FDOT Stormwater Research Update

FDOT Water Quality Research Investments

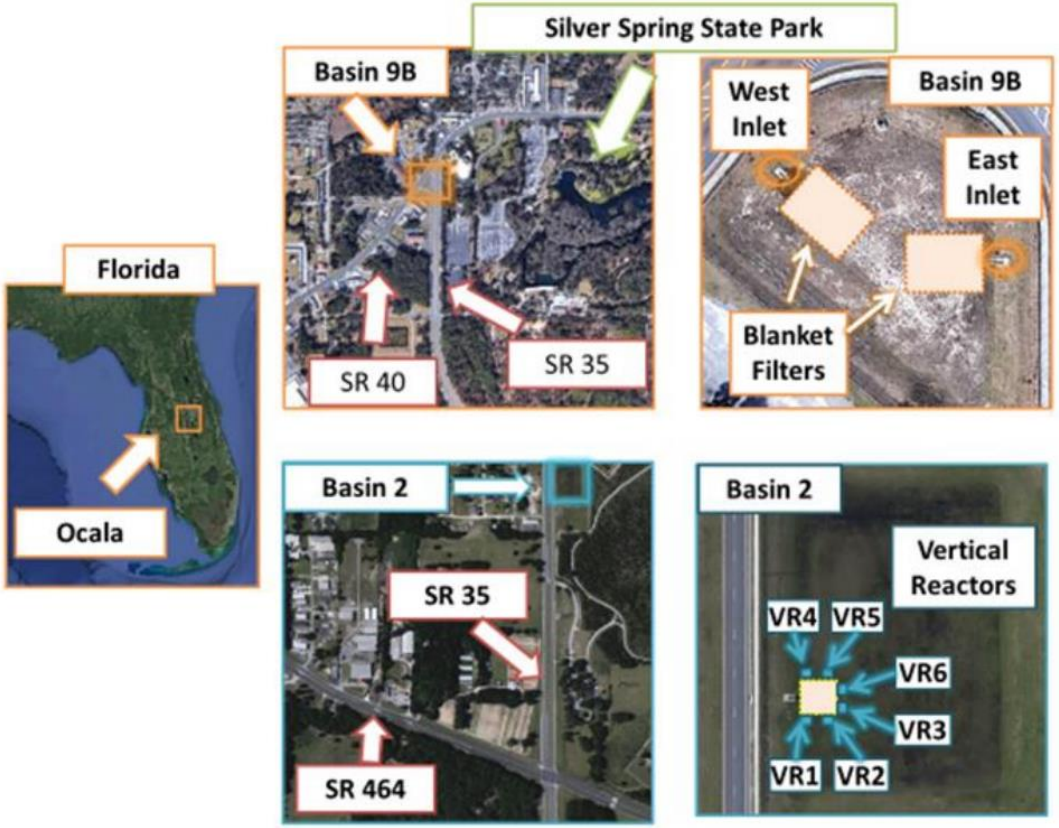
Year	Project Numb	Title	Cost	University	Researcher
2023	BDV24-977-	Design of Stormwater BMPs for Surface and Groundwater Protection Based on Site-Scale Soil Properties: Phase I	$ 407,409.00	University of Central Florida	Kibler
2022	BDV31-977-	Improving the Cost/Benefit Ratio of Impaired Stormwater Basins	$ 196,033.00	University of Florida	Sansalone
2021	BDV24-977-	Innovative and Integrative Best Management Practices (BMPs) for Surface and Groundwater Protection	$ 797,512.00	University of Central Florida	Kibler
2020	BDV24-977-	Optimal Design of Stormwater Basins with Bio-Sorption Activated Media (BAM) in Karst Environments - Phase II: Field Testing	$ 400,921.00	University of Central Florida	Kibler
2018	BDV24-977-	Comparative Nitrogen and Pesticide Removal with Sorption Media In Linear Ditch for Groundwater and Stormwater	$ 204,901.00	University of Central Florida	Chang
2017	BDV24-977-	Removal Effectiveness of Co-mingling Off-site Flows with FDOT Right-of-way Stormwater	$ 149,537.00	University of Central Florida	Chang
2015	BDV24-977-	Optimal Design of Stormwater Basins with Bio-sorption Activated Media (BAM) in Karst Environments-Phase I: Site Screening	$ 38,868.00	University of Central Florida	Chang
2014	BDK78-977-	Demonstration Bio Media for Ultra-urban Stormwater Treatment	$ 261,166.00	University of Central Florida	Wanielista
2014	BDK78-977-	Evaluation of Pollution Levels Due to the Use of Consumer Fertilizers under Florida Conditions: Examination of Lower Slopes	$ 103,170.00	University of Central Florida	Chopra
2013	BDK78-977-	Stormwater Harvesting Using Retention and In-Line Pipes for Treatment Consistent with the new Statewide Stormwater Rule	$ 364,121.00	University of Central Florida	Wanielista
2011	BDK78-977-	Evaluation of Pollution Levels Due to the Use of Consumer Fertilizers under Florida Conditions	$ 170,525.00	University of Central Florida	Chopra
2011	BDK78-977-	Pervious Pavements, Installation, Operation and Strength	$ 210,036.00	University of Central Florida	Chopra
2010	BDK78-977-	Inlet Protection Devices and their Effectiveness	$ 160,000.00	University of Central Florida	Wanielista
2010	BD521-04	Florida Manuals for Erosion and Sediment Control and the Creation of the Stormwater Management Academy Research and	$ 642,280.00	University of Central Florida	Wanielista
2008	BD545-55	Seasonal Variability of Near Surface Soil Water and Groundwater Tables in Florida -Phase II	$ 115,741.00	University of Florida	Hatfield
2010	BD521-05	Index Testing to Support the Stormwater Management Erosion and Sediment Control Laboratory	$ 100,032.00	University of Central Florida	Wanielista
2007	BD521-03	Regional Stormwater Irrigation Facilities	$ 181,546.00	University of Central Florida	Wanielista
2007	BD521-02	Performance Assessment of Portland Cement Pervious Pavements	$ 147,547.00	University of Central Florida	Wanielista
2005	BD521-01	Wekiva River Stormwater Management Manual of Practice	$ 496,500.00	University of Central Florida	Wanielista
	BKD78 985-01	Floating Treatment Wetlands	$ 80,523.00		
		Total	**$ 5,228,368.00**		

Outline

- **BDV24-977-20** - Optimal Design of Stormwater Basins with Bio-Sorption Activated Media (BAM) in Karst Environments – Phase II: Field Testing of BMPs (2020)
- **BDV24-977-25** - Innovative and Integrative Best Management Practices (BMPs) for Surface and Groundwater Protection (2021)
- **BDV24-977-43** - Design of Stormwater BMPs for Surface and Groundwater Protection Based on Site-Scale Soil Properties: Phase 1 (2023)
- **Future Research**

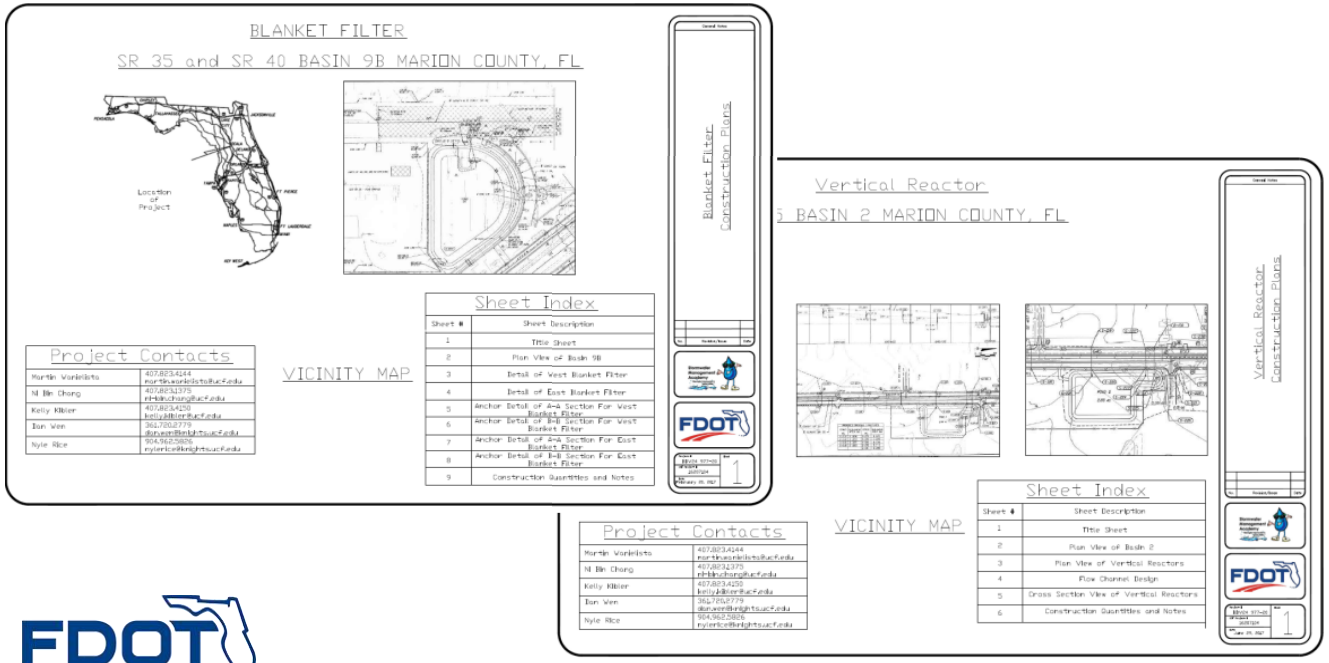
BDV24-977-20 - Introduction

- **Optimal Design of Stormwater Basins with Bio-Sorption Activated Media (BAM) in Karst Environments – Phase II: Field Testing of BMPs**
- **PI: Kelly Kibler, UCF**
- **Studied Bio-Activated Media**
  - Blanket Filters
  - Vertical Reactors
- **Installed and tested in Ocala, FL**

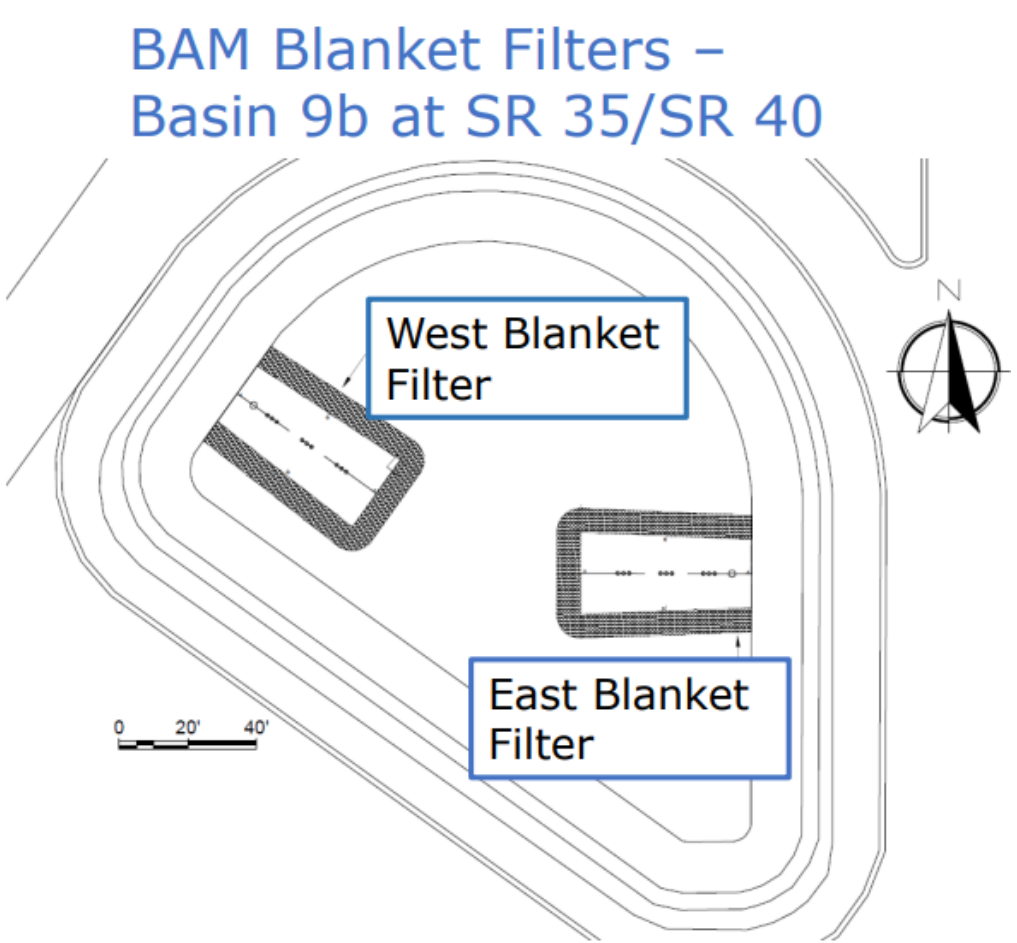


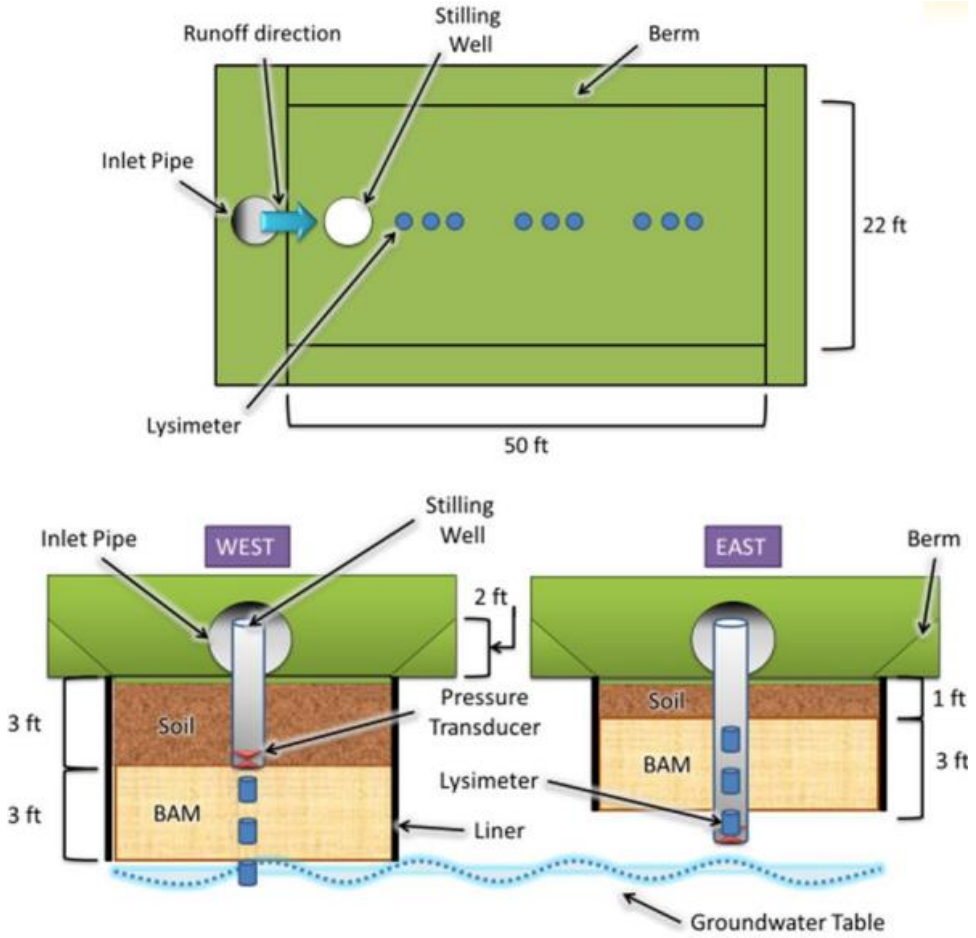
BDV24-977-20 - Objectives

- Design BMPs with Bio-Activated Media
- Assess nitrogen removal
- Understand costs and benefits over BMP design life



BDV24-977-20 – BMP Designs





BDV24-977-20 – BMP Construction

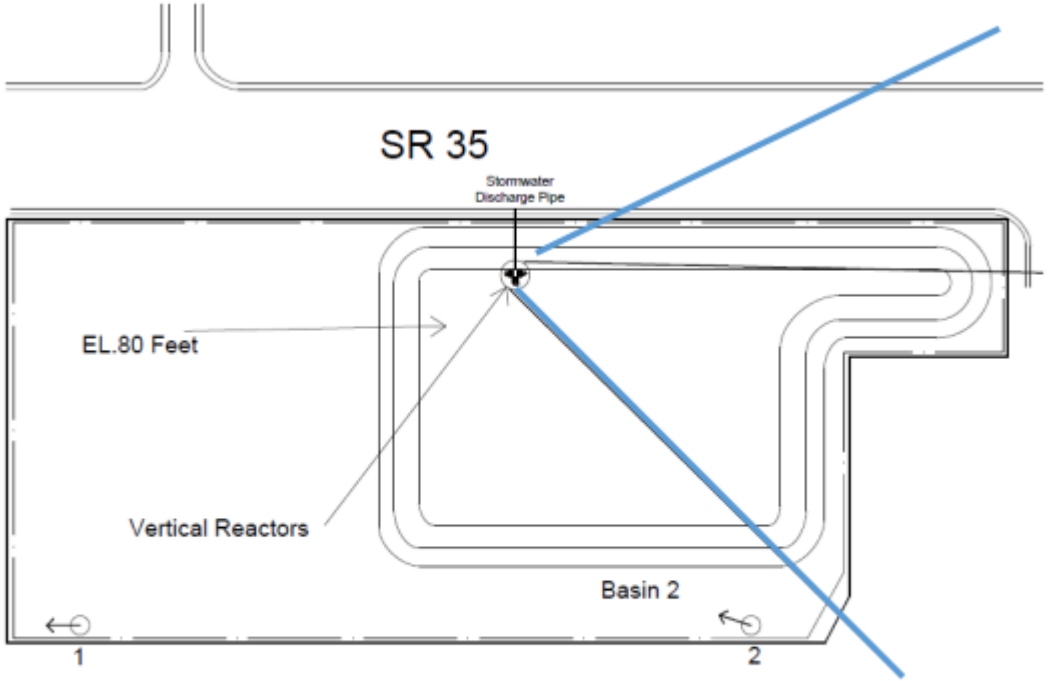
Blanket Filters, May 2017

Sampling equipment were embedded within media.

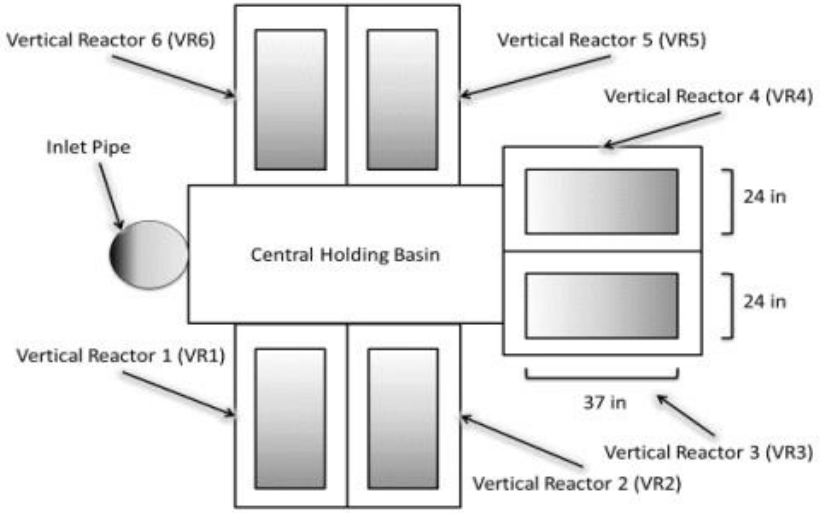
Placement of impermeable liner

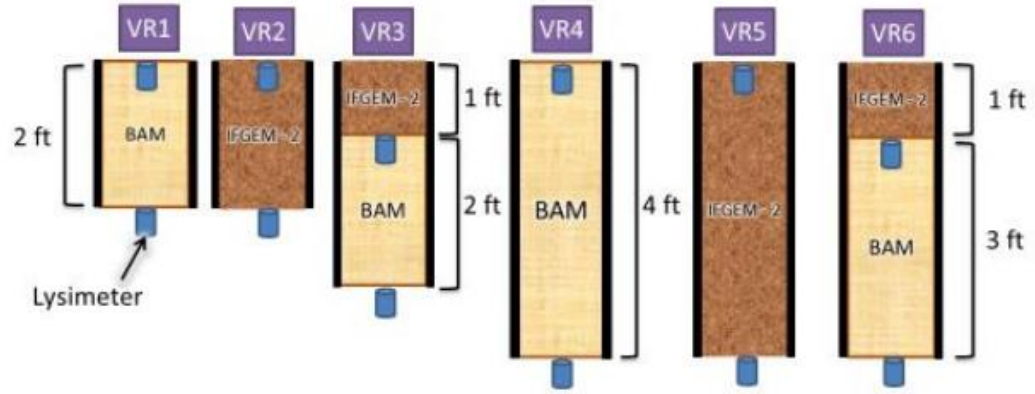
Completed blanket filter

BDV24-977-20 – BMP Designs



BAM Vertical Reactors–
Basin 2 off SR 35





BDV24-977-20 – Construction

Vertical Reactors, May 2017

Delivery and placement of vertical reactors

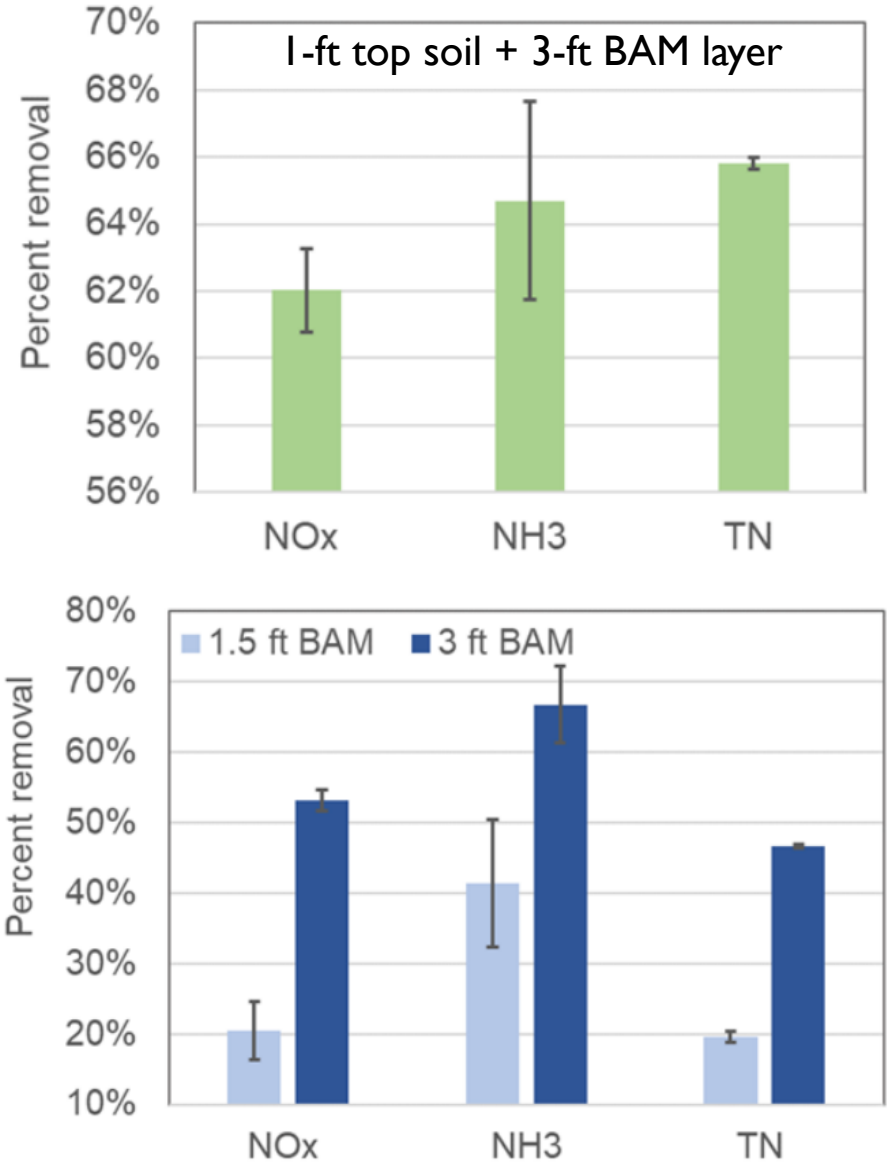
Excavation of BMPs

BDV24-977-20 – Testing

- **Hydrologic Monitoring**
  - Groundwater table depth
  - Inflows to BMPs
- **Storm Sampling**
  - 11 runoff events sampled for nutrients
  - Inflow
  - Media
  - 135 samples per event; 1,485 total samples
  - Analyzed for TN, NH_3 , NO_x

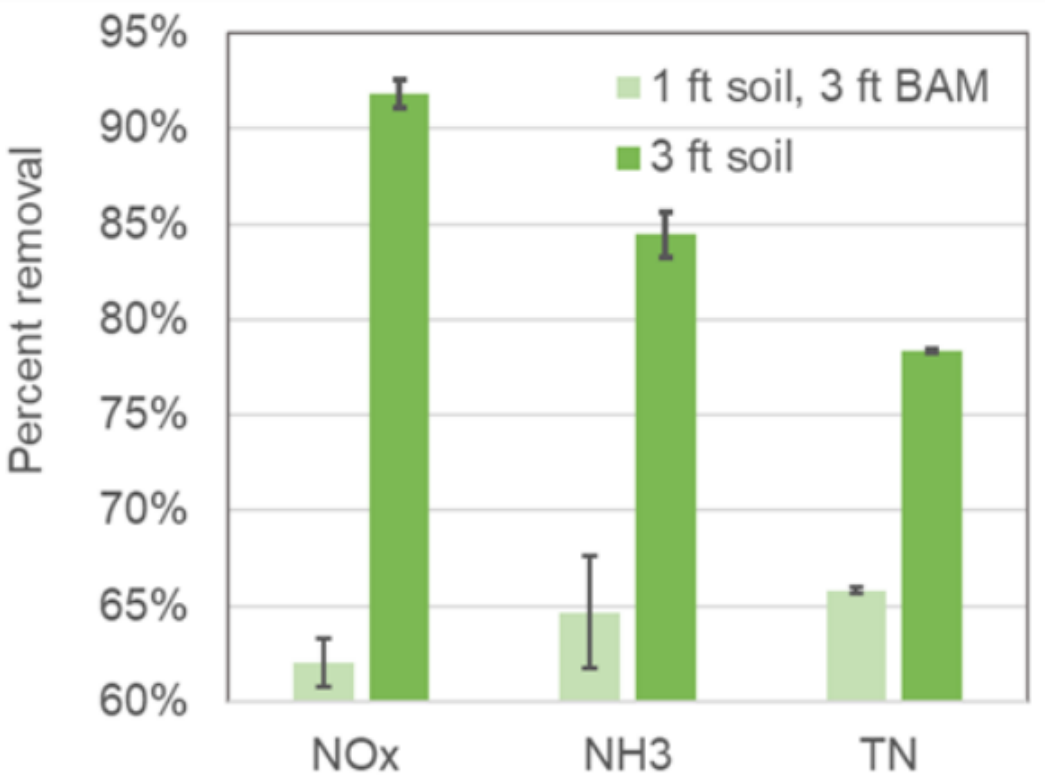
BDV24-977-20 - Findings

- **Blanket Filters – BAM**
  - Mean concentrations of NOx , NH3 , and TN after blanket filter treatment within the EBF (including both the 1-ft top soil layer and 3-ft BAM layer) are 60%-66% lower than stormwater inlet concentrations.
  - Increasing thickness of BAM layer will increase nutrient removal and increase costs.



BDV24-977-20 - Findings

- **Blanket Filters – Soil**
  - Mean removals of NOx , NH3 , and TN within a 3-ft soil layer range from 78%-92%, **exceeding mean removal in the filtration media blanket filter.**



BDV24-977-20 - Findings

- **Vertical Reactor**
  - Capture Efficiency 0.2%
  - Mean concentrations of TN and NOx after treatment with 4-ft BAM layer are respectively 49% and 54% lower than stormwater inlet concentrations.

BDV24-977-20 - Findings

BMP		20-year Design Life	30-year Design Life
Blanket Filter (Based on East Bank Filter)	TN	$ 715 ± $27	$ 611 ± $ 23
	NO_x	$ 1,590 ± $ 61	$ 1,360 ± $ 52
Vertical Reactor (Based on VR4)	TN	$ 498 ± $ 25	$ 453 ± $ 23
	NO_x	$ 732 ± $ 37	$ 701 ± $ 35

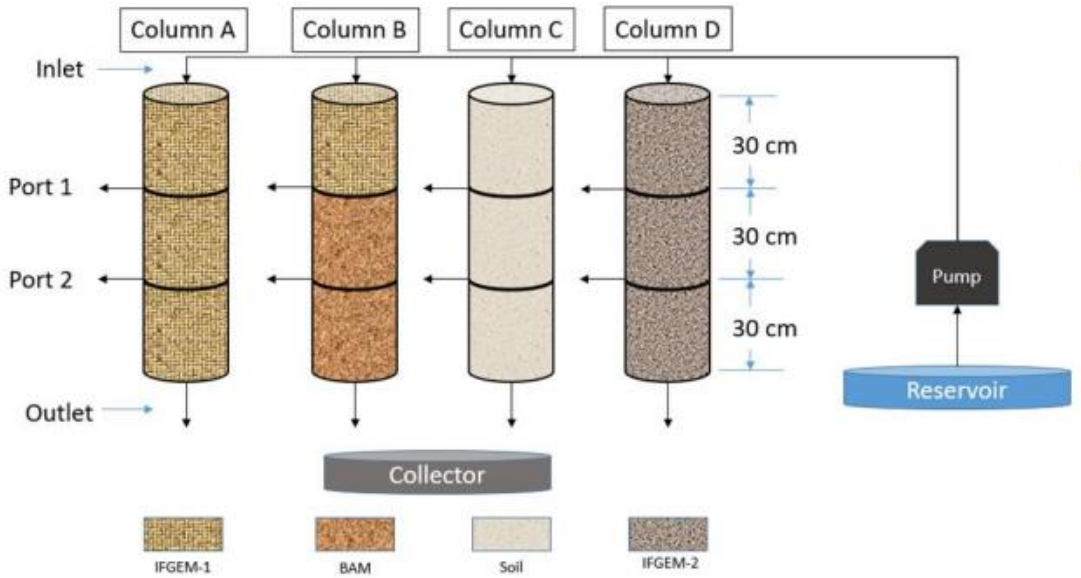
COST per pound of TN or NOx ($/lb)

BDV24-977-25 - Introduction

- Innovative and Integrative Best Management Practices (BMPs) for Surface and Groundwater Protection
  - Chemically activated media (CAM) development
  - Bio-activated media in vegetated filter strip
  - Updates to BMP Trains
  - Groundwater flow-nutrient model in Karst geology
- PI - Dr. Kelly Kibler, UCF

BDV24-977-25 - CAM

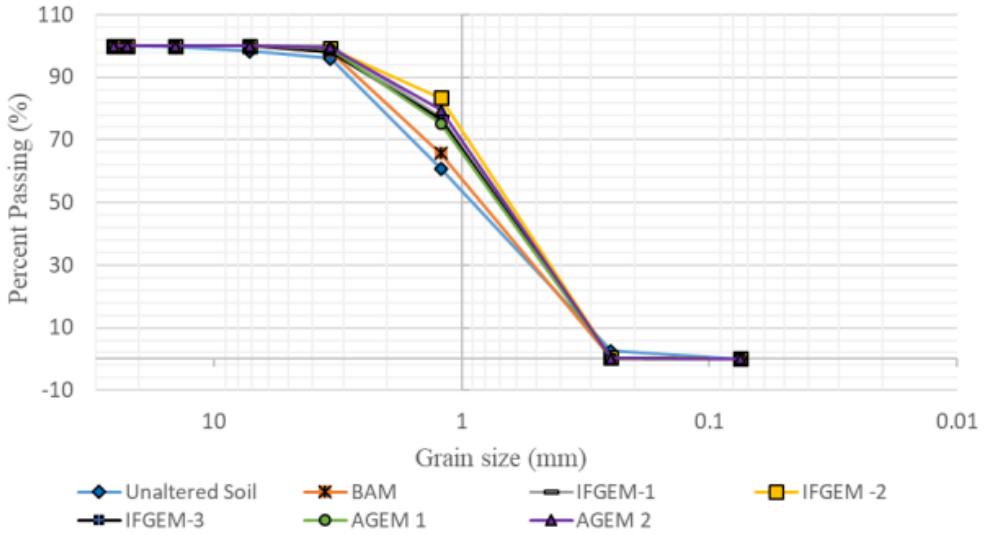
- Research
- Development
- Testing

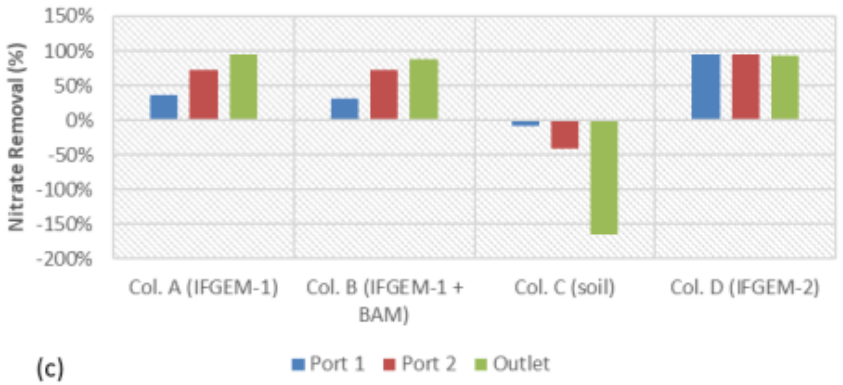


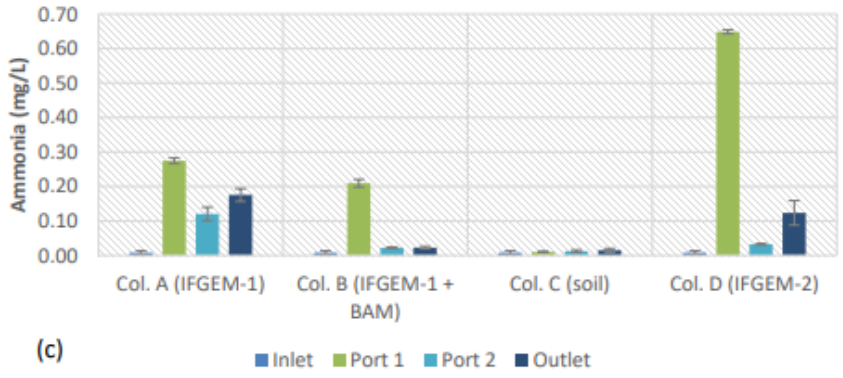
Material (%)	BAM	IFGEM-1 (CAM-1)	IFGEM-2 (CAM-2)	IFGEM-3 (CAM-3)	AGEM -1 (CAM-4)	AGEM-2 (CAM-5)
Sand	85	96.2	80	83	78	85
Tire Crumb	10	--	10	10	10	--
Clay	5	--	5	2	2	3
Iron filings	--	3.8	5	5	5	7.5
Aluminum flakes	--	--	--	--	5	--
Aluminum powder	--	--	--	--	--	4.5

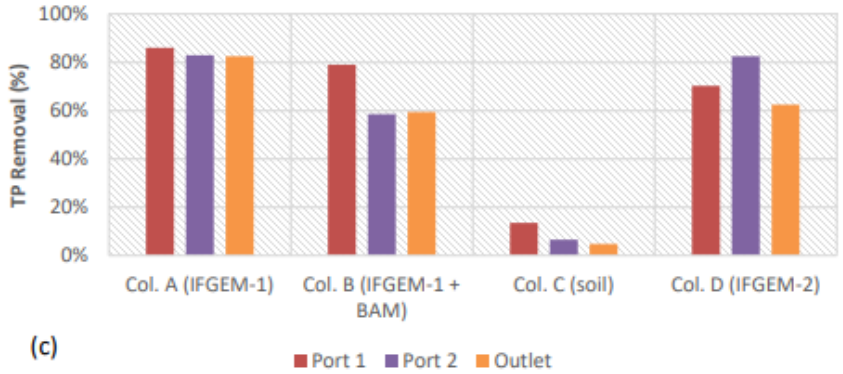
BDV24-977-25 – CAM

- **CAM development**
  - Material property characterization
- **Nutrient removal column studies**







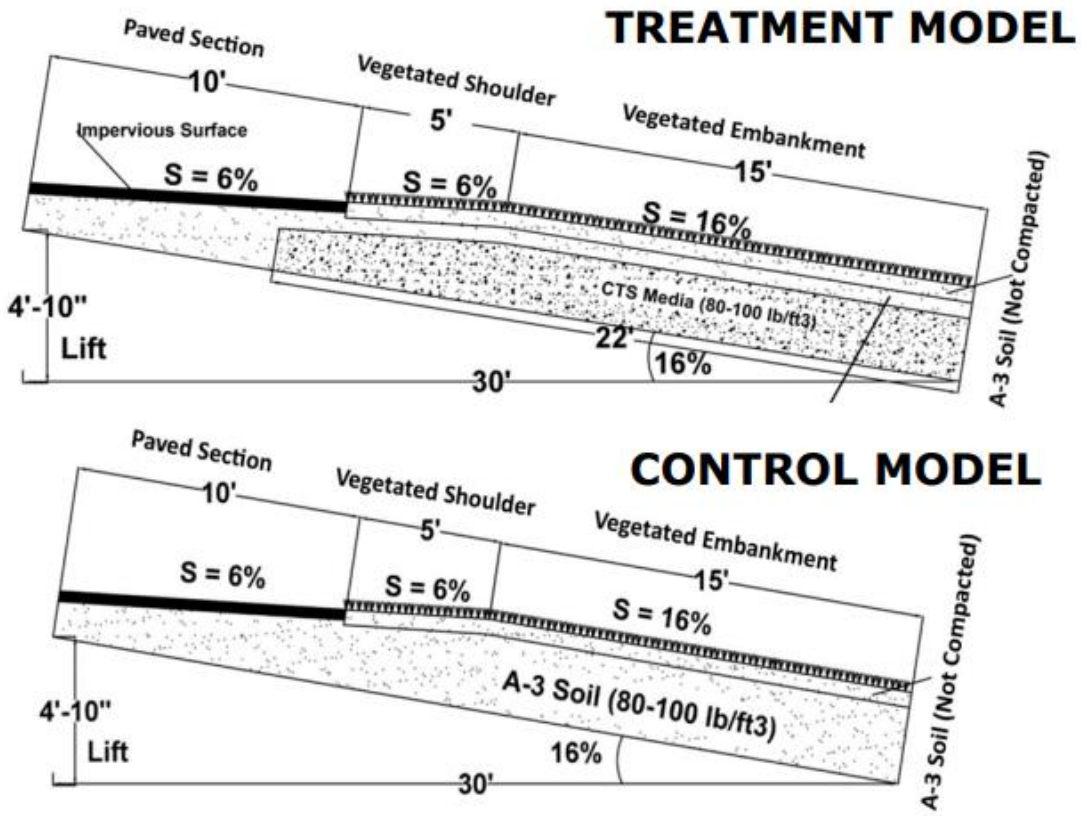


BDV24-977-25 – CAM Results

- In situ regeneration may be possible in IFGEM-3
- AGEM-2 – regeneration may not be possible.

Nutrient	Total nutrient loading (mg)	Nutrient adsorbed (mg)	Maximum sorption capacity (mg/g)	Nutrient produced and released during adsorption (mg)	Nutrient released during desorption (mg)	Nutrient generated (recovered) (mg)
IFGEM-3						
NO_3^-	385.65	161.42	0.32	--	4.33	--
PO_4^{-3}	385.64	377.56	0.76	--	215.98	--
NH_3^+	0	--	--	68.03	1.13	69.16
AGEM-2						
NO_3^-	385.65	200.61	0.40	--	2.03	--
PO_4^{-3}	385.64	371.20	0.74	--	84.29	--
NH_3^+	0	--	--	93.4	2.49	95.89

BDV24-977-25 – BAM Vegetated Filter Strip



BDV24-977-25 - BAM Vegetated Filter Strip

BAM into treatment model

A3 soils into control model

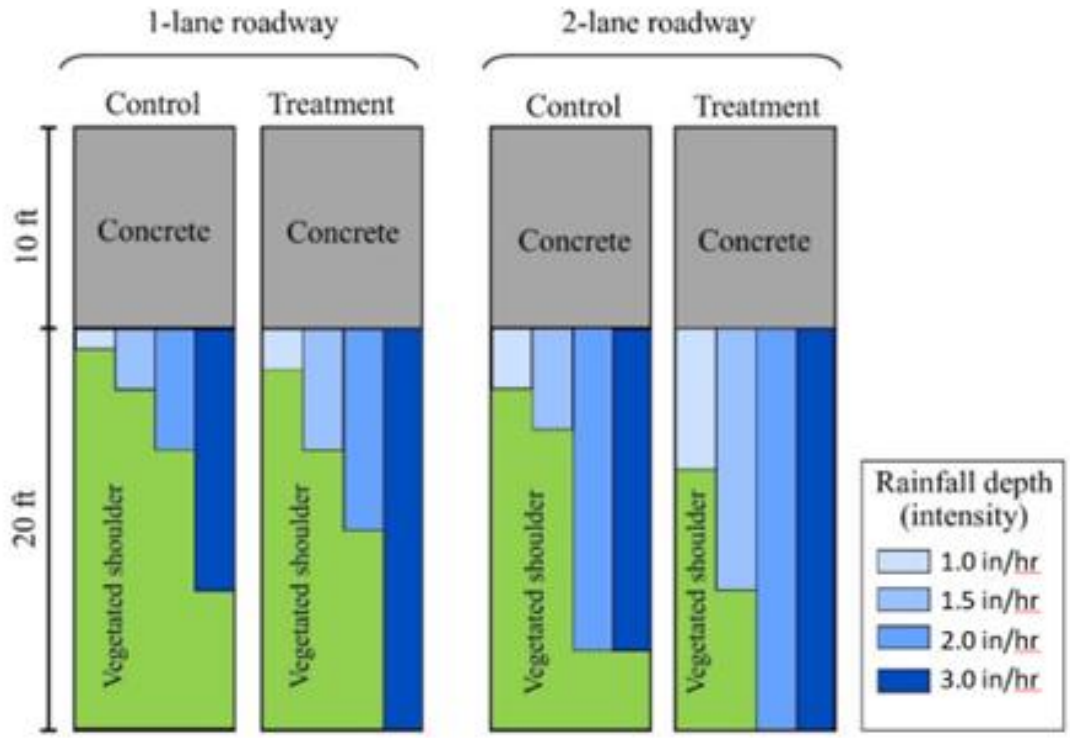
- Physical roadway models
- Materials testing
- Vegetation establishment
- Simulator preparation and testing

BDV24-977-25 – BAM Vegetated Filter Strip Results

- 60 tests
- 1-lane and 2-lane typical sections
- Various rainfall intensity conditions (0.5, 1, 1.5, and 3 in/hr)
- Nutrient removal performance tested for various rainfall depths (0.5 0.75, 1, 1.5, and 3 inches)

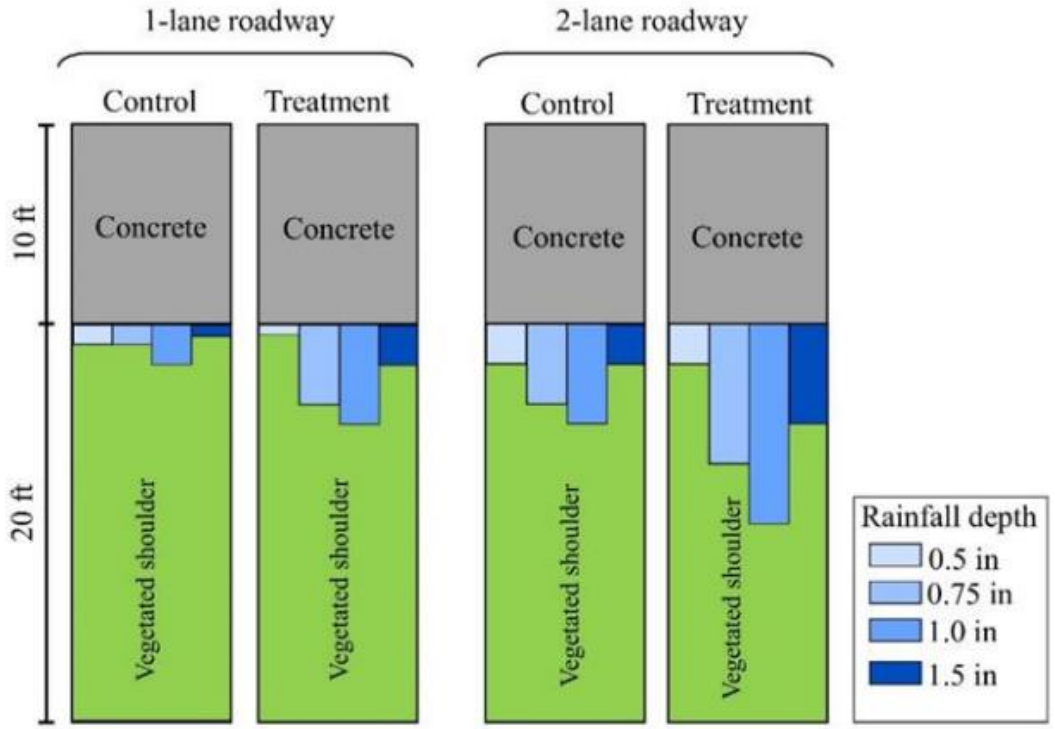
BDV24-977-25 – BAM Vegetated Filter Strip Results

- **For high intensity events**
  - All surface water infiltrated in control model (sandy soils)
  - The treatment model generated runoff at 20 ft
  - Maximum rainfall intensity for 20 ft BAM VFS:
    - <2in/hr for 2-lane roadways
    - <3in/hr for 1-lane roadways



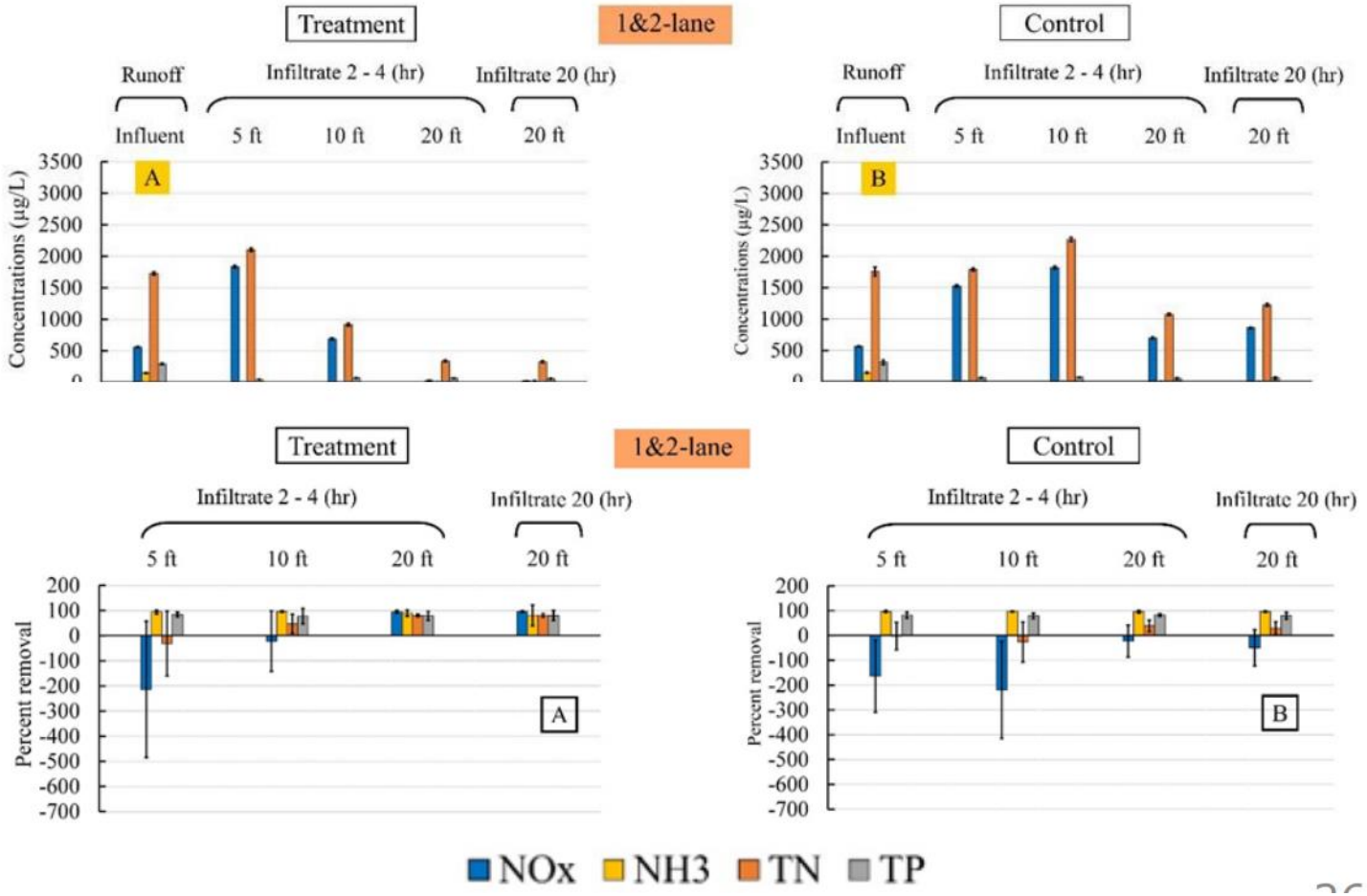
BDV24-977-25 – BAM Vegetated Filter Strip Results

- **For typical events**
  - All surface water infiltrated both models
  - Intensities exceeding hydraulic capacity of the 20 ft VFS are rare



BDV24-977-25 – BAM Vegetated Filter Strip Results

- *Nutrient removal*
  - *20-ft BAM VFS removed more nitrate and TN*
  - *No performance difference in TP removal*

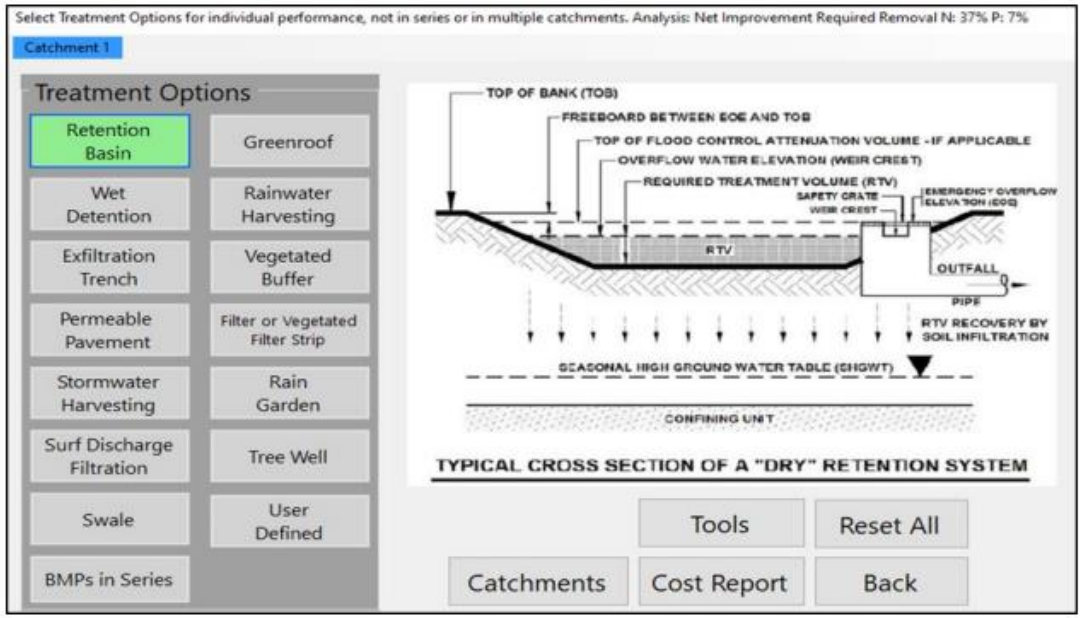


BDV24-977-25 – BMP Trains Overhaul

- **Requests for improvement from**
  - FDEP
  - Water Management Districts
  - FDOT
- **Focus group testing throughout project**
- **14 workshops**
- **360 professionals**

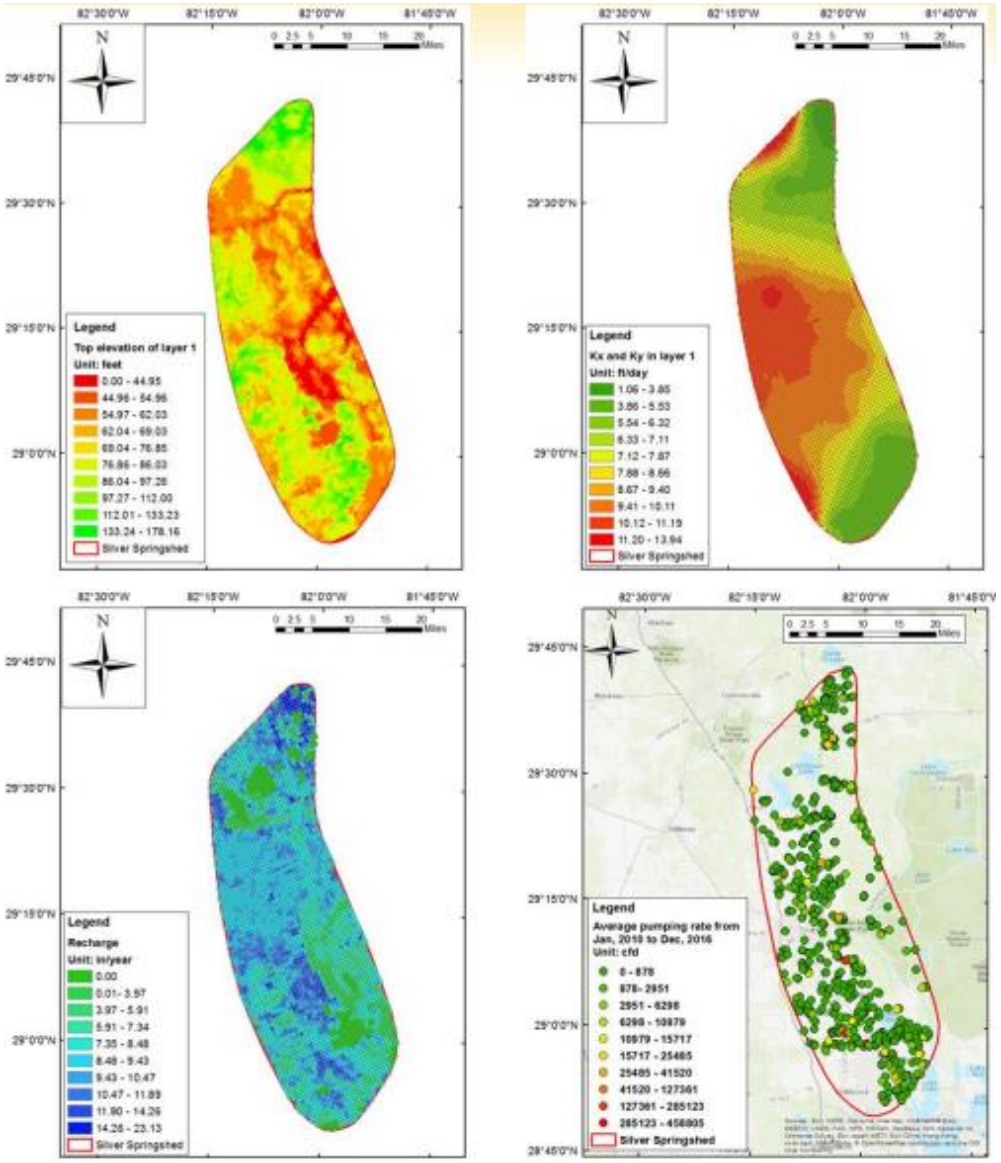
BDV24-977-25 – BMP Trains

- Recoded from EXCEL to C++
- Developed graphics user interface
- Renamed BMP Trains 2020
- Model testing and validation
- User manual updated with example problems
- Model and user manual perpetually maintained and available at UCF's STARS repository

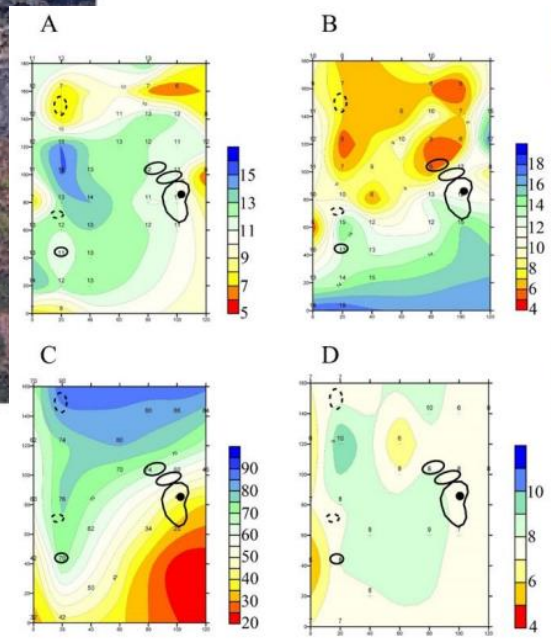


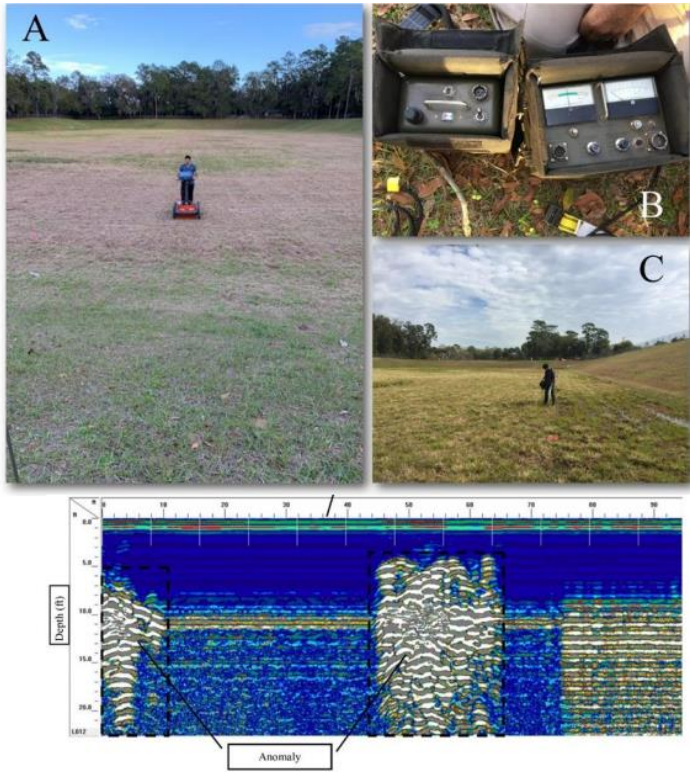
BDV24-977-25 – Groundwater model

- Location: Silver Springs, FL
- MODFLOW with CFPv2
- CMT3D

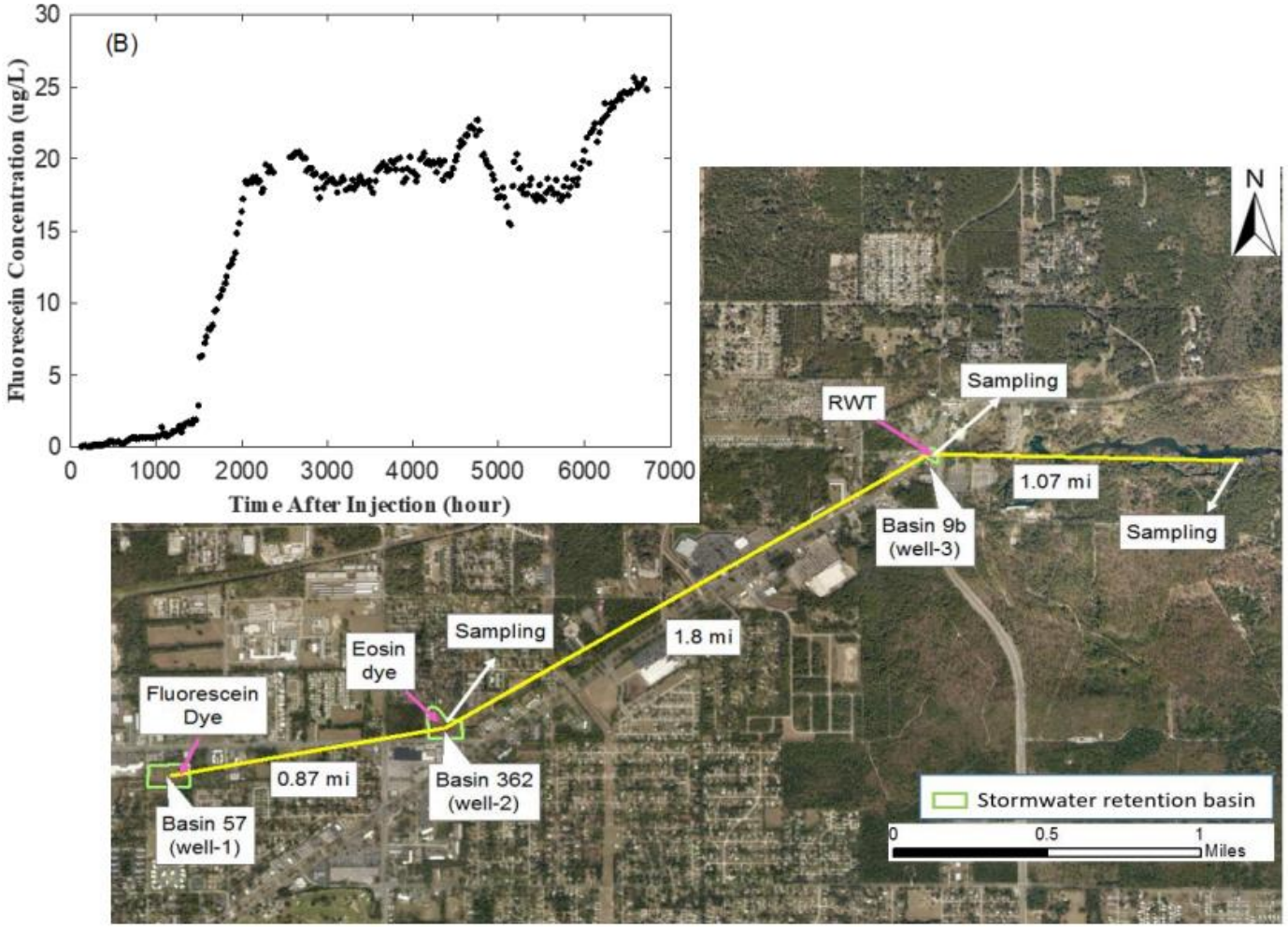


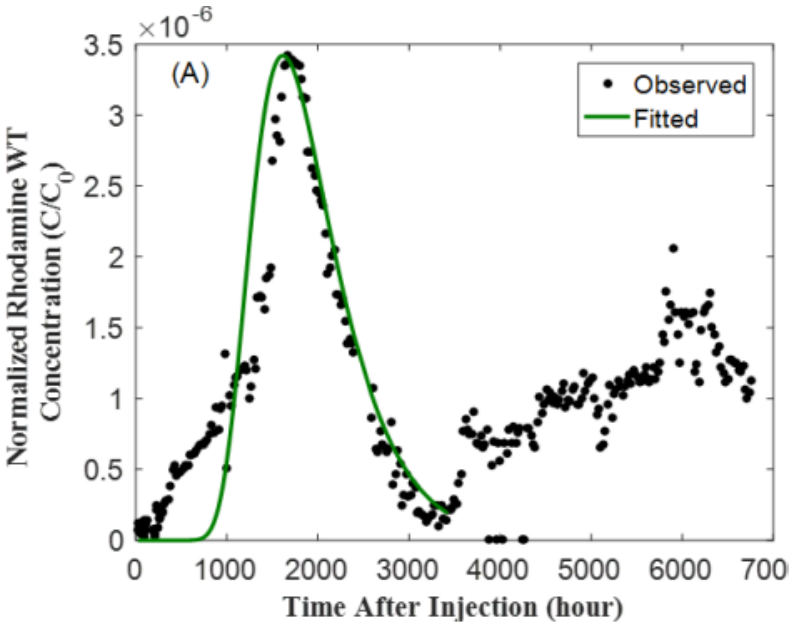
BDV24-977-25 – Groundwater Model





BDV24-977-25 – Groundwater Model Results





BDV24-977-25 – Groundwater Model Results

MODFLOW CFPv2 groundwater flow model

Period		Groundwater Level		Spring Discharge	
		RMSE (ft)	Relative Error	NSE	Relative Error
Calibration	Mean annual	1.79	3%	0.86	6%
Validation	Mean annual	1.19	2%	0.70	7%
	Monthly	1.04	2%	0.84	6%

CMT3D nutrient transport model

Statistics	NO_3		TN		TP	
	Calibration	Validation	Calibration	Validation	Calibration	Validation
Data range	2000-2008	2009-2016 and 2019	2001-2007	2008-2010 and 2019	2000-2007	2008-2010 and 2019
RMSE (mg/L)	0.06	0.09	0.10	0.07	0.007	0.006
Relative error (%)	4.4	5.2	7.0	5.0	11.7	11.3

BDV24-977-25 – Groundwater Model Results

Scenario	Blanket filter implementation	Area (acres)	Percent of SRB area (%)	Roadway shoulder implementation	Length (miles)	Percent of roadways (%)
1	Baseline - no BAM is implemented	0	0	Baseline - no BAM is implemented	0	0
2	BAM blanket filters are implemented in 26 FDOT SRBs	3,682	13	No BAM VFS	0	0
3	BAM blanket filters are implemented in all FDOT SRBs	27,651	100	No BAM VFS	0	0
4	No BAM blanket filters	0	0	BAM VFS are implemented in 30% of roadway shoulders	2,368	30%
5	No BAM blanket filters	0	0	BAM VFS are implemented in 60% of roadway shoulders	4,735	60%
6	BAM blanket filters are implemented in all FDOT SRBs	27,651	100	BAM VFS are implemented in all roadways shoulders	7,893	100%

BDV24-977-25 – Groundwater Model Results

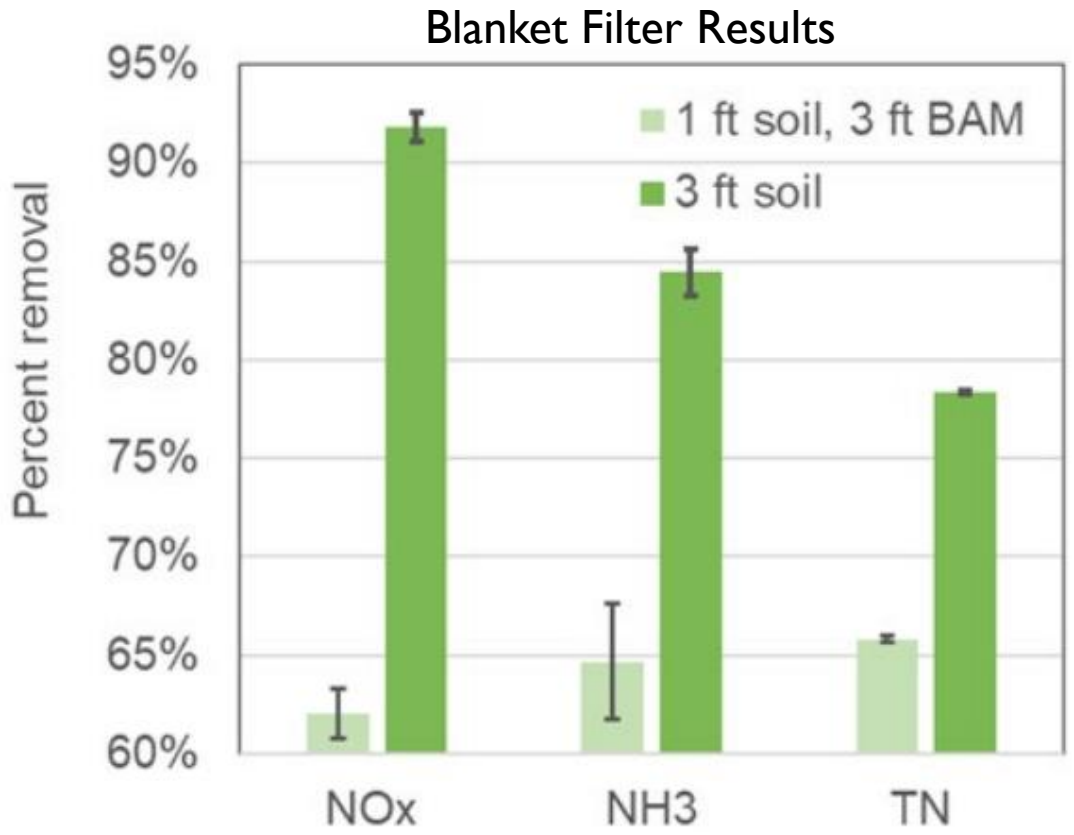
- Cumulative water quality benefits of BAM BMPs to Silver Springs are minimal.
- Considering the resources required for such implementation and the limited water quality benefits, the BAM-based BMPs investigated may not be a rational investment to improve Silver Springs water quality.

Roadway Shoulder Implementation	Total Nitrate Concentration Reduction	TN Concentration Reduction	TP Concentration Reduction	Cost to Implement
30%	2.3%	1.7%	0.7%	$3,055,868,066
60%	4.5%	3.4%	1.5%	$6,110,445,528
100%	5.8%	5.2%	1.6%	$10,185,796,353

Percent nutrient concentration reduction assumes the worse case native soil nutrient removal efficiencies (i.e. BAM is highly more efficient than soil).

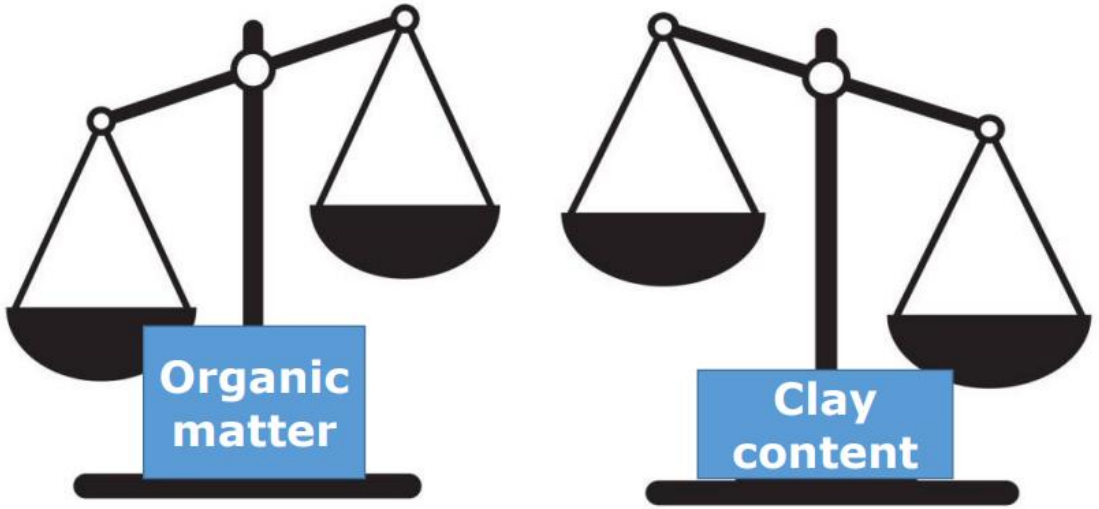
BDV24-977-43 - Introduction

- Design of Stormwater BMPs for Surface and Groundwater Protection Based on Site-Scale Soil Properties: Phase I
- PI: Kelly Kibler, UCF
- Follow-up to BDV24-977-20 and FDEP NS001 (2016-2020)
- Recall - BAM did not remove nitrogen from stormwater as effectively as unaltered site soils.



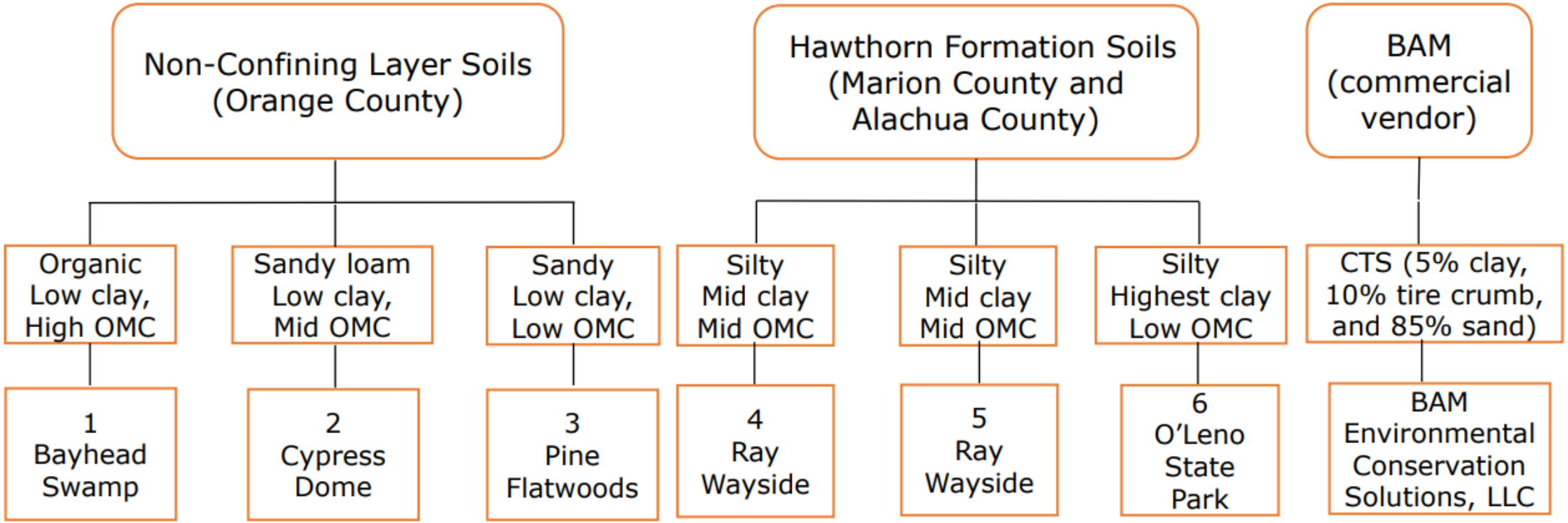
BDV24-977-43 - Objectives

- Quantify the nutrient removal/retention potential
- Isolate the material properties
- Compare nutrient remediation of BAM



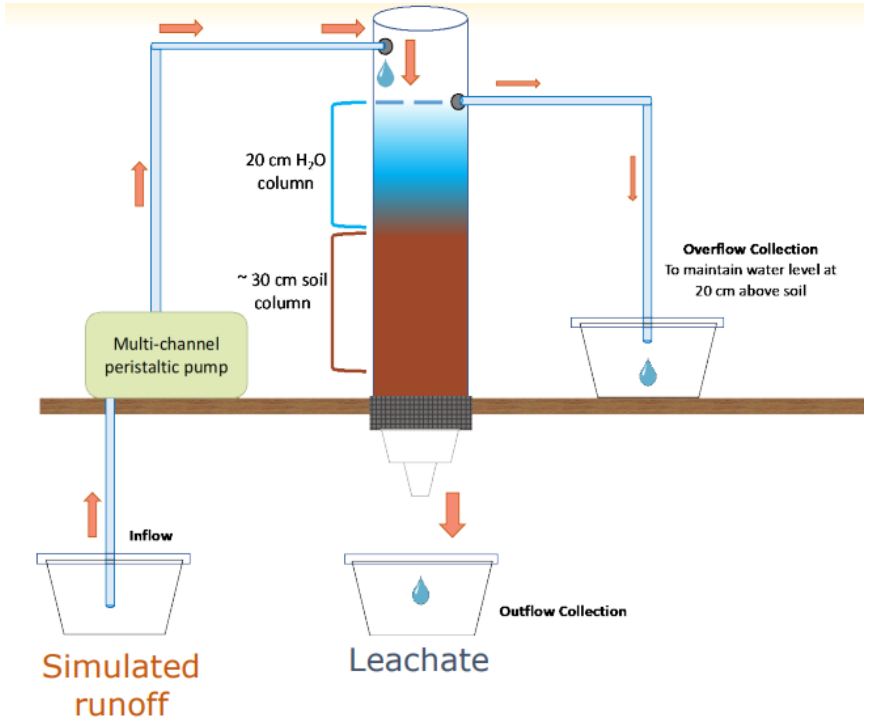
Vs.

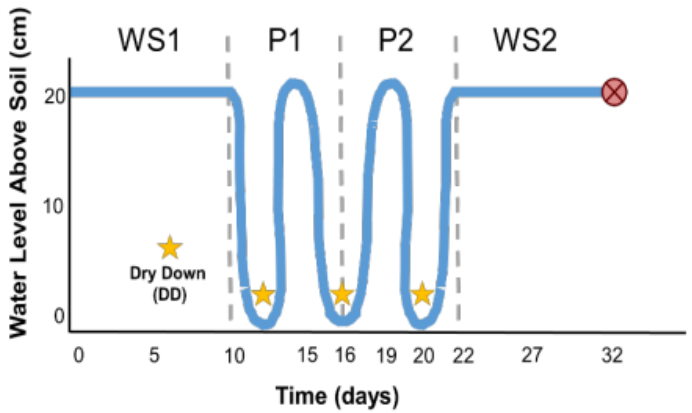
BDV24-977-43 – Site Selection



BDV24-977-43 - Testing

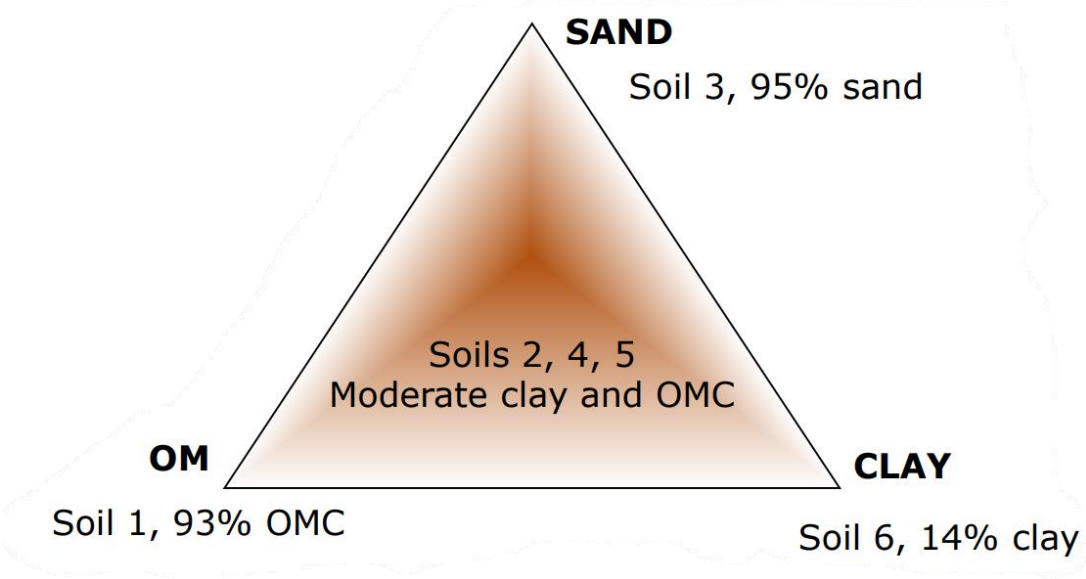
- **Soils Characterization**
  - 16 parameters
- **Denitrifying Enzyme Activity (DEA) – N Removal**
- **Potentially Mineralizable Nitrogen (PMN) – N Release**
- **Column Study**
  - Leachate
  - Hydraulic performance





BDV24-977-43 - Findings

- Soils with combination of OMC and clay may be most effective at remediating nutrients
- Soils with mixture of moderate OMC and clay (Soils 2, 4, 5) removed/sequestered nutrients more effectively
- P sequestration was most effective in soils with higher pH and metal content (Soils 1, 4, 5)



BDV24-977-43 - Recommendations

- Native soils are an important tool in stormwater nutrient remediation
- Understanding the soil remediation potential can justify potential water quality benefits of using BAM.

Future Research

- **Design of Stormwater BMPs for Surface and Groundwater Protection Based on Site-Scale Soil Properties: Phase 2**
  - Continuation of Dr. Kibler research
  - Evaluate nutrient efficiency range of natural soils based on in-situ composition under natural hydrologic conditions
  - Investigate nutrient efficiency range of FDOT Specification’s 987 Soil Layer Materials
  - Develop guidelines based on native soil's composition to make site-specific recommendations of whether BAM would be beneficial or not

Future Research

- **Event Mean Concentration updates for Transportation**
  - Differentiate EMCs based on land cover to demonstrate nutrient loadings are not directly proportional to runoff generation.

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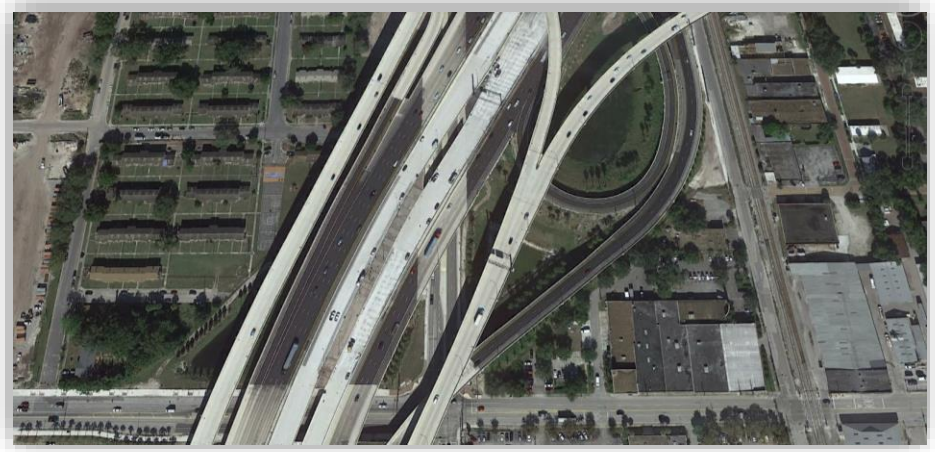
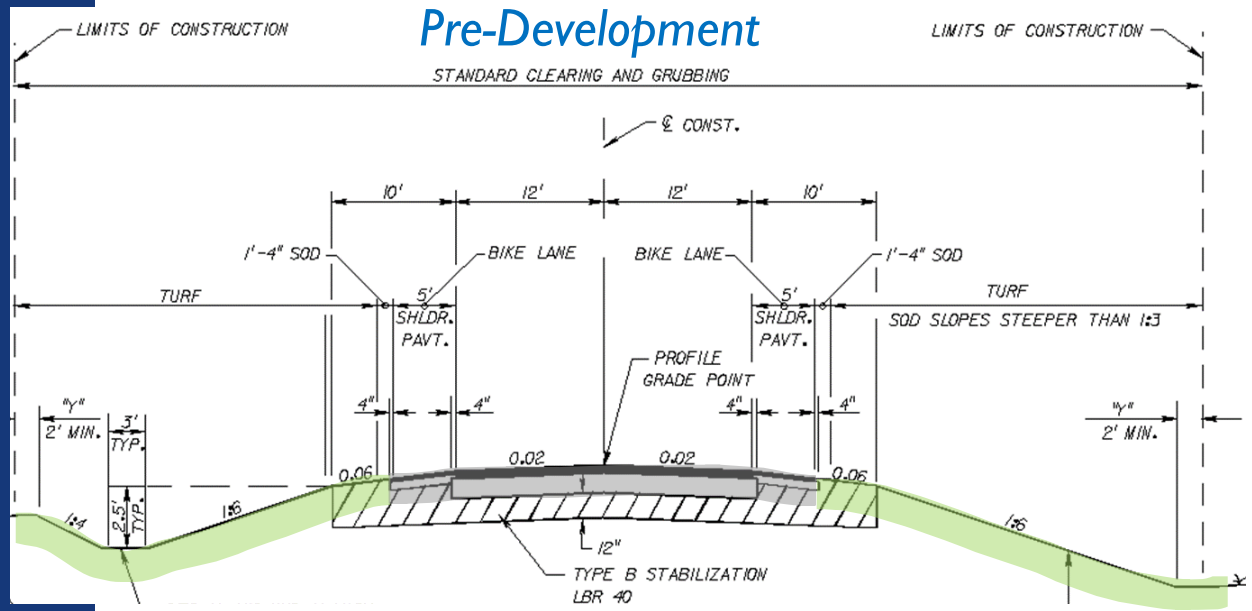
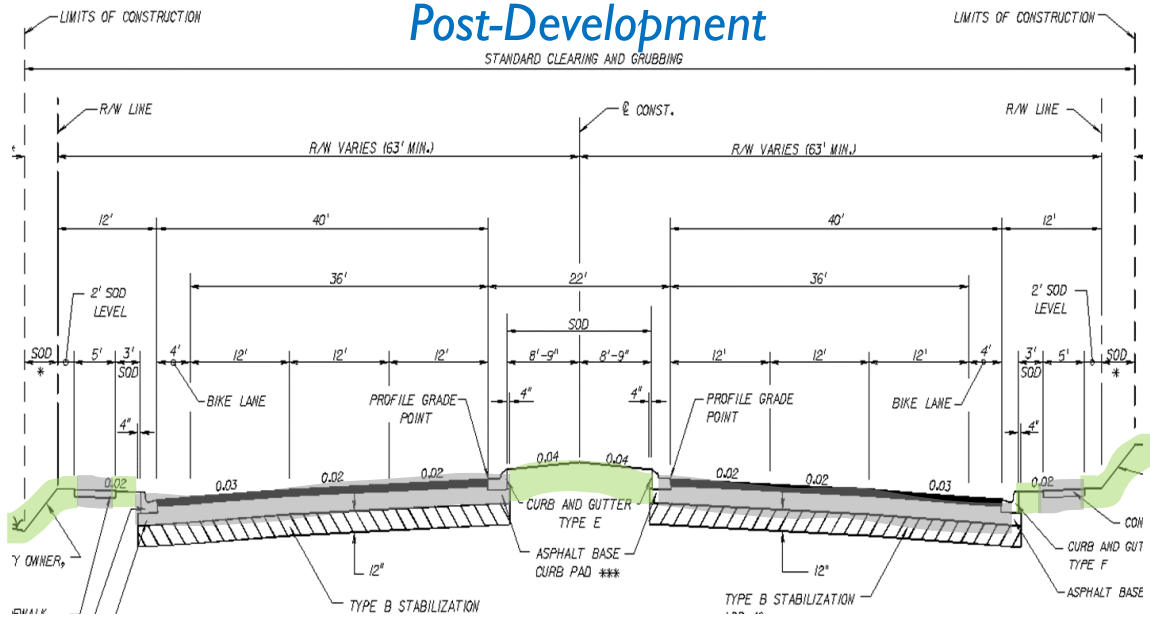


Future Research

- Event Mean Concentration updates for Transportation



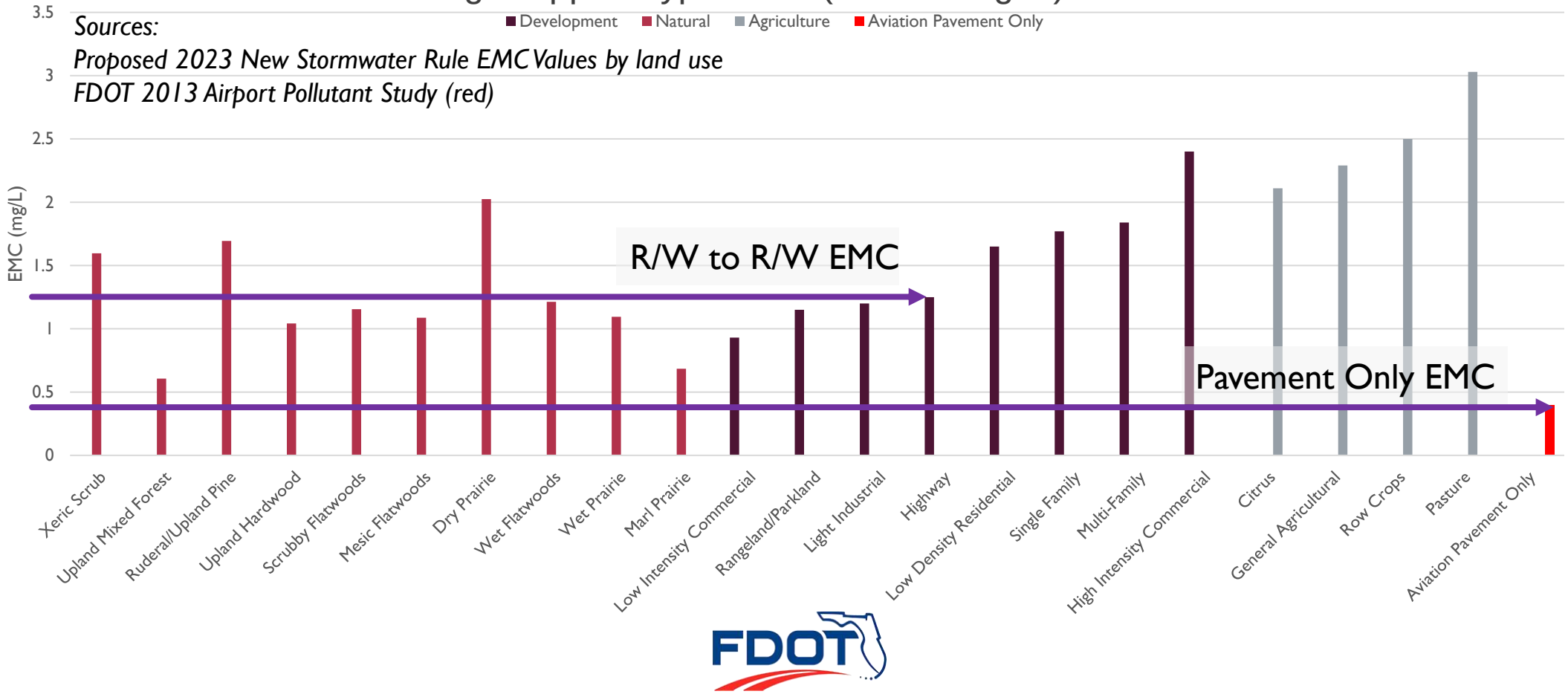


	Pre-development	Post-development	Increase
Annual Runoff (ac-ft)	2.89	9.11	**215%**
Loading for TN (lbs./yr.)	10.78	33.93	**215%**
Loading for TP (lbs./yr.)	1.34	4.22	**215%**

Future Research

Event Mean Concentration updates for Transportation

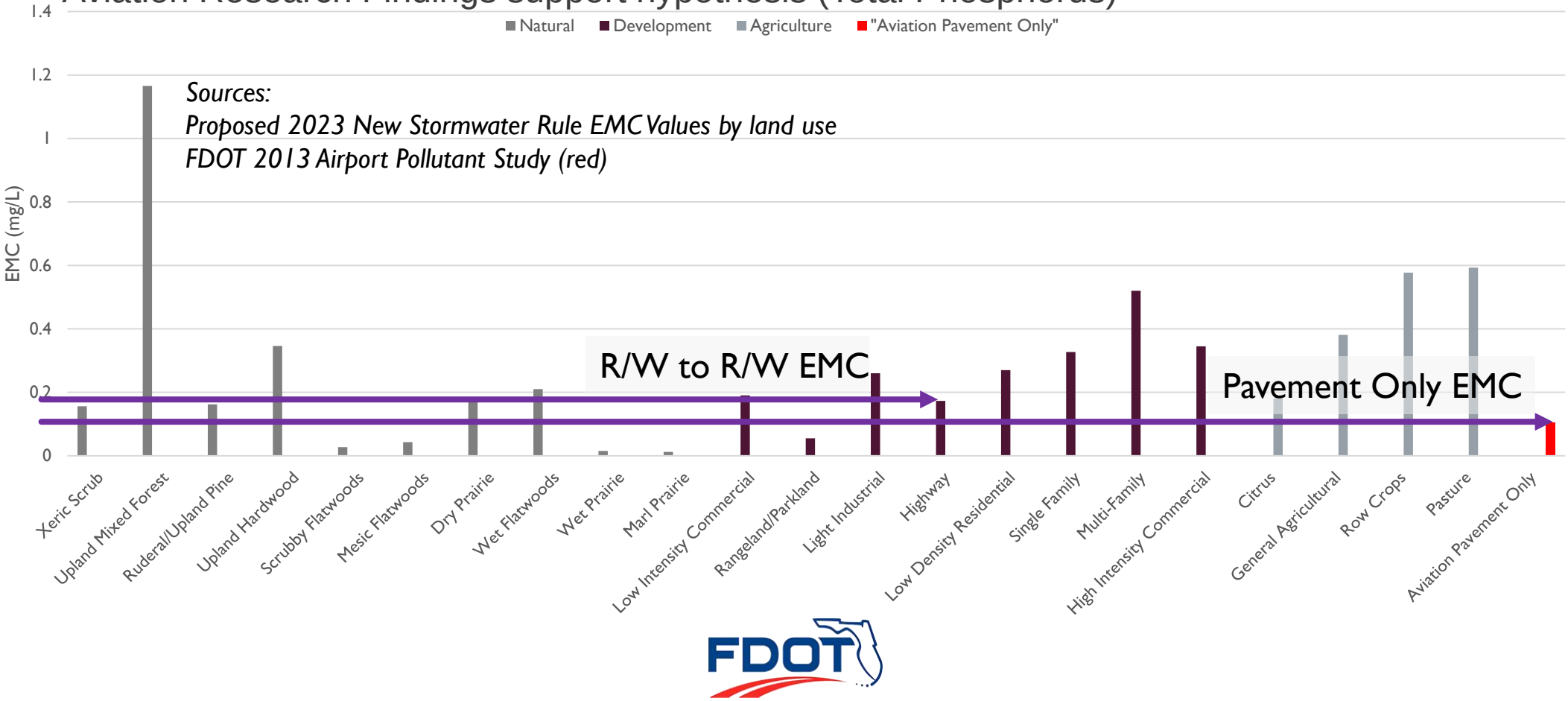
- Aviation Research Findings support hypothesis (Total Nitrogen)



Future Research

Event Mean Concentration updates for Transportation

- Aviation Research Findings support hypothesis (Total Phosphorus)



Future Research

- **Event Mean Concentration updates for Transportation**
  - Status - Pending management approval and research funding allocation.

Conclusions

- **To substantially improve watershed, targeted nutrient removal investments at high load sources**
  - FDOT has invested in septic-to-sewer projects, estuary circulation for sea grass habitat enhancements, etc.
- **Measured nutrient concentrations from rural roadways are below Springshed BMAP target Nitrate concentrations**
- **Soils have a range of natural nutrient cycling efficiencies**
  - Current research to develop guidance
- **BAM may not be appropriate in all cases**
  - Significant taxpayer investment should result in significant load reductions
  - BAM could be used if efficiency is significantly higher compared to the native soils

Questions

Contact:

Jennifer Green, P.E., CPM

State Drainage Engineer – Roadway Design Office

850-414-4351

jennifer.green@dot.state.fl.us

Kelly Kibler

Associate Professor – Water Resources Engineering

407-823-4150

Kelly.kibler@ucf.edu