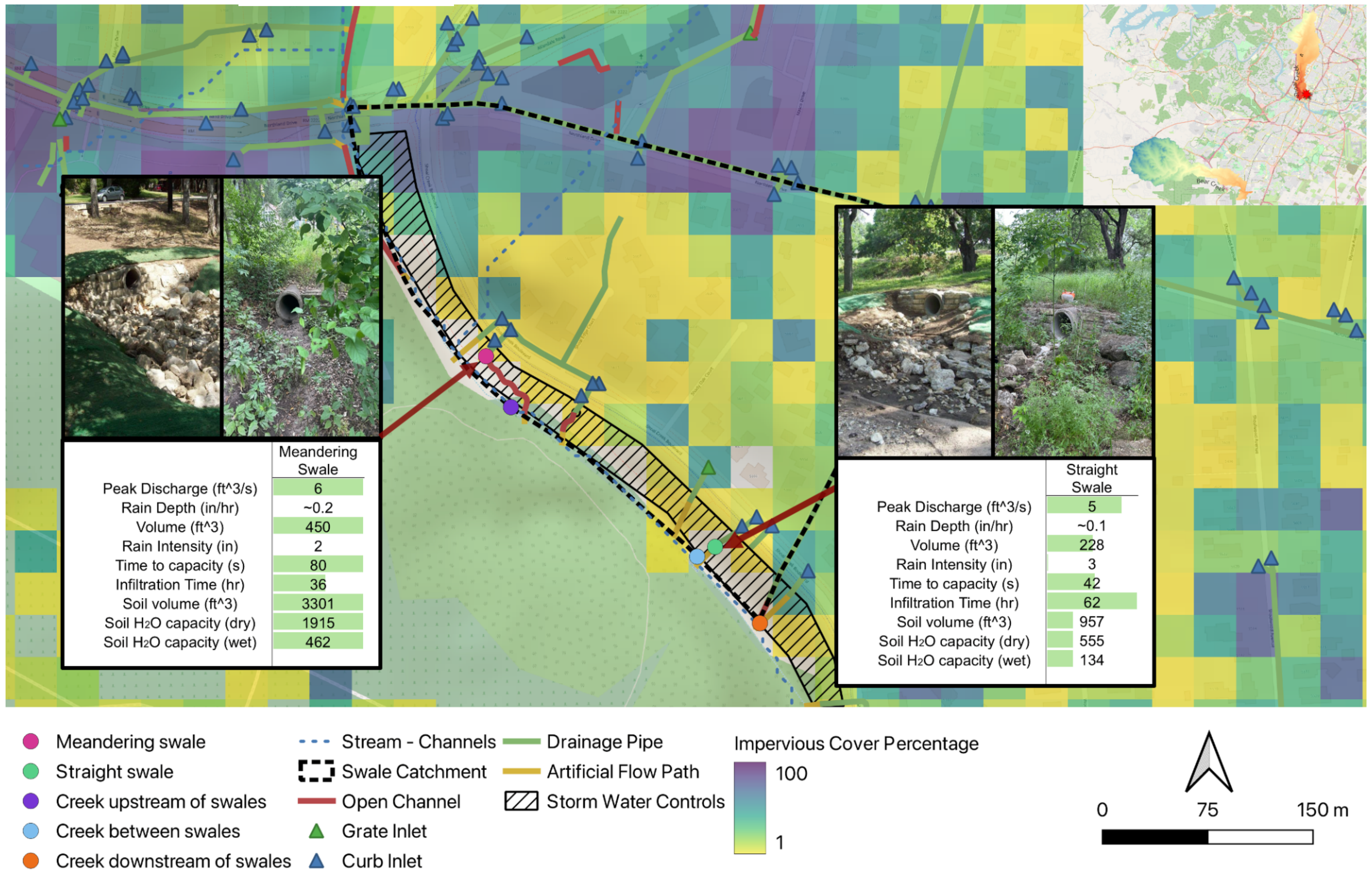
- Determine the turbidity of the water samples by using a spectrophotometer.

Limitations and Extensions

- Overall water quality measurements are difficult to decipher and restoration projects like the Shoal Creek swales are not conducive to controlled experiments.
- There are various difficulties in testing and measuring green infrastructure, particularly infiltration bioswales, since their outputs are diffuse and spread over time.
- Since Shoal Creek has many different water sources and storm drains, it would be challenging to isolate an overall impact on water quality from a single site.
- Lack of availability and consistency of historical measurements. Camp Mabry is the only reliable local rain gauge with hourly data; 5% of historical COA water quality samples were taken on days with rainfall; our field testing results used samples from one storm.
- Affordable water quality tests are imprecise. For example, we utilized Coliscan Easygel, a consumer-grade *E. Coli* test that accommodates a maximum of 5mL/sample. However, the IDEXX Colilert test with 100 mL of water sample is a scientific standard.
- We lacked a detailed 3D model of the bioswale area. In terms of stormwater runoff and discharge we would need a more precise elevation model of the sub-basins to calculate how much runoff could flow into each swale in a given precipitation storm.
- Gathering more precise data about soil composition would also allow us to further analyze infiltration rates and compare those to flow rates in each swale.



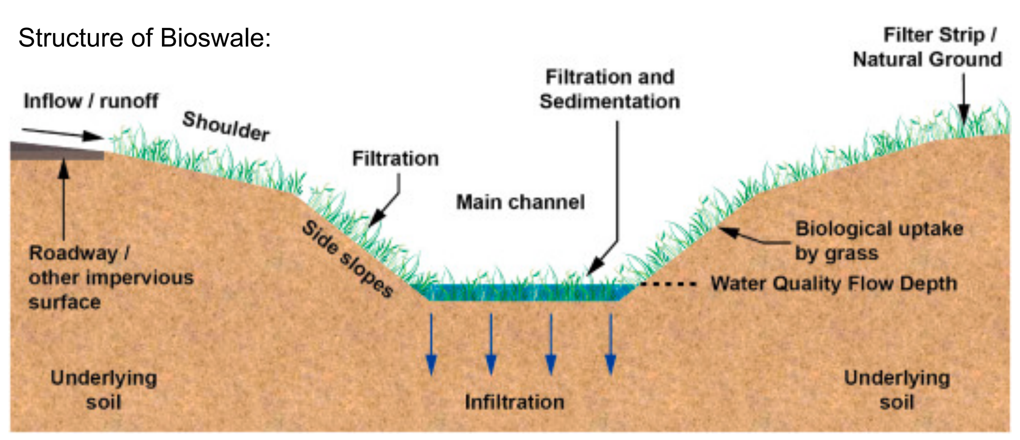




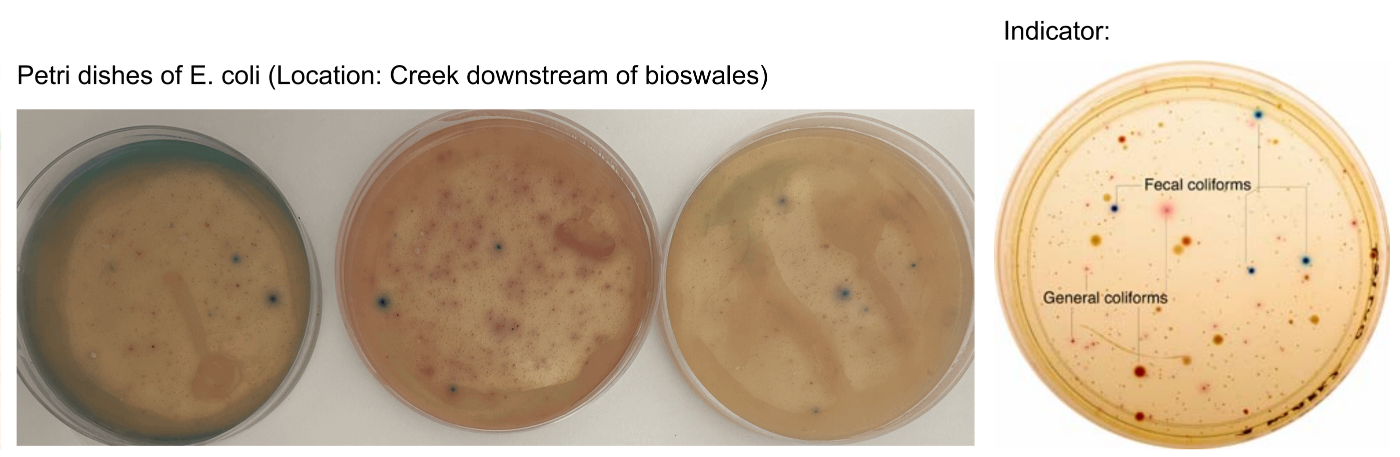
	Meandering Swale
Peak Discharge (ft^3/s)	6
Rain Depth (in/hr)	~0.2
Volume (ft^3)	450
Rain Intensity (in)	2
Time to capacity (s)	80
Infiltration Time (hr)	36
Soil volume (ft^3)	3301
Soil H_2O capacity (dry)	1915
Soil H_2O capacity (wet)	462

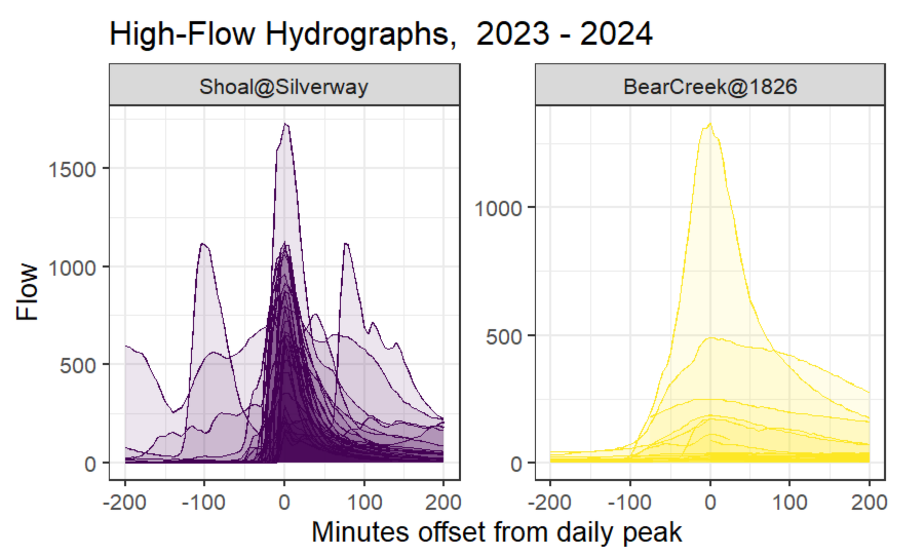
	Straight Swale
Peak Discharge (ft^3/s)	5
Rain Depth (in/hr)	~0.1
Volume (ft^3)	228
Rain Intensity (in)	3
Time to capacity (s)	42
Infiltration Time (hr)	62
Soil volume (ft^3)	957
Soil H_2O capacity (dry)	555
Soil H_2O capacity (wet)	134

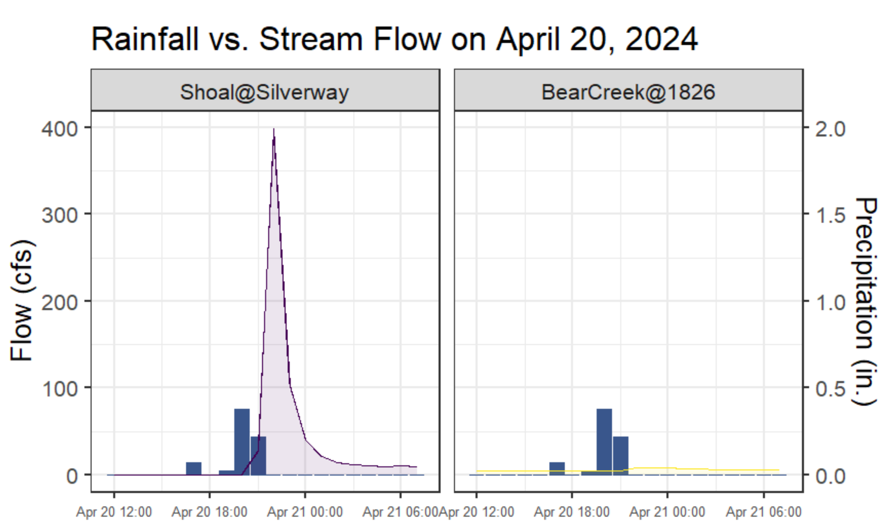
Structure of Bioswale:

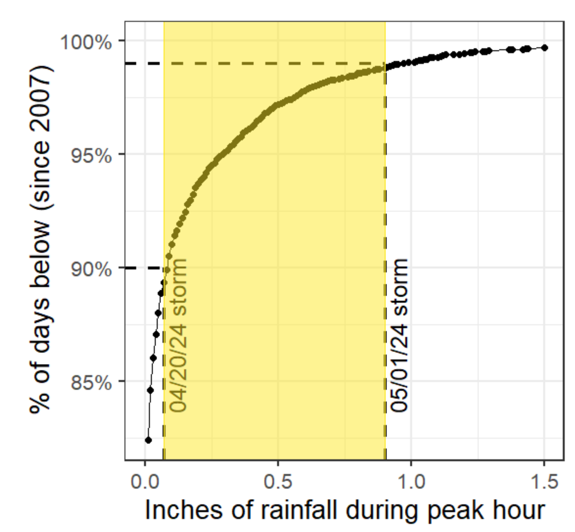


Petri dishes of E. coli (Location: Creek downstream of bioswales)









Results

Historical water quality data demonstrated that water quality measurements have a high variance between times and measurement locations. *E. coli* and turbidity measurements in Shoal Creek and Bear Creek have low medians but occasional extreme outliers. Because >95% of measurements were taken when Shoal Creek had a flow of <1 cfs, they may not characterize water quality during rainfall events. We did not identify any clear patterns or trends in water quality at the Shoal Edge location before and after the installation of the bioswales, and Bear Creek does not have obviously superior water quality to Shoal Creek.

Two significant rainfall events occurred during the project which illustrated the hydrological performance parameters of the swales. We observed 0.07" of rain in an hour on April 20th, which easily infiltrated; this exceeded roughly 50% of local rainfall events. On May 1st, a storm surpassed 95% of rainfall events. 1.62" of rain fell, including 0.9" in one hour. This overwhelmed the swales and flooded the creek to a depth of 7.5 feet. Standing water remained the next morning but continued to infiltrate into the Oakalla soil of the Meandering Swale at a rate of approximately 4" per hour.

Compared to Shoal Creek, Bear Creek has slower and less extreme hydrological responses to rainfall. This may be due to its significantly lower impervious cover and higher infiltration. Water samples collected during and after the April 20th storm showed that the turbidity of water infiltrating into the swales was significantly higher than the turbidity of the creek. However, there were no similar patterns in *E. coli* or conductivity test results.

Catchment and subcatchment rainfall and corresponding runoff generation to each swale

- Catchment: 20 acres, 25% impervious cover
- Meandering swale subcatchment: 5 acres, 9% impervious cover
- Straight swale subcatchment: 3 acres, 13% impervious cover

April 20th Storm at 5:51 pm: 0.07 inches of rainfall in 60 minutes

- Catchment: 1 ft³/s, 1,425 ft³ in total
- Meandering swale subcatchment: 0.2 ft³/s, 162.4 ft³ in total
- Straight swale subcatchment: 0.1 ft³/s, 126 ft³ total

April 20th Storm at 9:51 pm: 0.38 inches of rainfall in 60 minutes

- Catchment: 3 ft³/s, 4,480 ft³ in total
- Meandering swale:0.6 ft³/s, 511 ft³ in total
- Straight swale: 0.3 ft³/s, 395 ft³ total

May 1st Storm at 8:51 pm: 0.9 inches of rainfall in 60 minutes

- Catchment: 13 ft³/s, 18,328 ft³ in total
- Meandering swale: 2 ft³/s, 2,088 ft³ in total
- Straight swale: 1 ft³/s, 1,614 ft³ in total

1-year Recurrence Interval Storm: 1.61 inches of rainfall in 60 minutes

- Catchment: 23 ft³/s, 32,786 ft³ in total
- Meandering swale: 4 ft³/s, 3,736 ft³ in total
- Straight swale: 3 ft³/s, 2,888 ft³ in total

Conclusions

The Shoal Creek Allandale bioswales are capable of retaining and infiltrating the water from most local storms. The storm sewer water that feeds into the swales has a higher measured turbidity during light rainfall than the creek itself. On a larger scale, this attenuation and infiltration of rainwater may help the Shoal Creek watershed to resemble the less-flood-prone hydrology of the Bear Creek watershed. While there are many storm drains that could benefit from the addition of a swale, there is very little land available for this purpose. Our results shed light on the role that soils and plants can have in both cleaning water and mitigating flooding. Bioswales are a potential way to mitigate the negative effects of wide-spread impervious cover and the pollutants of human activities, such as road oils, dog poop, and trash. More infiltration systems like bioswales could be implemented in our city.

Future Research

- Measure flow, water quality and rainfall consistently in the same locations at the same times to see if more patterns emerge
- Measure the water quality parameters at more timing points after rainfall to ensure any impact is captured adequately
- Conduct a similar project in a more contaminated area, such as Little Shoal Creek
- Investigate the relationship between E. coli and native and/or invasive plants, like Elephant Ear, found in most of the bioswales.

References

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