Optimizing the Removal of Stormwater Pollutants in Small-scale Constructed Treatment Wetlands

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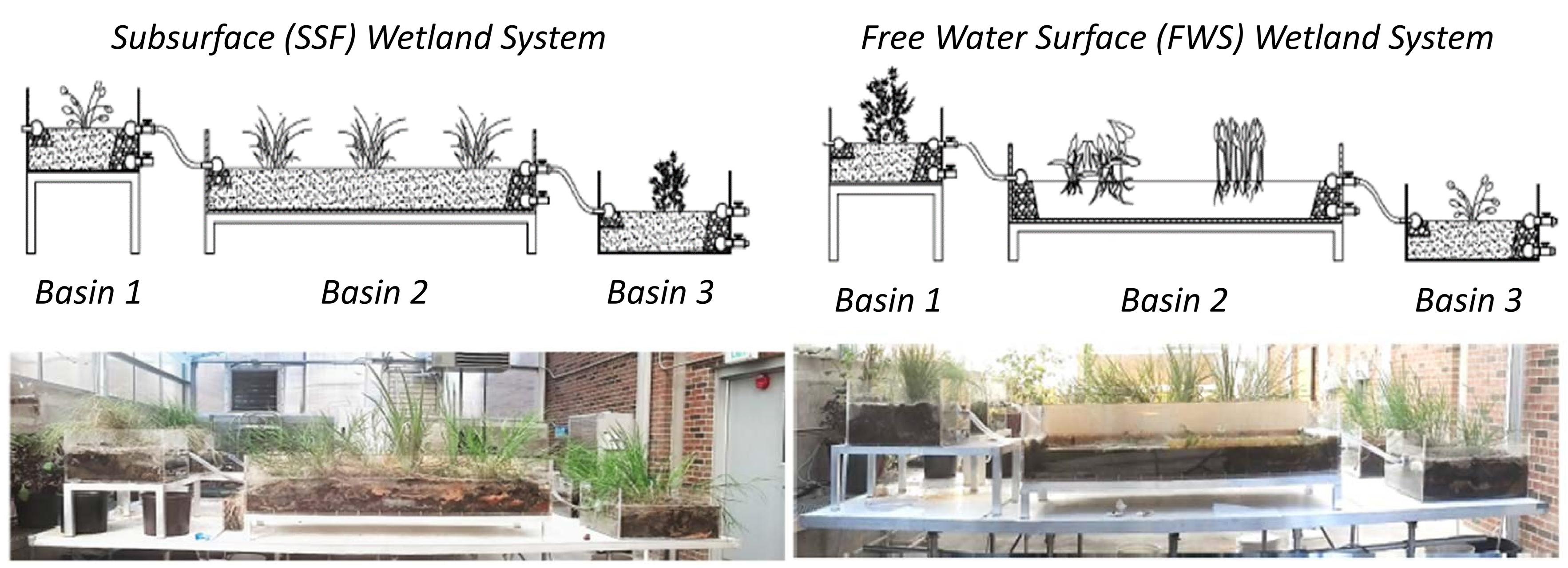
Objectives

- Optimize the hydraulics of the current wetland setups by developing a recycle line to increase retention time in the wetland
- Create artificial stormwater runoff
- Test removal of nitrate and turbidity in each wetland system

Wetland Set-up



Optimizing Hydraulics

We changed the wetland hydraulics to increase the retention time in order to optimize the efficiency of the treatment wetlands. We replaced a single reservoir and one pump with two separate reservoirs and two pumps that pump into the individual trains. By making this change, we were able to verify that the same amount of water was flowing into each of the two treatment wetland trains. We added two basins beneath the wetland setups in order to capture the water so that it was easily recycled through the wetlands. This modification required two additional pumps, extra connections, and tubing to make the recycled system work.

Creating Artificial Stormwater Runoff

We developed a recipe for artificial stormwater runoff so that testing would not be dependent on the weather. We collected stormwater runoff in order to mimic the turbidity and nitrate concentration. The stormwater runoff had a turbidity of 3.09 +/- 0.446 NTU and a nitrate concentration of 0.177 +/- 0.0000333 mg/L. Because the stormwater runoff was taken after several days of rain, we assumed the nitrate concentration to be diluted and used past nitrate concentration data in order to make the artificial stormwater runoff.

Artificial stormwater recipe: Nitrate

Total Nitrate Desired (mg/L)	Amount Tap Water (gal)	Multiplier Factor	KNO_3 to add (g)
3.0	25	10	1.21

Artificial stormwater recipe: ZIPP (turbidity)

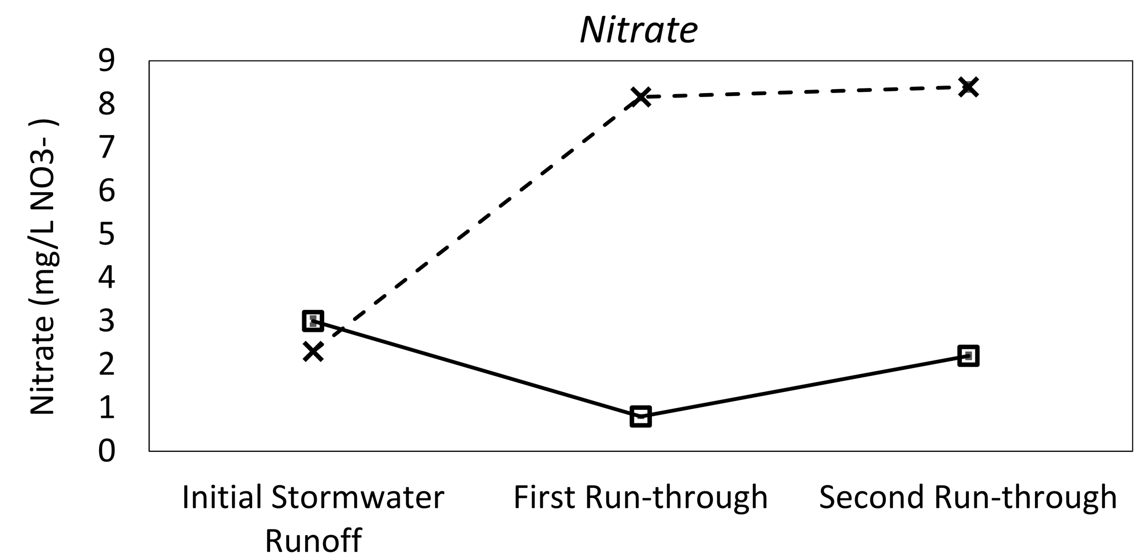
Turbidity Desired (NTU)	Amount Tap Water (gal)	Multiplier Factor	ZIPP to add (g)
3.5	25	5	8.04

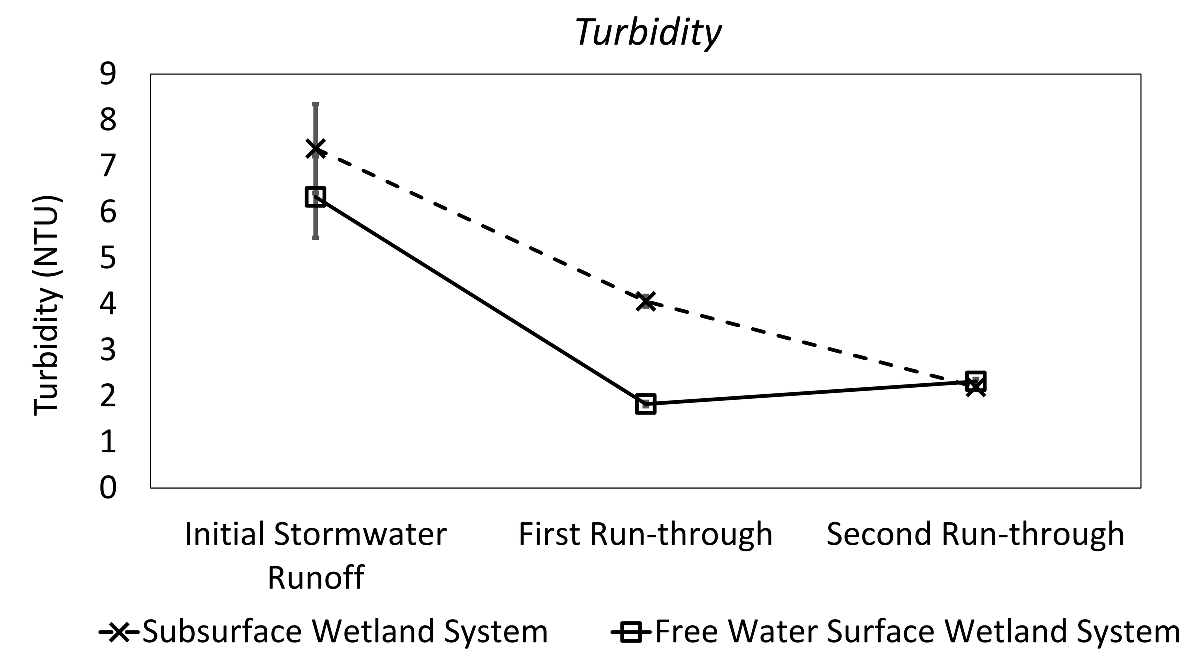
Results of Removing Nitrate and Turbidity

After completing the set-up of the wetland with the added recycle line and creating a formula for artificial stormwater, we performed a run-through of the two treatment wetlands. During these test, we measured the temperature, pH, nitrate concentration, and turbidity of the water. The temperature and pH remained generally constant throughout the wetland samples. The standard deviation shown in the error bars was low because the results are from one artificial stormwater test.

Abstract

By mimicking natural wetlands with constructed wetlands, we were able to use plants to absorb and break down stormwater pollutants. We used the two small-scale treatment wetlands in the Cook Laboratory for Bioscience Research to perform experiments to optimize the removal of stormwater pollutants. Past studies has lead us to expect greater pollutant removal with a greater hydraulic retention time. In our project, to lengthen the retention time and test its effect, we recycled water that has gone through the wetland to different basins. Our findings indicated that the updated wetland setup is successful in providing a recycle line for treating the stormwater runoff. The values for removing nitrate and turbidity require future research in order to be confident with the values. This project provided insight on how to improve the efficiency and effectiveness of the two constructed wetlands. This information will be used to relate to a larger scale wetland to be put in place to filter stormwater.





SSF Wetland:

- retained 3/4 of the water pumped through it after one run-through
- increase of nitrogen when stormwater runoff filtered through
- strong removal of turbidity when stormwater runoff filtered through

FWS Wetland:

- retained 1/3 of the water pumped through it after one run-through
- decrease of nitrogen when stormwater runoff filtered through
- removal of turbidity when stormwater runoff filtered through

Comparing our wetlands to previously published work using published models

From previously published work, we were able to connect our work to a first-order steady flow design equation, the authors were able to relate hydraulic loading rate (q) to inlet concentration (C) (Carleton et al., 2001).

$$\frac{C}{C_i} = e^{-\frac{k_a}{q}}$$

k_a = "areal" rate constant [units of length over time]

Subsurface Wetland System Nitrate Removal

$C_i := 2.3$

$C := 8.4$ After second run-through

$q := \frac{104 \cdot 2}{6} \frac{in}{hr} \quad q = (7.719 \cdot 10^3) \frac{m}{yr}$

$\frac{8.4}{2.3} = e^{-\frac{k_a}{7.719 \cdot 10^3}}$

$k_a := -\ln\left(\frac{8.4}{2.3}\right) \cdot 7.719 \cdot 10^3 = -9.999 \cdot 10^3$ m/yr

Subsurface Wetland System Nitrate Removal

$C_i := 3.0$

$C := 2.2$ After second run-through

$q := \frac{104 \cdot 2}{6} \frac{in}{hr} \quad q = (7.719 \cdot 10^3) \frac{m}{yr}$

$\frac{2.2}{3.0} = e^{-\frac{k_a}{7.719 \cdot 10^3}}$

$k_a := -\ln\left(\frac{2.2}{3.0}\right) \cdot 7.719 \cdot 10^3 = 2.394 \cdot 10^3$ m/yr

The values for k_a range from 57.1 to -9.6 +/- 16.6 m/yr in previous studies, however our values differ by more than a factor of ten from the range presented in previous studies, leading us to believe that more tests must be performed in order to calculate the ideal retention time for a specified concentration removal.

Conclusions and Future Work

Our research has shown that the hydraulics of the treatment wetlands can greatly affect the success of run-throughs. From the new wetland setup, we found that the SSF wetland absorbs over half of the water that is pumped into the system. This is a beneficial quality of SSF wetlands because of their ability to absorb a large quantity of water for stormwater control. The turbidity decrease for the SSF wetland show the strongest correlation with reduced turbidity for each run-through.

Because much of our research consisted of the setup of the treatment wetlands, it is important to continue testing in order to build on our data. Future testing should involve testing the removal of turbidity and nitrate in order to build on the research from other sources as well. Further use of the equation from previously published work would be very useful in comparing results with other wetland data.

References

Barten, J. M. (1987). "Stormwater runoff treatment in a wetland filter: effects on the water quality of clear lake." Lake and Resevoir Management, 3(1), 297-305.

Carleton, J., Grizzard, T., Godrej, A., and Post, H. (2001). "Factors affecting the performance of stormwater treatment wetlands." Water Research, 35(6), 1552–1562.

García, J., Aguirre, P., Barragán, J., Mujeriego, R., Matamoros, V., and Bayona, J. M. (2005). "Effect of key design parameters on the efficiency of horizontal subsurface flow constructed wetlands." Ecological Engineering, 25(4), 405–418.

Kadlec, R. H., and Wallace, S. D. (2009). Treatment wetlands. CRC Press, Boca Raton, FL.

Muller Price, J. S. (2015). "Providing Students with Hands-on Experience through the Construction of a Treatment Wetland. Paper presented at the 122nd American Society of Engineering Education Annual Conference and Exposition, Seattle, WA.

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