Green Roofs: a Sustainable Solution to Management of Storm Water Runoff on Northern Forest Working Landscapes

Principal Investigator: Gary J. Hawley
Affiliation/Institution: Research Associate, University of Vermont
Email: ghawley@uvm.edu
Mailing address: Rubenstein School of Environment and Natural Resources (RSENR)
204A Aiken Center, University of Vermont (UVM)
Burlington, VT 05405
Co-Principal Investigators: Paul G. Schaberg[1], Carl E. Waite[2], Alan W. McIntosh[2] and Deane Wang[2]
[1]USDA Forest Service, Northern Research Station, Burlington, VT
[2]RSENR, UVM, Burlington, VT
Emails: pschaberg@fs.fed.us, cwaite@uvm.edu, awmcinto@uvm.edu, deane.wang@uvm.edu
Completion date: 5/30/15

Green roof research and demonstration project reduces stormwater discharge and mediates extreme temperatures in the Northern Forest region.

Funding support for this project was provided by the Northeastern States Research Cooperative (NSRC), a partnership of Northern Forest states (New Hampshire, Vermont, Maine, and New York), in coordination with the USDA Forest Service.
http://www.nsrcforest.org

Project Summary

Large areas of impervious surfaces found in urban ecosystems often result in uncontrolled rapid runoff of stormwater. During runoff events in urban ecosystems, the high volume of water being deposited into nearby waterways carries pollutants that have washed off of impervious surfaces, as well as silt from erosion, and contributes to elevated water temperatures. Some of the newest methods to reduce stormwater impacts in the built environment include treating stormwater on-site before clean water is either reused or discharged in a controlled manner. This green roof research/demonstration project includes 8 rooftop watersheds on the Green Aiken Center at the University of Vermont that are monitored separately to provide water quality and water flow rates for each watershed. Four green roof treatments (control, standard plants with standard soil, standard plants with alternative soil, and alternative plants and standard soil), replicated twice, were used in this study. To assess the thermal benefits of green roofs, we monitored 56 temperature probes at different heights. In 2013, we assessed green roof treatment performance during 5 storm events and in 2014, we used continuous measurement of water quantity and quality. Two years of results confirm that green roof treatments had significantly less discharge than the control. Standard plants and soil had half as much discharge than the control, and the other treatments had about 25% less than the control. Peak flows were substantially less in vegetative watersheds than in the controls. Summer temperatures were lower under vegetative watersheds and winter temperatures were higher under vegetative watersheds than under non-vegetative control watersheds. Discharge concentrations were less than other green roof studies. Nitrate leaving the vegetative watersheds was higher than the controls while ammonium leaving vegetative watersheds was lower than the controls. Phosphorus leaving vegetative watersheds was greater than the controls while the standard plants and soil watershed had over twice as much phosphorus discharge as the biochar and alternative plants watersheds. Biochar as a soil additive appears to have some promise of reducing discharge of nitrogen and phosphorus.

Background and Justification

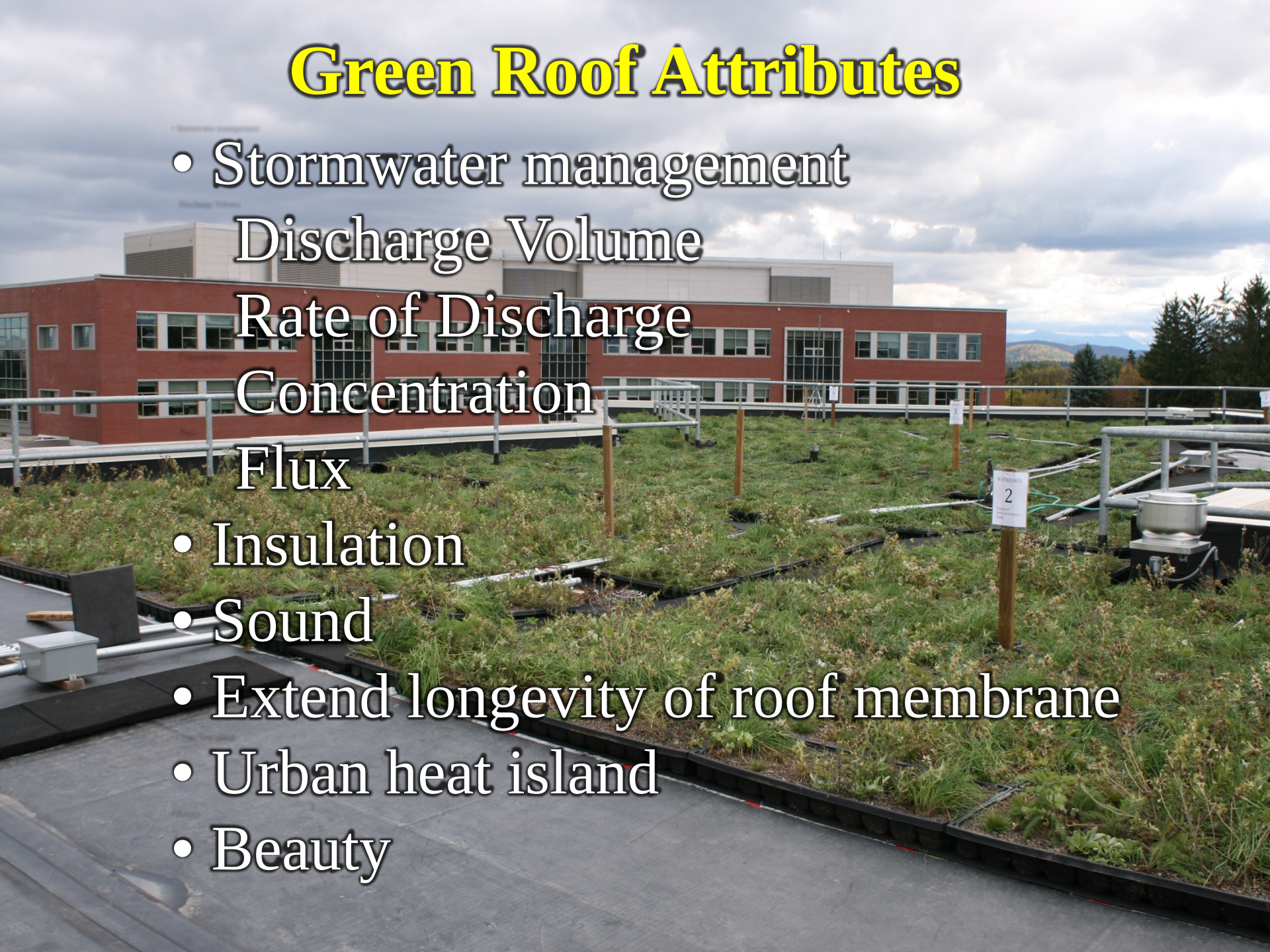
- In Vermont, nearly all of the 15 Stormwater Impaired Watersheds are associated with runoff from the working landscapes in urban ecosystems. Impervious surfaces found in these working landscapes often result in uncontrolled rapid runoff of stormwater

- Green roofs provide a mechanism that reduces rapid runoff from impervious surfaces and also absorb significant amounts of stormwater thus reducing the total amount of stormwater leaving urban ecosystems

- This green roof research/demonstration project includes 8 rooftop watersheds on the Green Aiken Center that are monitored separately to provide water quality and water flow rates for each watershed

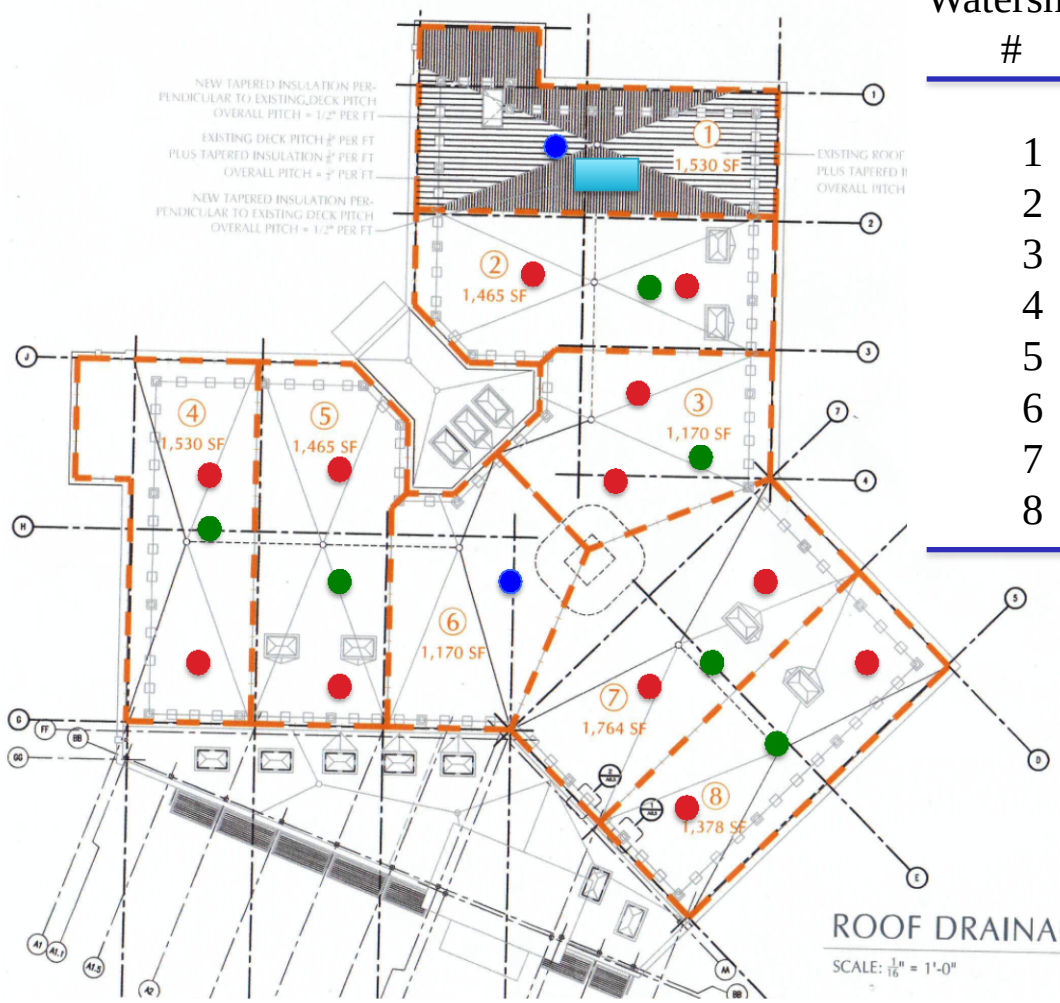
- We varied the plant species and soil type used in each of the watersheds in a replicated design in order to assess the differential stormwater management abilities of each plant/soil type combination

Green Roof Attributes



- Stormwater management
  - Discharge Volume
  - Rate of Discharge
  - Concentration
  - Flux
- Insulation
- Sound
- Extend longevity of roof membrane
- Urban heat island
- Beauty

Aiken Center Experimental Green Roof Project
The University of Vermont



Rooftop Watershed #	Size (m^2)
1	141.1
2	124.5
3	100.2
4	140.1
5	125.6
6	99.4
7	155.9
8	112.4

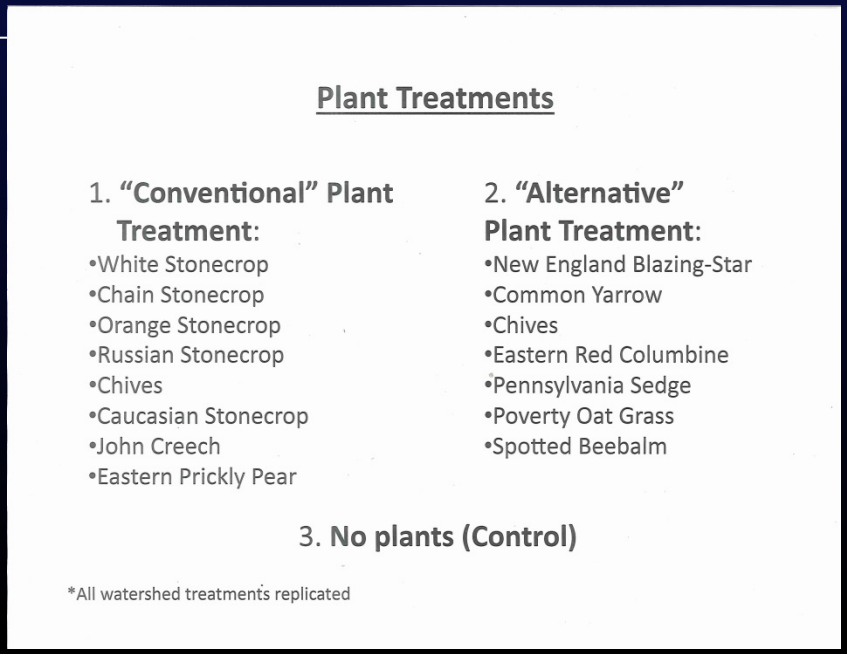
Methods

Green Roof Treatments

	Plants	Soil
Treatment 1	Control	Control
Treatment 2	Standard (Conventional)	Standard
Treatment 3	Standard	Biochar added
Treatment 4	Alternative mix	Standard

Each treatment replicated 2 times

- Green roof treatments (shown above) were selected to compare non-vegetated, standard soil and vegetation to alternative plants and soil treatments
- Treatments and plants used are listed to the right



Plant Treatments

1. **"Conventional" Plant Treatment:**
   - White Stonecrop
   - Chain Stonecrop
   - Orange Stonecrop
   - Russian Stonecrop
   - Chives
   - Caucasian Stonecrop
   - John Creech
   - Eastern Prickly Pear

2. **"Alternative" Plant Treatment:**
   - New England Blazing-Star
   - Common Yarrow
   - Chives
   - Eastern Red Columbine
   - Pennsylvania Sedge
   - Poverty Oat Grass
   - Spotted Beebalm

3. **No plants (Control)**

*All watershed treatments replicated

Data Collected

2013 Data:

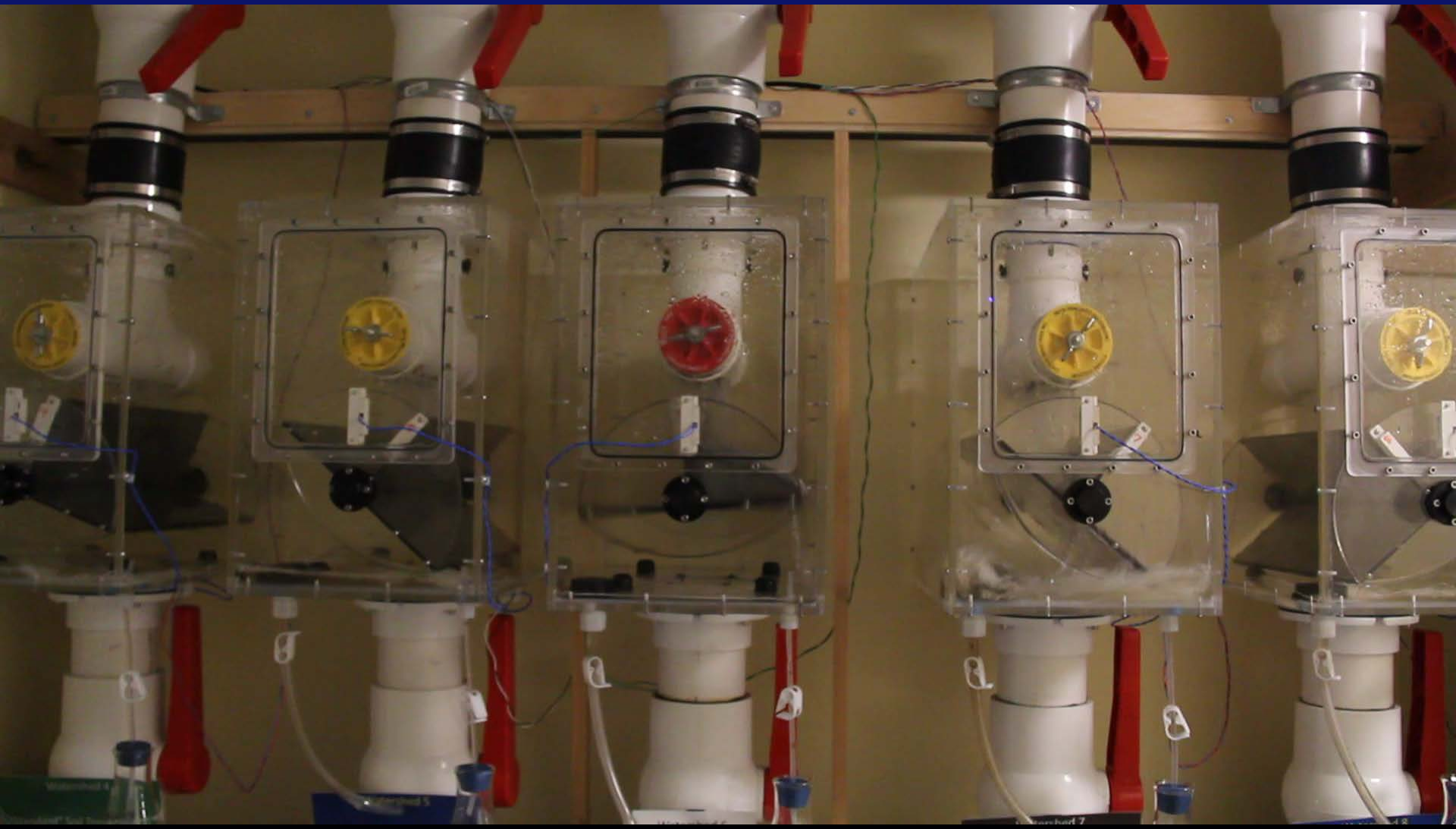
- Discharge volume and rate for 5 storms
- Grab samples of 5 storms (3 samples per storm)
- Water quality samples completed
- Temperature data

2014 Data:

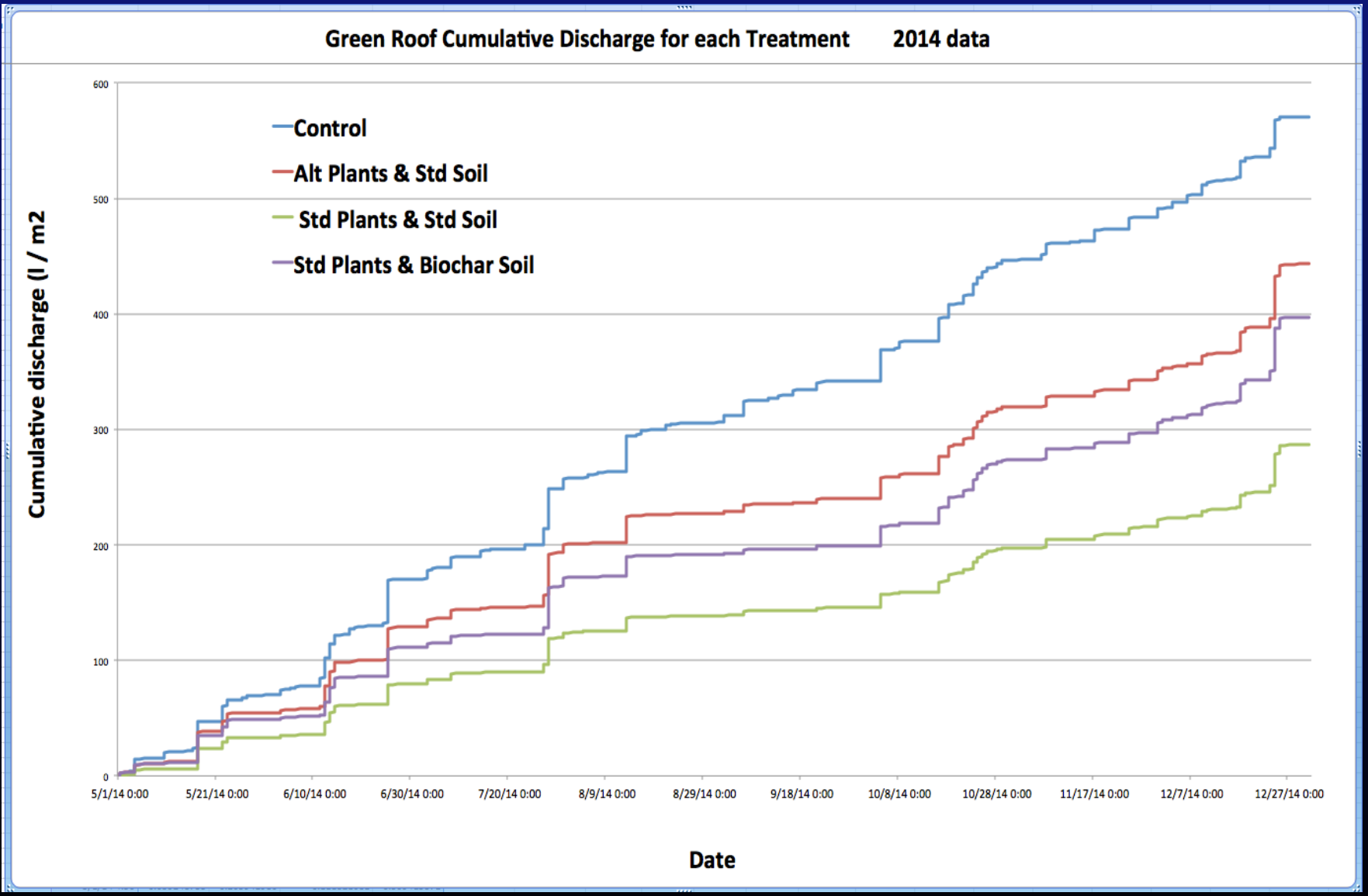
- Continuous Discharge volume and rate
- Continuous proportional sampling from May 1 to December 31, 2014
- Water quality samples being assessed in analytical lab
- Temperature data

Tipping Buckets

Water quantity and water quality measures



Results/Project outcomes



% of Control

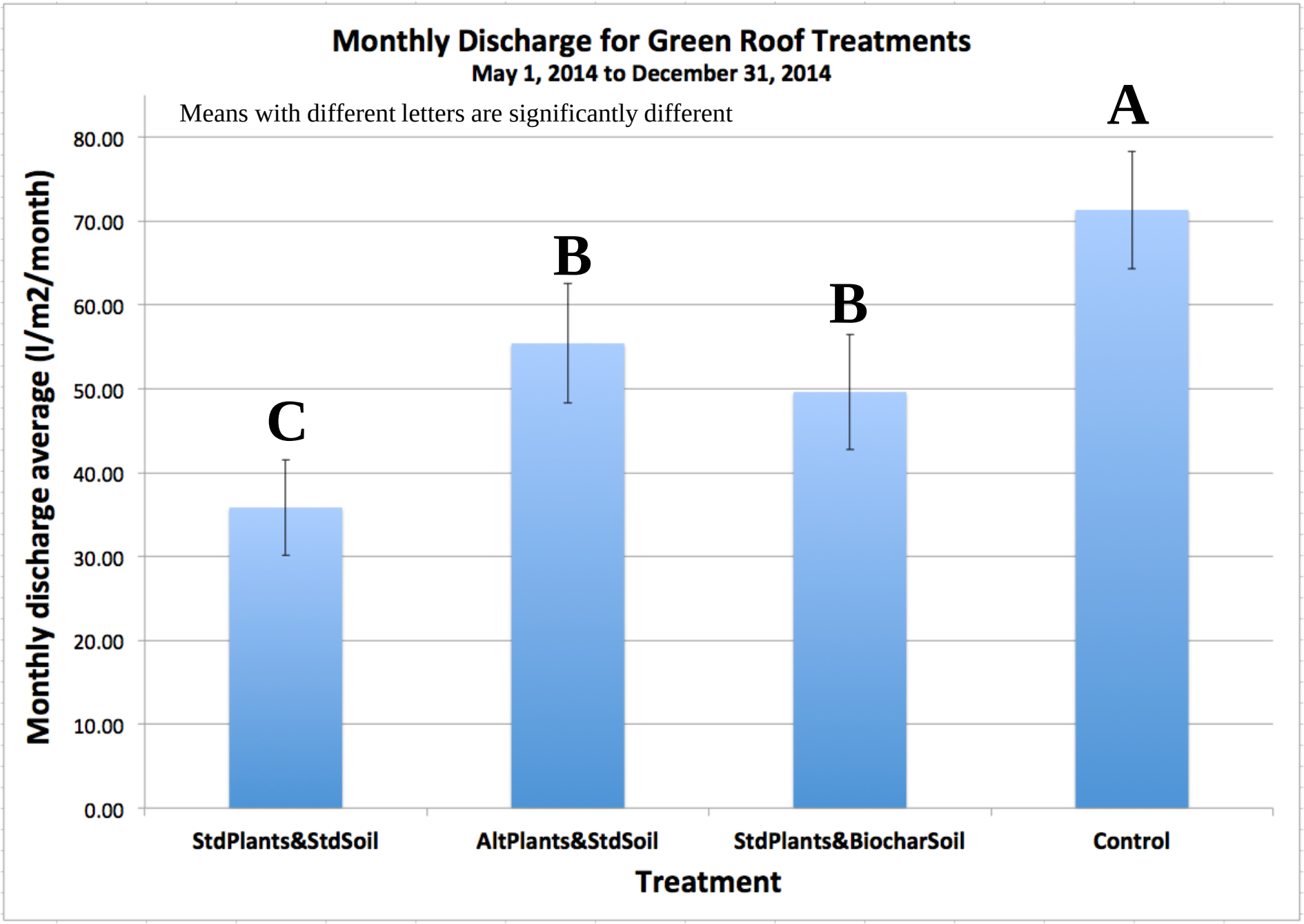
100%

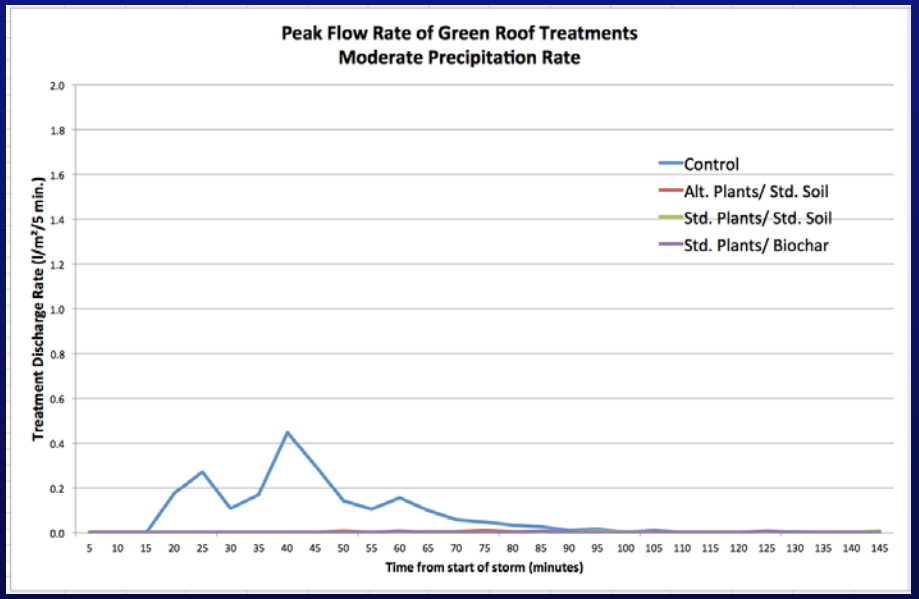
77.5%

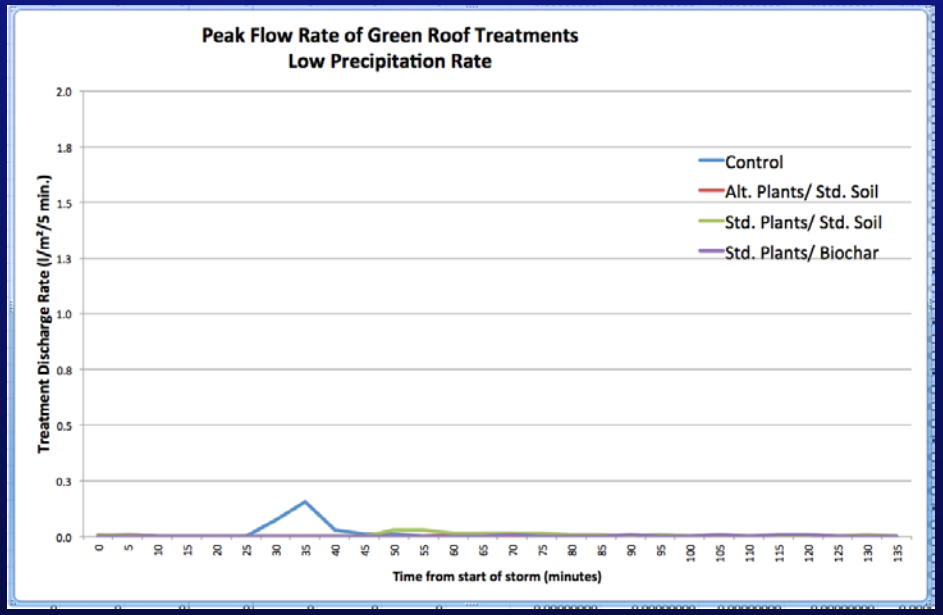
69.6%

50.3%

Vegetated watersheds reduced total yearly cumulative discharge by 25 to 50%

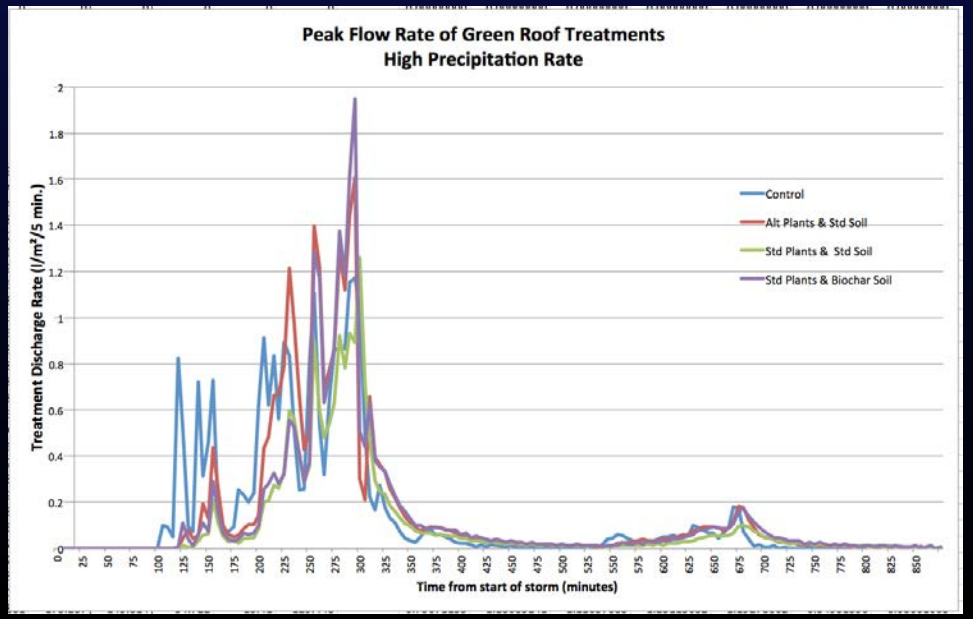

Monthly Discharge for Green Roof Treatments
May 1, 2014 to December 31, 2014
Means with different letters are significantly different
A
B
B
C
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Monthly discharge average (l/m2/month)
StdPlants&StdSoil
AltPlants&StdSoil
StdPlants&BiocharSoil
Control
Treatment

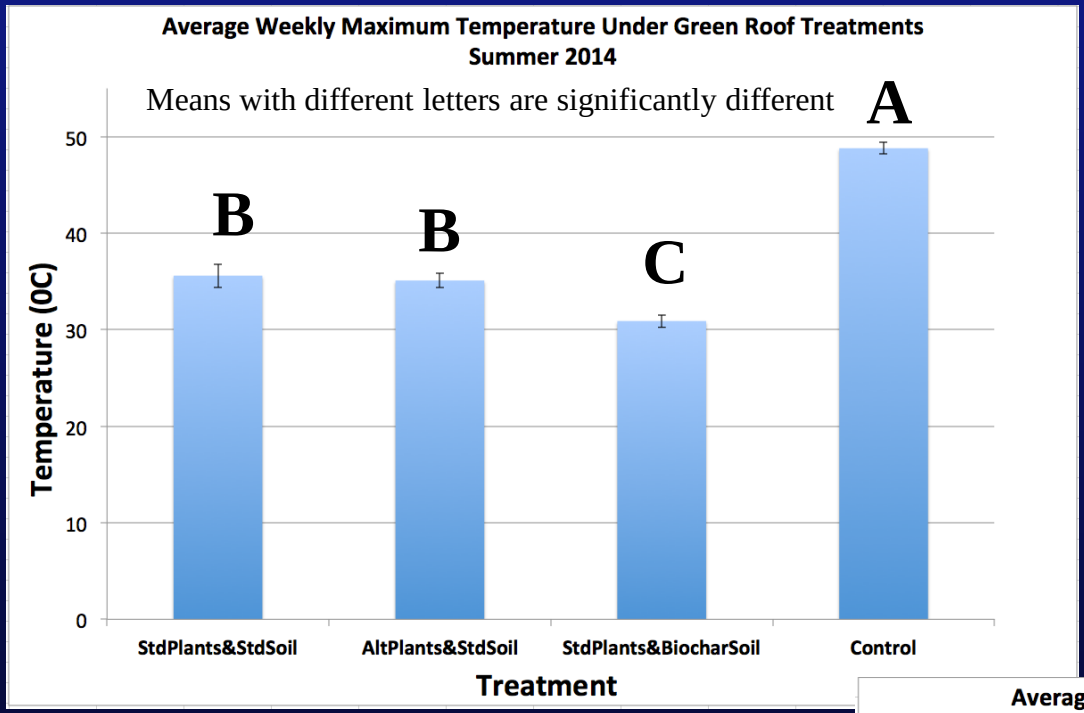




Storms with low and moderate precipitation rates were almost entirely absorbed by the green roof (above and upper right)

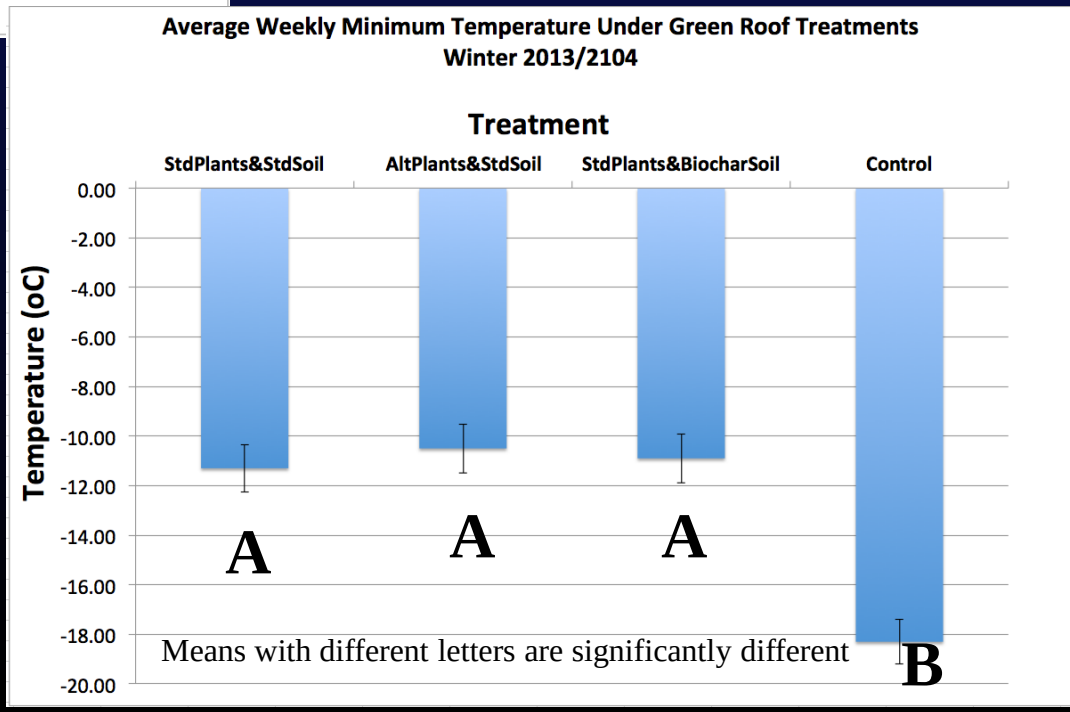
After vegetative watersheds became saturated in high precipitation rate storms they discharge similar amounts as the control watersheds (see figure at bottom right)



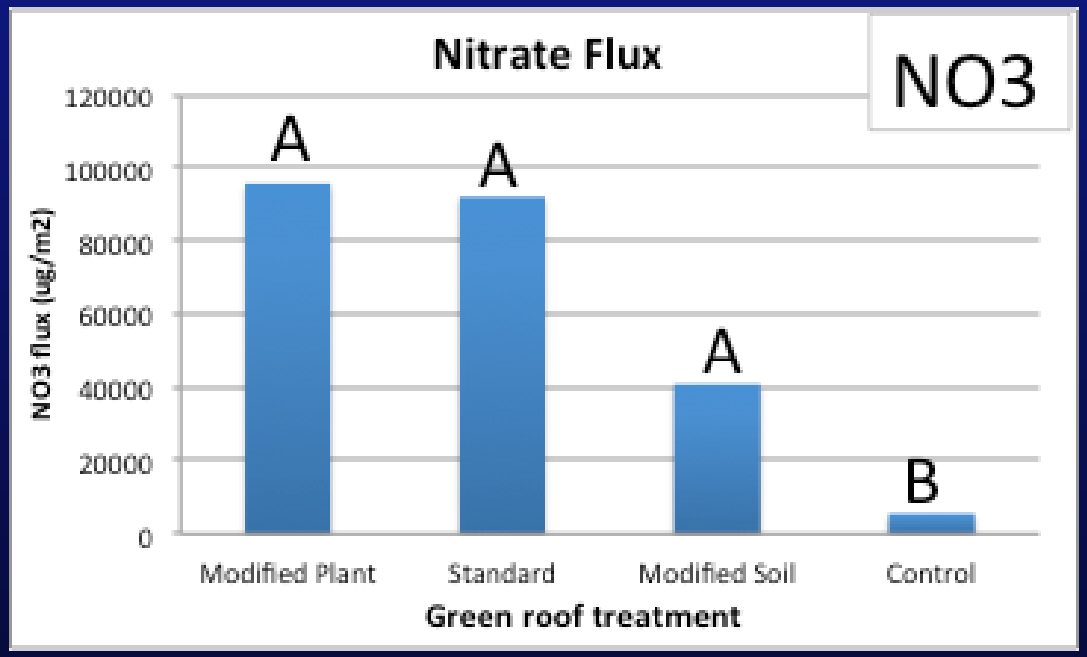


Vegetative watersheds are significantly cooler than control watersheds in the summer (see left figure)

Vegetative watersheds are significantly warmer than control watersheds in the winter(see right figure)

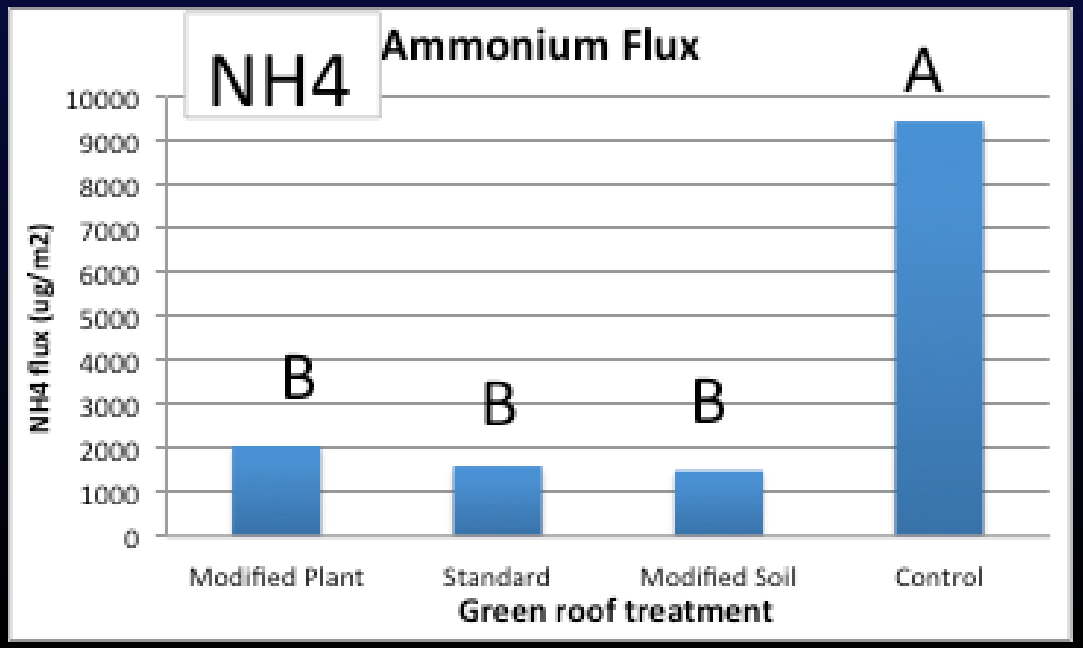


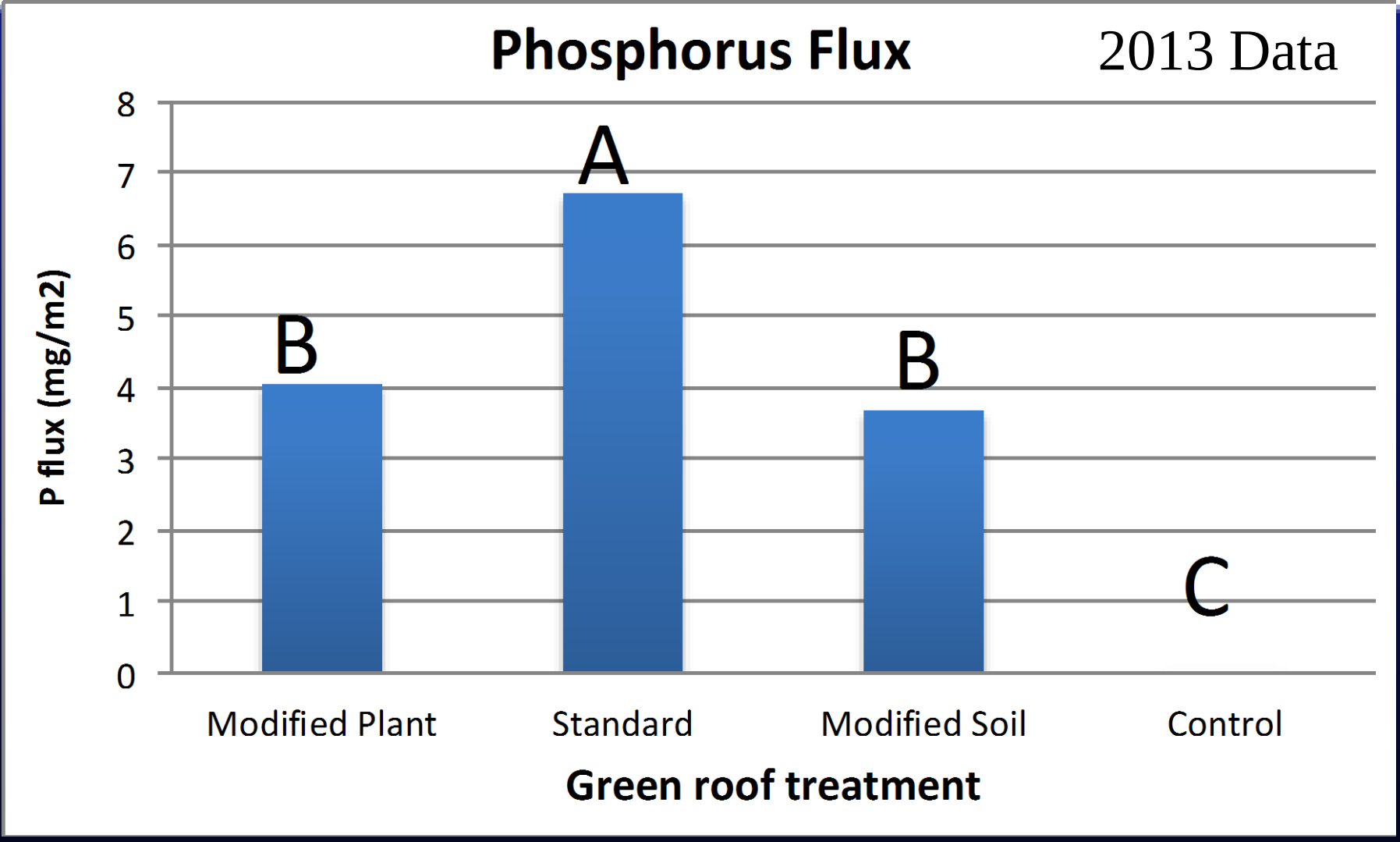
2013 Data



Significantly more nitrate was discharged from vegetative watersheds compared to the control (left)

Significantly less ammonium was discharged from vegetative watersheds compared to the control (right)





- Significantly more phosphorus was discharged from vegetative watersheds compared to the control
- Standard plants and soil discharged the most amount of phosphorus compared to other treatments

Outreach Efforts

Outreach efforts resulting from this project were and continue to be substantial

•During the installation of the green roof project there were numerous media outlets that documented the process including the significant student involvement and educational benefits.

•Multipage Burlington Free press articles highlighted this research and associated educational benefits

•Slide shows and professional videos from this project are shown on the UVM Rubenstein School web page

•Hundreds of tours of this research involving 500 or more students, scientists, politicians, builders, developers and local citizens have and continue to take place

•This project is also part of a yearly class of interns that learn from the sustainable building practices taking place in UVM's Aiken Center. This class has taught over 300 interns in the last 14 years

Implications and applications in the Northern Forest region

- This project has shown the water quality and water quantity impacts of green roofs on stormwater in the Northern Forest region. With this information municipalities in the Northern Forest Region with stormwater problems can estimate the impacts of installing green roofs and potentially invest in green roofs to help minimize stormwater impacts

- This work is also a working example of sustainable green building practices that are beneficial to many students who want to minimize human impacts on our natural ecosystems

Future directions

- Results from this project highlight the benefits of providing vegetative buffer zones around wetlands, streams, rivers, ponds and lakes

- Expanding the results from this study to show the benefits of adding green roofs to all flat-roofed buildings in a municipality could help encourage new green roofs and result in the improvement of water quality and erosion problems

List of products

- We have and will continue to involve students in this project in all aspects of the research. For examples of Greening of Aiken Interns, projects including those involving the green roof, please look on the following Wiki site: http://greening-aiken.wikispaces.com/Greening+Aiken+Home

- There was an undergraduate Honors Thesis completed on the first summer of green roof data. In addition I was asked to give an invited presentation at the Winooski Natural Resource Conservation District Annual Meeting. Citations for this work are shown below:

- Hawley, G.J., E. Bennett and C.E. Waite. First-year stormwater runoff results from the green roof treatments on the Aiken Center at the University of Vermont. Invited presentation. Winooski Natural Resource Conservation District Annual Meeting. Waterbury, VT. October 13, 2013.

- Bennett, E. 2013. First year results from the University of Vermont's Aiken Center green roof research project. University of Vermont Honors Thesis. 17 pp.

List of products continued

- There is a great deal of public interest in the project. The green roof installation was a big event with large delivery trucks, cranes to lift the plants onto the roof and many UVM students, faculty and staff involved. The local TV and written press, UVM press and the Across the Fence program personnel documented this event. This installation was an important public event for all the funding groups involved with the project (NSRC, EPA, and McIntire Stennis). Links to examples of the numerous press activities associated with the Aiken Center Green Roof are shown below:

- http://www.uvm.edu/rsenr/aiken/files/Hawley-IBelieve-BFP-4Nov12-1.pdf

- http://www.uvm.edu/~uvmpr/?Page=news&storyID=14596&category=ucommall

- http://www.wcax.com/story/19808552/rooftop-lessons-at-uvm

- http://www.uvm.edu/rsenr/?Page=aiken/aiken.html

- Presented an international webinar sponsored by the Agency of Natural Resources titled “Green Stormwater Infrastructure Webinar: Green Roof. Presented webinar along with Mark Gleason form Middlebury College. YouTube of video shown at: https://youtu.be/4gmhjemLQQQ .Presented June 10, 2015.