Can a synthetic rhizosphere be created in a bioretention cell, and aid in the denitrification processes of urban stormwater runoff?

Luke Perry[1]; Amanda Cording[2]; Dr. Stephanie Hurley [3]

[1]Undergraduate Student, Alfred University, Intern Researcher, Plant and Soil Sciences University of Vermont Email: lsp1@Alfred.edu

[2]PhD Candidate Plant and Soil Science University of Vermont

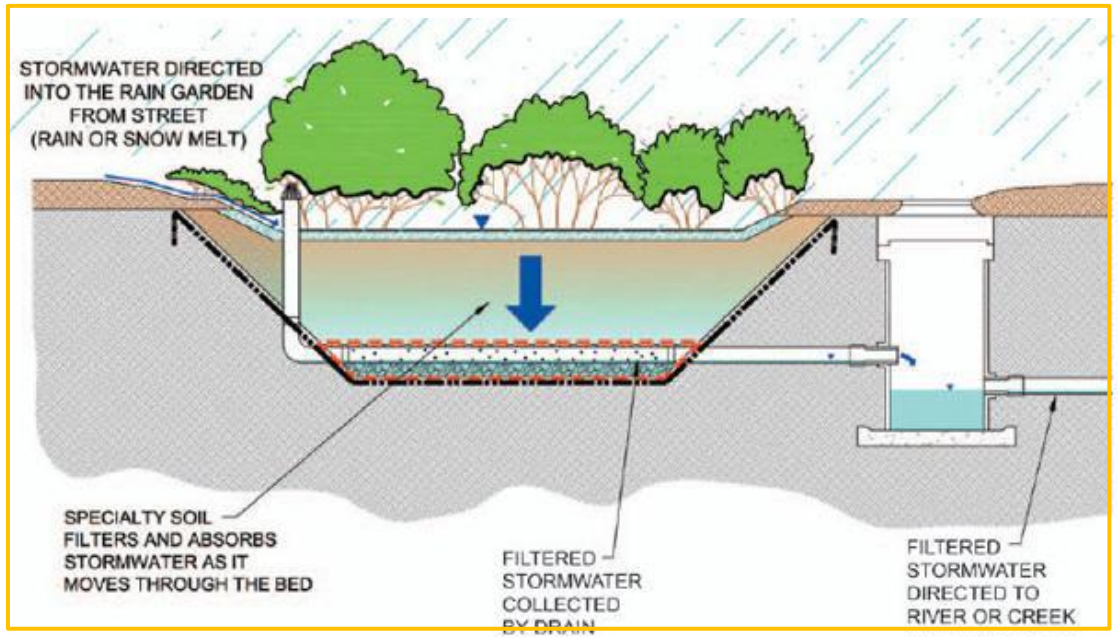
[3]Assistant Professor, Plant and Soil Science, University of Vermont

Bioretention Cell Mission

- Similar to rain gardens.
- Low maintenance solution to pollutant removal (Dietz).
- Most often used in urban settings.
- Green Stormwater Infrastructure (GSI) System

-Chris Whitis and Brian Phelps, *Site Phocus*.

-*Rainwise Seattle*. City of Seattle, "Building a Rain Garden."



-City of Calgary, Alberta, Canada "Rain Gardens in Calgary."

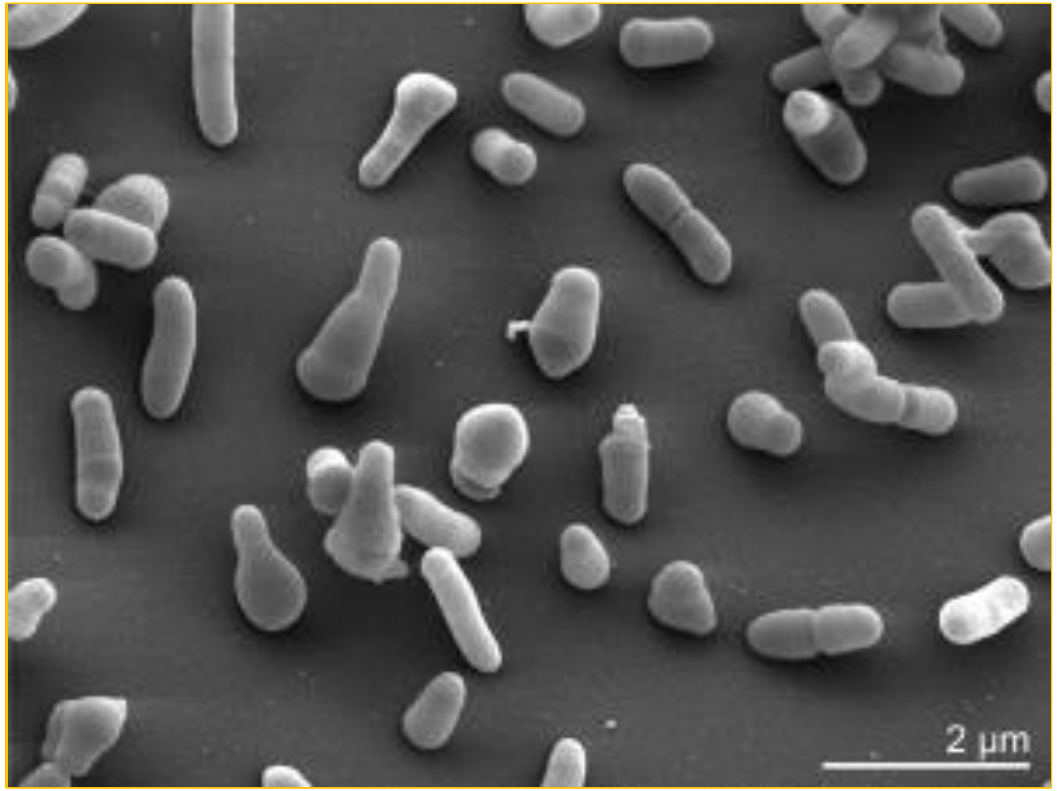
The Importance of Bacteria

The rhizosphere is the area in and around a plant's roots that is influenced by a unique population of microorganisms.

- **Bacteria in the rhizosphere play active roles in natural denitrification, removing up to 50% of nitrogen in tropical environments (van der Heijden 2008).**

Conditions that are unique to rhizosphere:

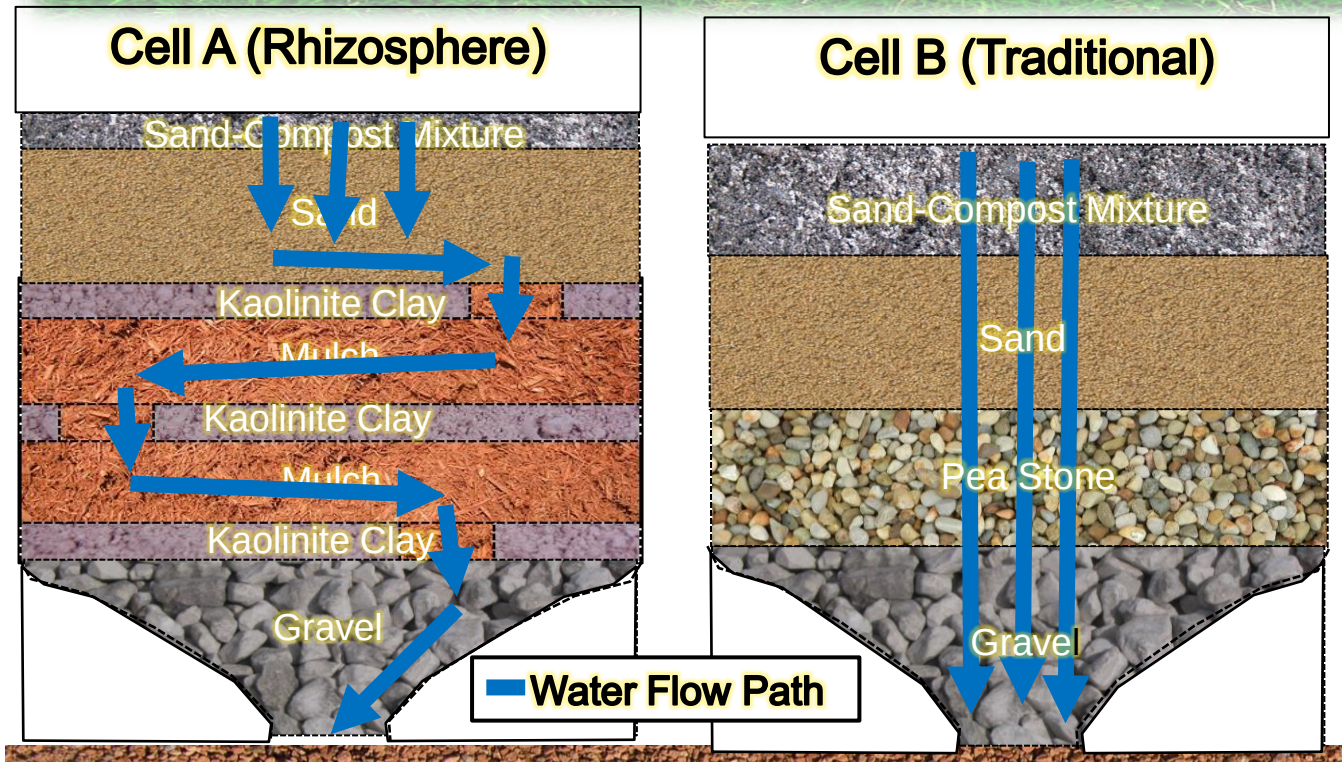
- **Anaerobic (<2% oxygen) and anoxic conditions.**
- **Sufficient nutrients to reproduce and grow present (Heylen 2006).**



-Scanning electron micrograph of J. denitrificans Prevot 55134T (Manfred Rohde, Helmholtz Centre for Infection Research (HZI), Braunschweig

Experimental Design

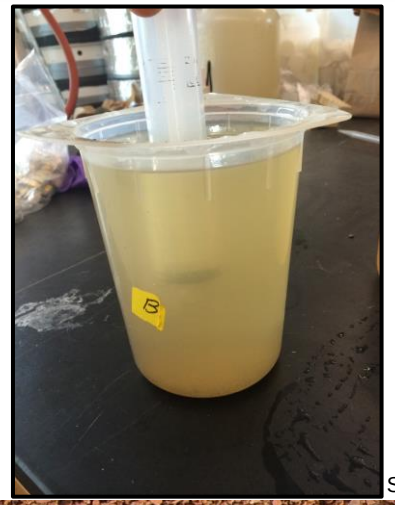
- Two mesocosms with two different Bioretention designs.
- Cell A represents the attempt to create conditions similar to a rhizosphere, which also made preferential flow paths.
- Cell B represents a traditionally designed bioretention cell.

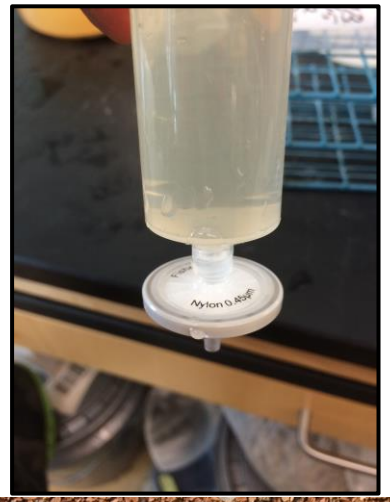


Layer	Cell A Height (cm)	Cell B Height (cm)
60:40 Sand Compost	1.5	6.8
Sand	8.9	8.3
Kaolinite Clay 1	0.5	0.0
Organic Mulch 1	2.0	0.0
Kaolinite Clay 2	2.0	0.0
Organic Mulch 2	2.0	0.0
Kaolinite Clay 3	2.0	0.0
Pea Stone	0.0	5.1

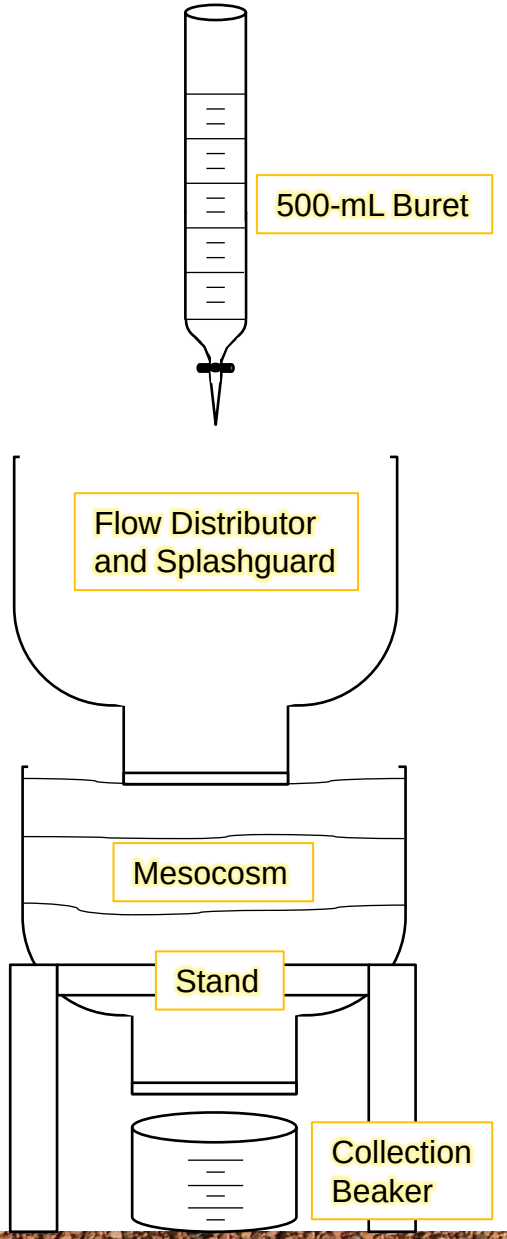
Methods

- Two mesocosms were designed and tested, utilizing flow distributors.
- A 500-mL buret was centered above the flow distributors.
- A collection beaker was placed underneath each mesocosm.
- Each cell design was subject to the same five series of tests, where water was distributed to, and permeated each mesocosm.
- Five replications were conducted for each test.
- Each test consisted of 1 L of water, with a 3 L flush in between each series.





Sampling and filtration of water collected.

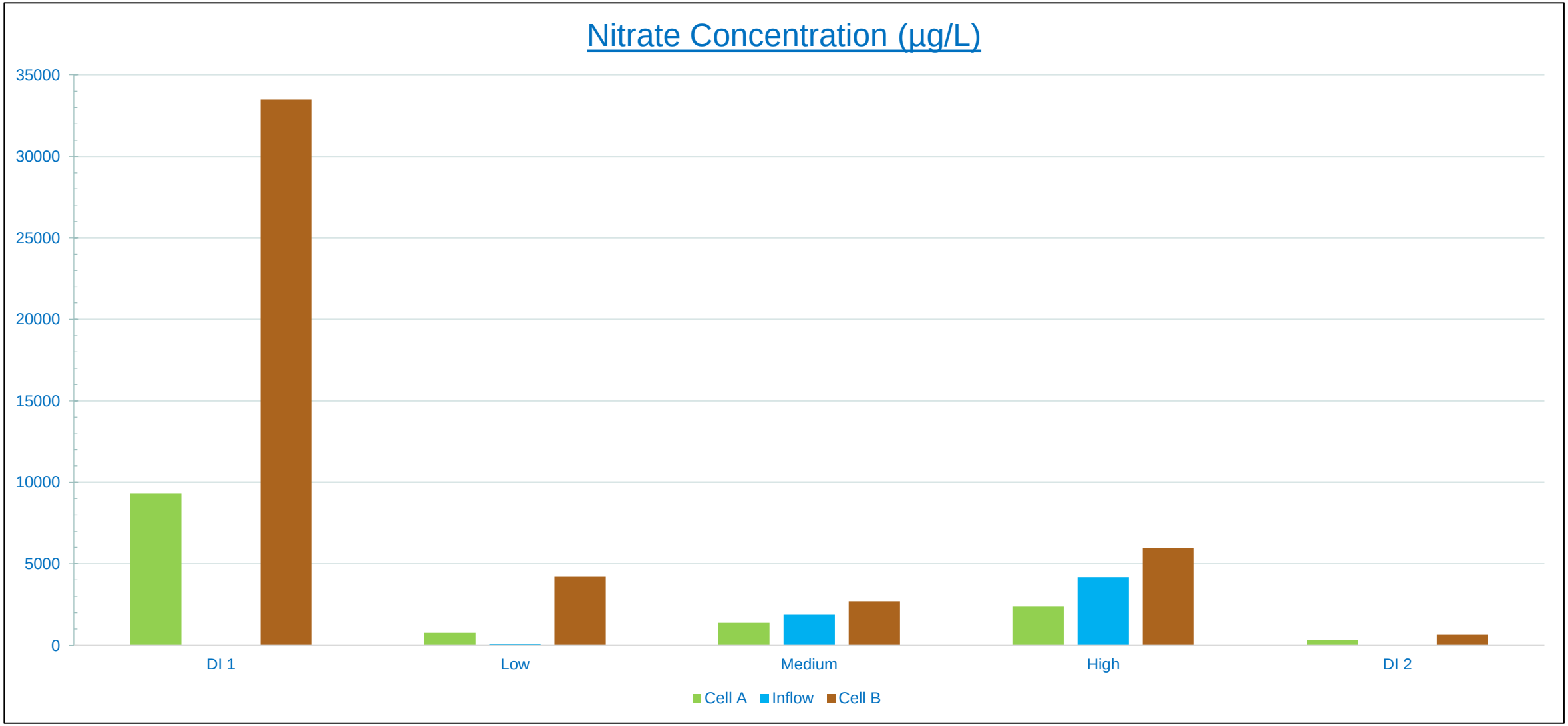


Methods Continued

- The mesocosms were given one hour to drain, starting from when the water was administered using the buret.
- The water volume was recorded, and a 15 mL sample taken.
- Soluble reactive phosphorus (SRP) and nitrate levels were then analyzed using the Quikem Lachat FIA+ 8000 series colorimeter.

Test Series	Starting Nitrate Conc. (µg/L)	Starting Phosphate Conc. (µg/L)
DI 1	0.00	0.00
Low	71.70	36.70
Medium	1870.00	1330.00
High	4170.00	3060.00
DI 2	0.00	0.00

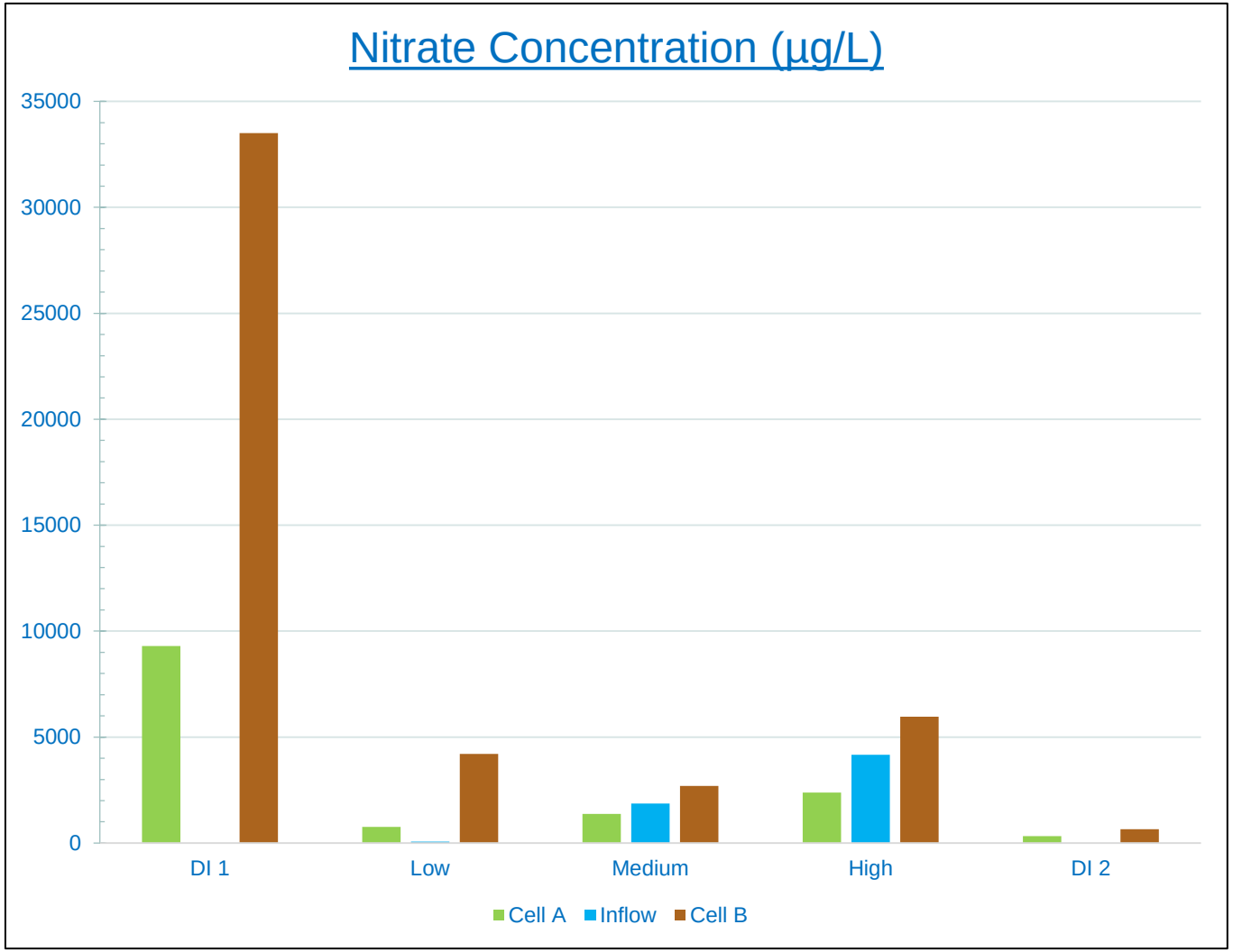
Comparison of Cells

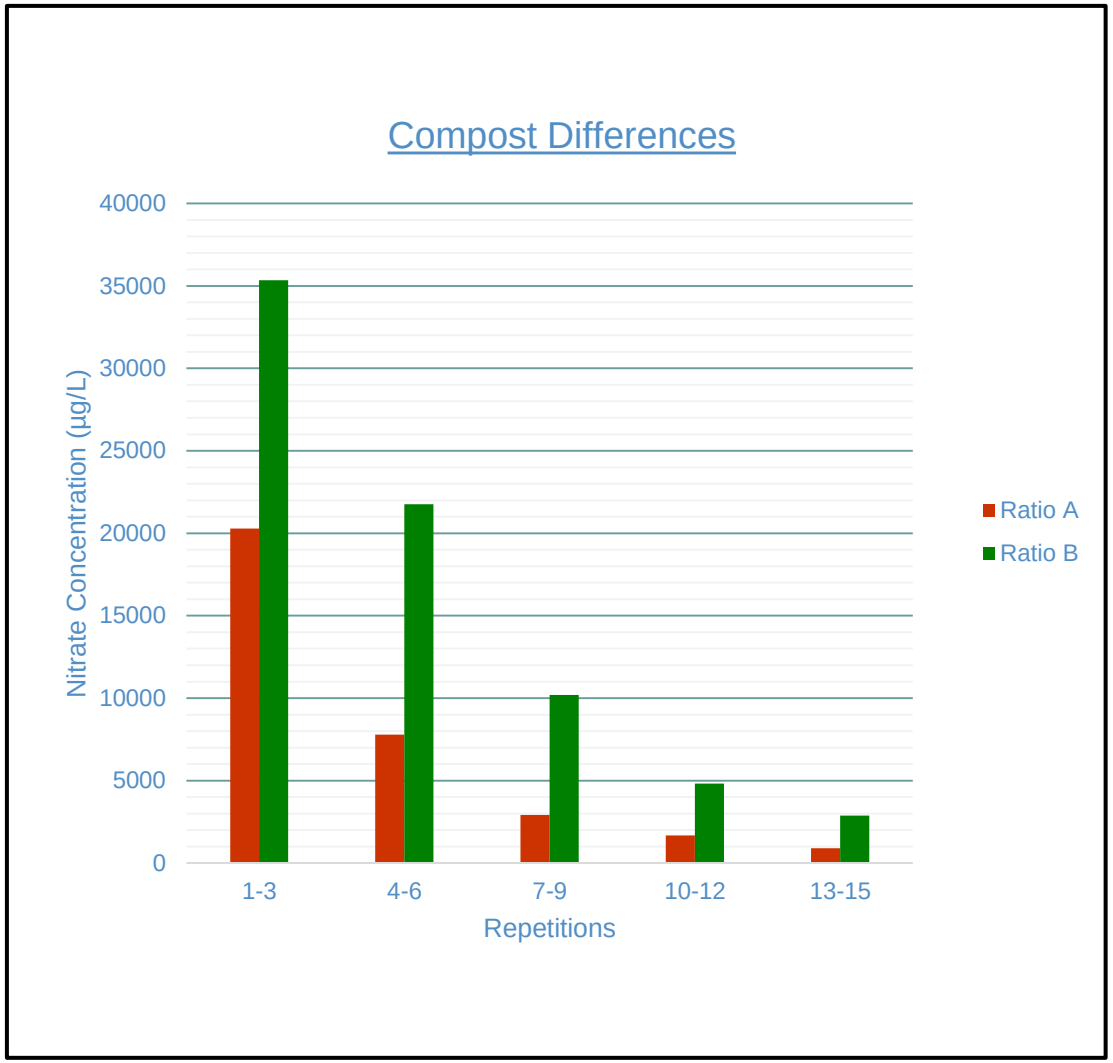


Results

- Results were analyzed using a Pooled T-test checking variances with Levene standard equations of each cell.
- Cell B exporting nitrate in every replicate of every test.
- Cell A exported nitrate in the first test of deionized water, as well as in the first few replicates of the second, low concentration test, but removed 23% or more in both the medium and high concentrations.
- Because there was a difference of compost:sand volume between the two mesocosms. A small test was conducted to determine how much this affected the outflow concentration of each mesocosm.

Comparison of Cells

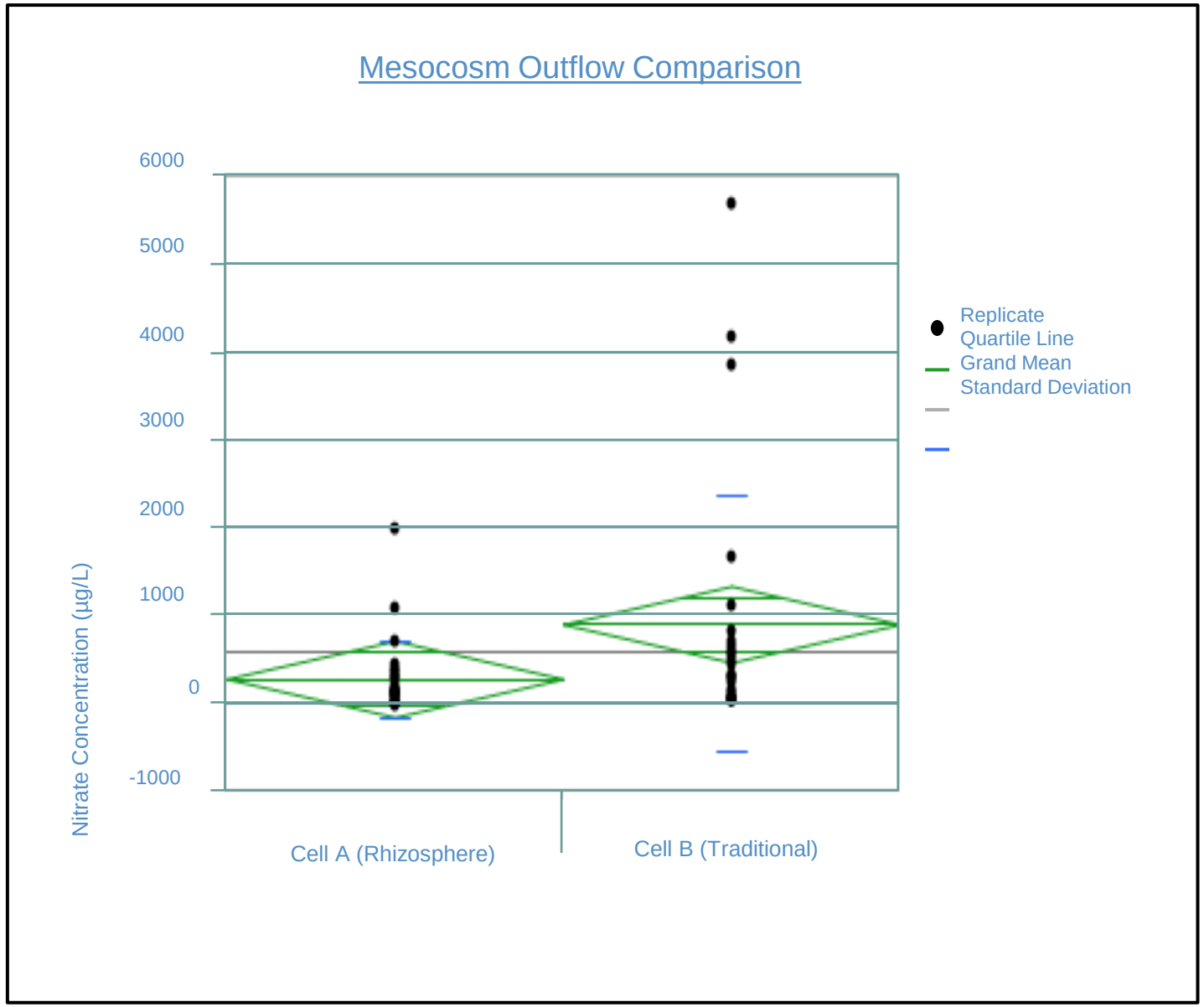




Results

- Cell A and Cell B were found to be statistically different.
- Cell A had outflow concentrations that were much lower than Cell B.

t Ratio	2.039547
DF	48
Prob > |t|	0.0469*
Prob > t	0.0235*
Prob < t	0.9765



Discussion

- Outflow from Cell A was statistically different from compost tests; however, further testing should be done in order to isolate individual variables between the two mesocosms.
- Overall, the new bioretention cell design did remove more nitrate and exported less nitrate than the traditional cell.
- Kaolinite clay and mulch was used in Cell A, which could have resulted in anaerobic pockets created within mulch layering, promoting denitrification. More study of system should be conducted in order to isolate and observe mulch and kaolinite clay layering.
- Nitrate could have been sorbed into the soil media, thereby favoring Cell A for nitrate removal, because of the more complex water pathways.

References

Dietz, Michael E., and John C. Clausen. "Stormwater Runoff and Export Changes with Development in a Traditional and Low Impact Subdivision." *Microbial and Nutrient Contaminants of Fresh and Coastal Waters* 87.4 (2008): 560-66. *Science Direct*. Elsevier B.V. Web. 29 July 2014.

Heylen, Kim. "Cultivation of Denitrifying Bacteria: Optimization of Isolation Conditions and Diversity Study." *American Society for Microbiology*. American Society for Microbiology, 30 Jan. 2006. Web. 29 Jun. 2014.

Ma, Chi, and Richard A. Eggleton. "Cation Exchange Capacity of Kaolinite."*Clays and Minerals* 47.2 (1999): 174-80. *Clays.org*. The Clay Mineral Society. Web. 27 July 2014.

Takaya, Naoki. "Aerobic Denitrifying Bacteria That Produce Low Levels of Nitrous Oxide." *American Society for Microbiology*. American Society for Microbiology, June 2003. Web. 24 Jun. 2014.

van der Heijden, M. G. "The Unseen Majority: Soil Microbes as Drivers of Plant Diversity and Productivity in Terrestrial Ecosystems." *US National Library of Medicine*. National Institute of Health, 11 Mar. 2008. Web. 29 Jul. 2014

Yang, Y. "Nitrogen Fixation Island and Rhizosphere Competence Traits in the Genome of Root-associated Pseudomonas Stutzeri A1501." Diss. Chinese Academy of Agricultural Sciences, n.d. *National Center for Biotechnology Information*. U.S. National Library of Medicine, 21 May 2008. Web. 27 Jul. 2014.

More information can be found at the University of Vermont's Plant and Soil Science Bioretention Lab's Page:
http://www.uvm.edu/~pss/?Page=bioretentionproject.html

Email: lsp1@Alfred.edu


Questions?
Alfred University
RACC
Research on Adaptation to Climate Change
Castleton
A VERMONT STATE COLLEGE
Vermont EPSCoR
CWDD
Center for Workforce Development & Diversity
AT SAINT MICHAEL'S COLLEGE
The UNIVERSITY of VERMONT