# ANALYZING SURFICIAL AND SUBSURFACE TRANSPORT OF SEDIMENTS AND NUTRIENTS USING TERRESTRIAL LIDAR SCANS AND HYDRUS 1D MODELS


VILLANOVA UNIVERSITY
COLLEGE OF ENGINEERING
CENTER FOR RESILIENT WATER SYSTEMS

Abdul-Rashid Zakaria[1], Virginia B Smith[1], Kristin Sample-Lord[1]

[1]Villanova University, Villanova, PA, USA



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Contact:
Abdul-Rashid Zakaria
E-Mail: azakaria@villanova.edu
zakjonr1@gmail.com
Tel.: +1 (484) 222-9042


## 1 PROJECT OVERVIEW

This study focuses on three rain gardens that have been in operation for more than a decade on the University's campus to investigate **distribution and accumulation of fines and nutrients** over time. The research program includes collection and analysis of soil samples, as well as numerical and spatial modeling.

**Soil core samples** were collected:

- over depths from 0 – 12 inches, at 5 – 6 locations at each site
- over 3 sampling periods

**Laboratory testing** was performed for:

- particle-size distribution, density, plasticity, organic content
- nutrient (nitrogen and phosphorus) concentrations

**Spatial and temporal analysis** utilized:

- GIS and Lidar surveys
- 1-D finite element flow & transport models (Hydrus 1-D)
- flow and morphodynamics analysis software (iRIC)

## 2 STUDY AREAS

| | |
|---|---|
| Bioinfiltration Traffic Island (BTI) | Designed for 1" storm and built in 2001. Drainage area ≈ 1.27 acres (50 % impervious, 50% pervious) |
| Fedigan Hall Retention (FR) & Infiltration (FI) Rain Gardens | Designed for 1" storm and built in 2009. 5:1 drainage to infiltration area, each covering one quarter of Fedigan Hall roof. FR constructed with impermeable liner. |

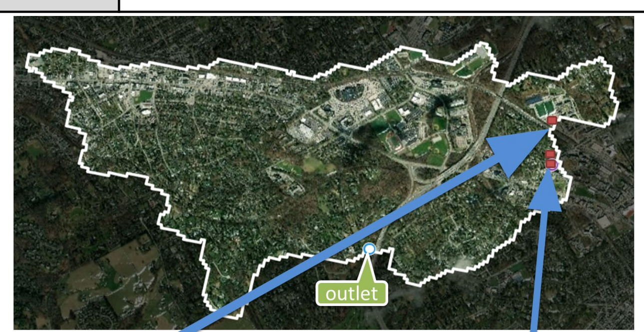


Figure 1. Watershed Containing Study Are, located in Villanova, PA (Wikiwatershed)

Figure 2. Bioinfiltration Traffic Island (BTI) Rain Garden

Figure 3. Fedigan Hall Retention (FR) and Infiltration (FI) Rain Gardens

## 3 NUTRIENTS AND FINES

Accumulation of fines and nutrients as orthophosphates and total nitrogen (TN) is generally concentrated in the first 0-4" of soil. Also, nutrients and fines concentrations are higher at the basin and outlet location of the BTI than the inlet location.

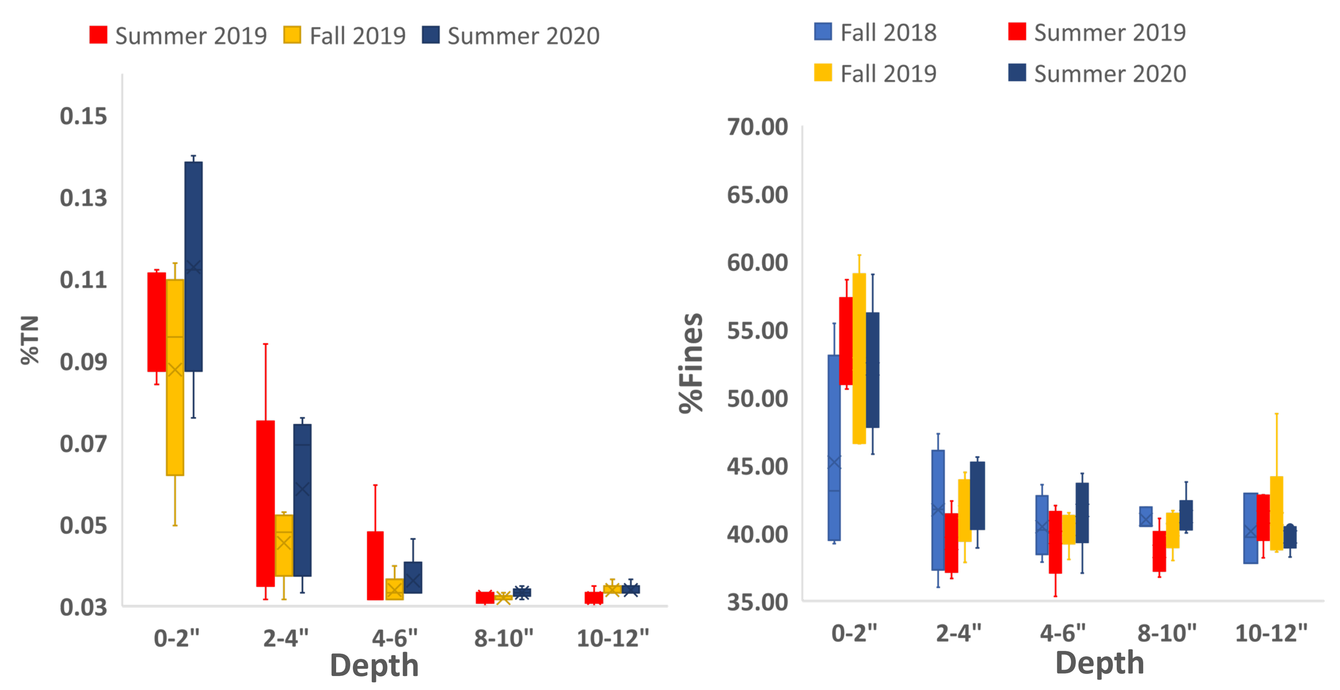


Figure 4. Variation in measured %TN and %Fines for BTI by depth.

## 4 LiDAR


Figure 5. NHERI Leica RTC 360 scanner

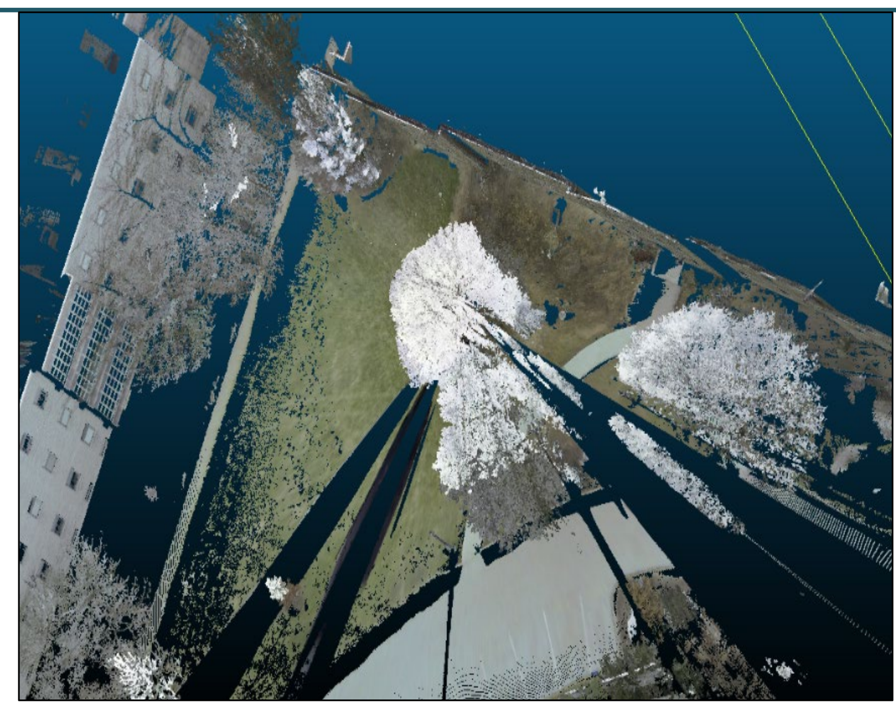


Figure 6. Preprocessing Cloud points with CloudCompare

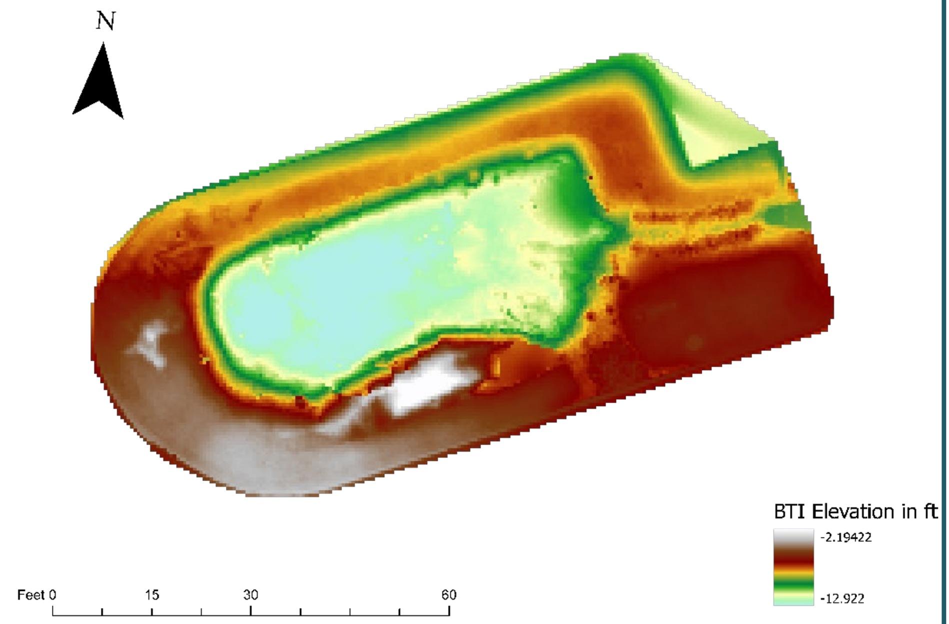


Figure 7. Digital Elevation model (DEM) of the BTI

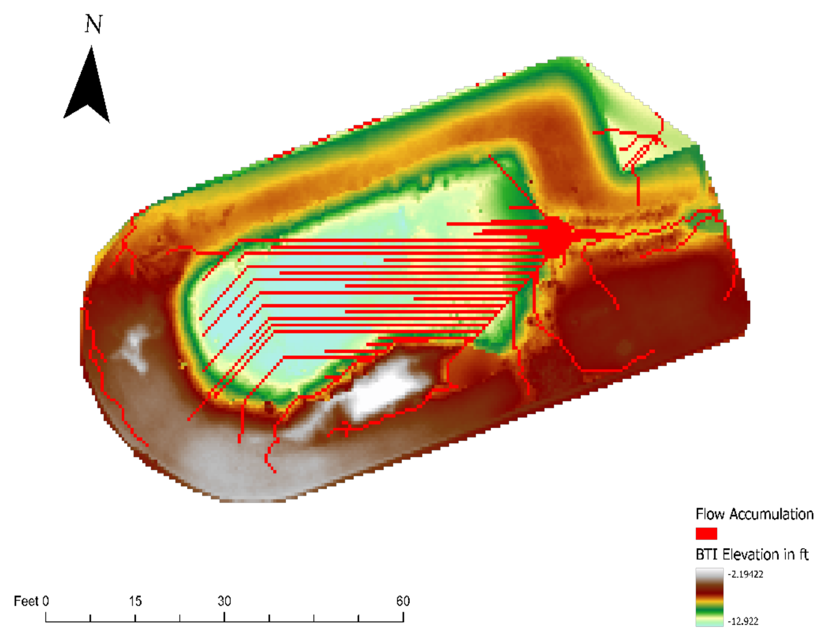


Figure 8. Flow accumulation lines of the BTI

A Lecia RTC 360 Lidar was used from the NSF funded NHERI program. This allowed us to generate a 3D point cloud of the GSI surface (Fig 5 and 6. The surface was cleaned (vegetation removed) and used to create a DEM (Fig. 7). The DEMs were then used to create slope maps (Fig. 9) and ultimately to generate flow lines within the GSI (Figure 8).

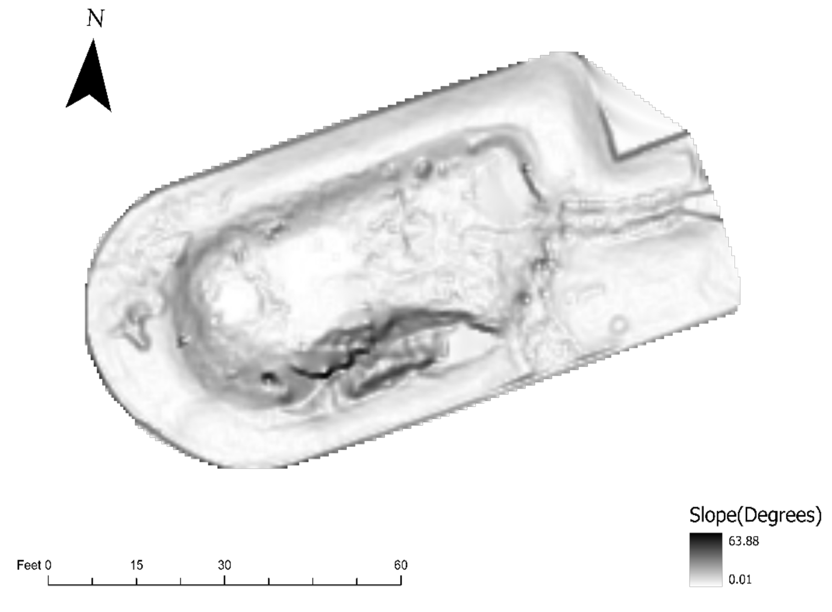


Figure 9. Slope raster of the BTI

## 5 SEDIMENT AND NUTRIENT TRANSPORT MODELS

### iRIC Model

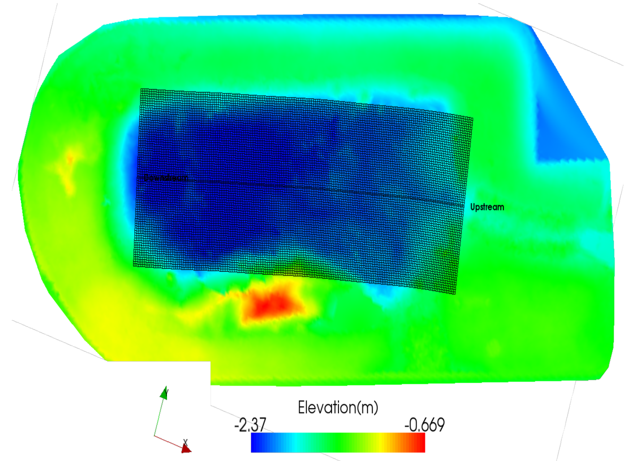


Figure 10. A BTI model using DEM using iRIC. The color scale shows elevation (derived from Lidar scans.

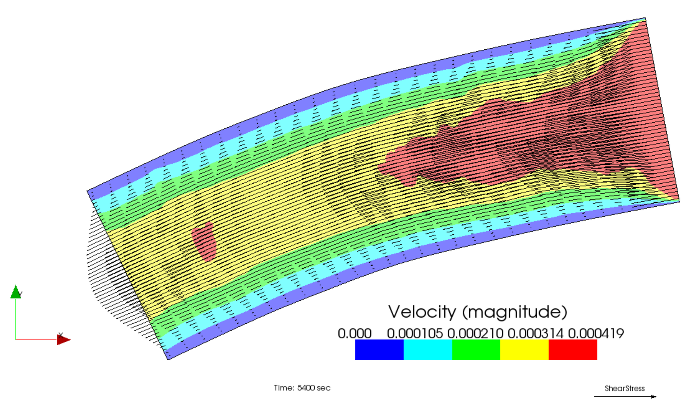


Figure 11. A sample velocity distribution from an iRIC simulation of a 2-year storm. The color scale represents velocity (warmer = higher).

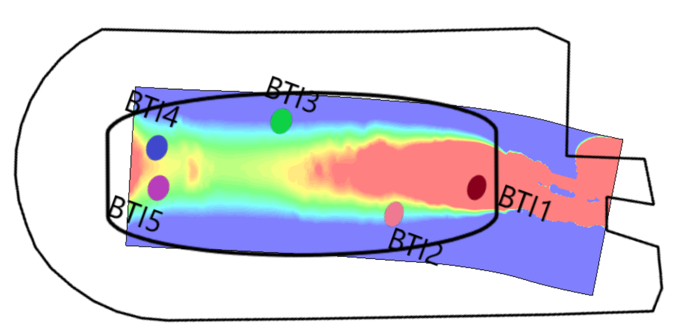


Figure 12. A shear stress distribution during a 2-year storm. from an iRIC simulation of a 2-year storm. The color scale represents shear stress (warmer = higher).

### Hydrus 1D Model

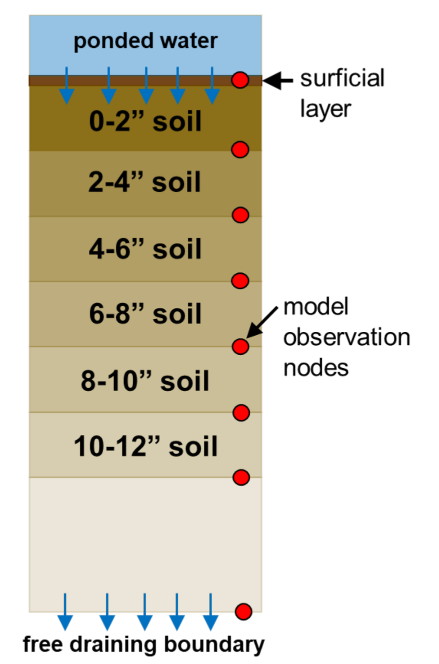


Figure 13. Conceptual image of Hydrus 1D model for the BTI. Models were developed based on the soil core results and then used to simulate infiltration, tracer transport, and reactive nutrient transport.

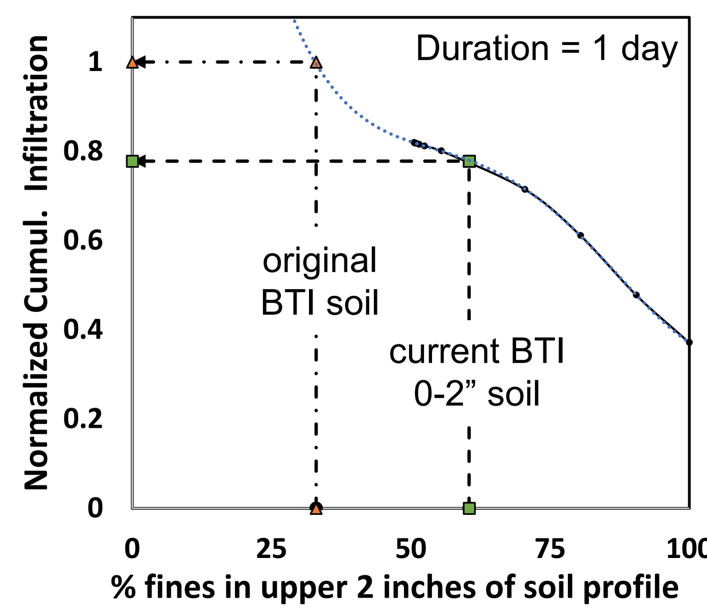


Figure 14. Example predicted cumulative infiltration results for BTI. For each point, the fines fraction in the upper 0-2" of soil in the model was incrementally increased.

## 6 RESULTS

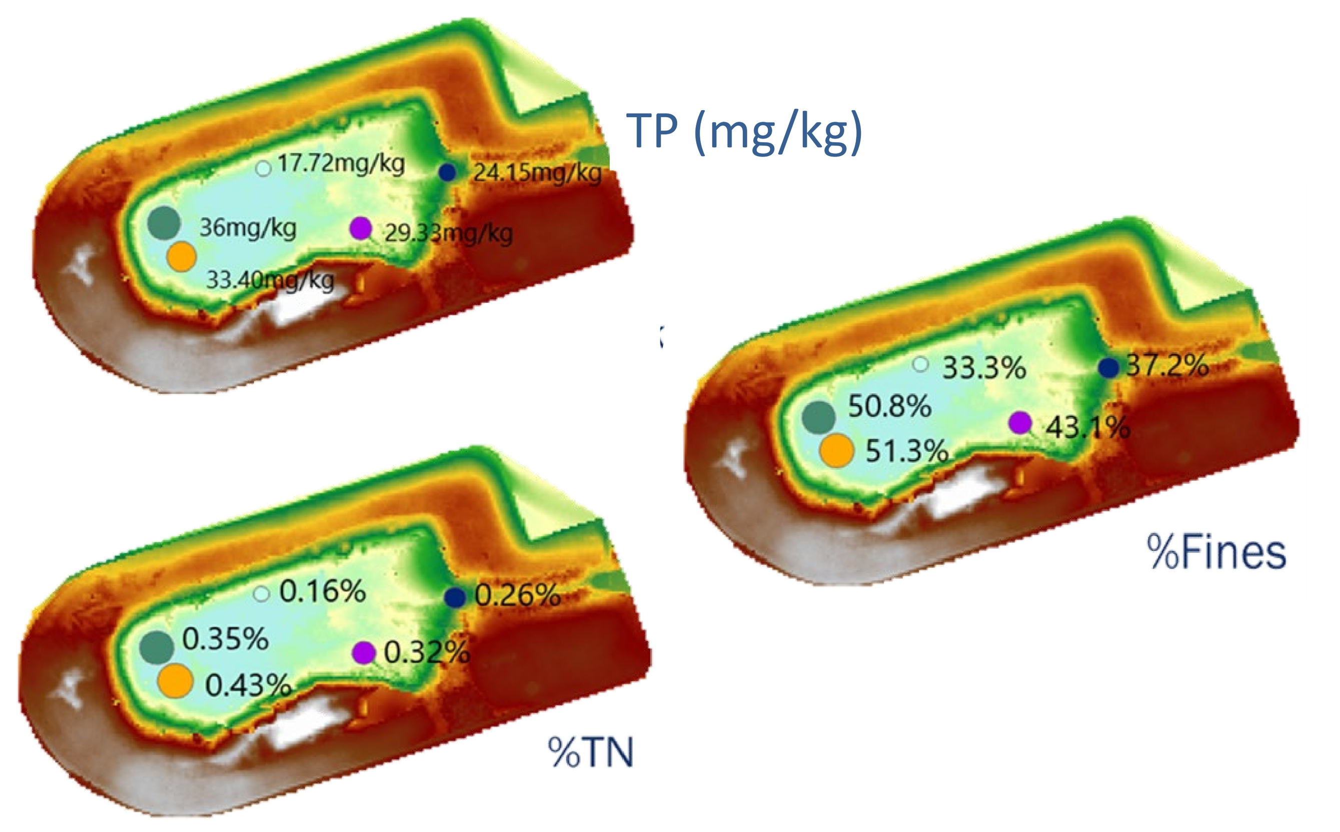
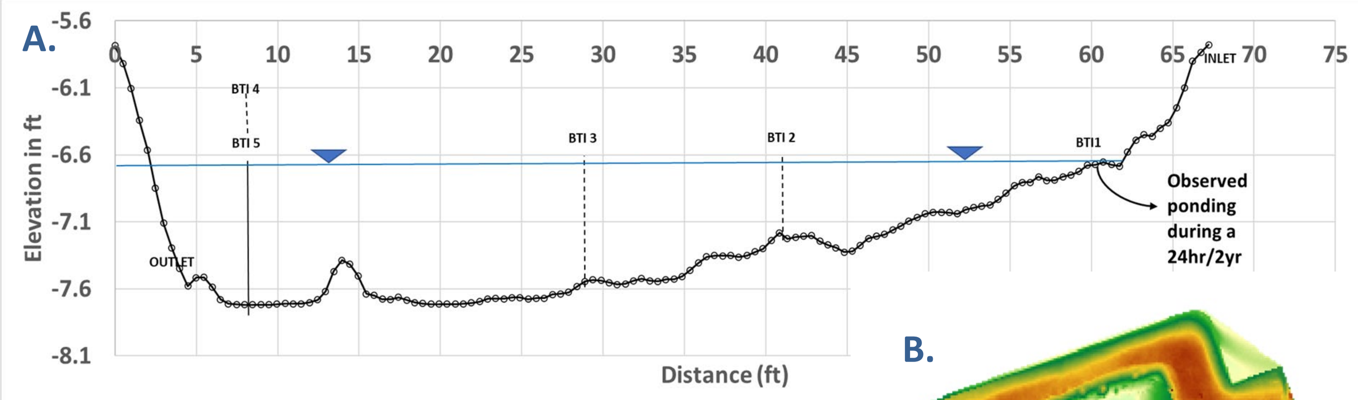


Figure 15. The spatial distribution of nutrients and fines in the BTI in the upper 4 inches of the soil. This spatial distribution was then aligned with models of shear stress and velocity. In locations experiencing higher shear stress or less frequent inundation there was less TP, TN, and fines.



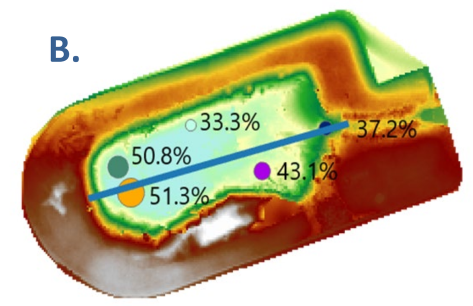



Figure 16. Image A shows the profile view along flow path from the inlet to the outlet of the BTI. Inset B shows the plan view of the profile taken.

## 7 CONCLUSIONS

- Sediments and nutrients accumulate more in areas of lower shear stress. Accumulation is typically limited to upper 4 inches of the soil.
- Areas of less frequent inundation show less accumulation of fines and nutrients.
- GSI layout impacts shear stress variations at the surface. These variations can be modeled.
- The limiting layer in infiltration of runoff in the rain garden is the upper 0-4 inch soil layer.
- The layout of the rain garden greatly affects the distribution and accumulation of nutrients and sediments in the rain garden.
- Proportion of fines dictates the infiltration and nutrient transport within the profile of a rain garden soil.

## 8 REFERENCES


1. Ramos, T. B., Šimůnek, J., Gonçalves, M. C., Martins, J. C., Prazeres, A., and Pereira, L. S. (2012). "Two-dimensional modeling of water and nitrogen fate from sweet sorghum irrigated with fresh and blended saline waters." *Agricultural Water Management*, 111, 87–104.
2. Komlos, J., and Traver, R. G. (2012). "Long-term Orthophosphate Removal in a Field-Scale Storm-Water Bioinfiltration Rain Garden." *Journal of Environmental Engineering*, 138(10), 991–998.



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