Planning and Implementing Green Infrastructure to Improve Watershed Resiliency in the Saw Mill Brook Watershed and Village of New Paltz

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Abstract
This project applied water and climate research to applications in a campus setting, as an example of ways to adapt to climate change in the watershed of the Hudson River Estuary. Green infrastructure and stormwater management practices were implemented on and near the SUNY New Paltz campus and monitored for their effect: a permeable pavement expansion of the largest parking lot on campus; vegetated swales adjacent to residence halls, enhanced bioretention areas and rain gardens at a heavily traversed location, and stream daylighting. An interpretive map and walking tour of project elements was constructed; including educational and interpretive signage to highlight the practices on campus and in the village for residents, visitors, and students. Learning modules about climate change, flooding, and green stormwater practices for middle school environmental curriculum were developed to accompany field trips to the tour. Interdisciplinary watershed management educational activities and materials with a focus on climate change, flooding, and stormwater management were created and infused into college curriculum. A faculty-student research team monitored water quality, establishing baseline data and ongoing measurement processes of progress toward achieving water quality goals in the Saw Mill Brook watershed.

Three Summary Points of Interest
- SUNY New Paltz is a model campus for green infrastructure practices.
- The SUNY New Paltz walking tour will highlight the infrastructure and water quality efforts on and off campus.
- Environmental monitoring has established a baseline of water quality and quantity through campus.

Keywords
water quality, green infrastructure, high resolution/real-time data, temporal, storms/precipitation, severity, land use/cover, watershed, campus, SUNY New Paltz, infiltration, green curriculum
This report is divided into seven sections:

1. Introduction
2. Green infrastructure (GI) practices
3. Water quality monitoring
4. Mapping, signage, and walking tour
5. Curriculum development and infusion
6. Presentations and media coverage
7. Future plans

Introduction
The Center for Research, Regional Education and Outreach (CRREO)’s “Planning and Implementing Green Infrastructure to Improve Watershed Resiliency” project sought to address climate change, reduce flooding, improve water quality, and restore watersheds. Collaborative partners included Cornell University’s Water Resources Institute, the Hudson River Estuary Program, SUNY New Paltz, and the Village of New Paltz. Green infrastructure and stormwater management practices were implemented on and near the New Paltz campus and monitored for their effect: a permeable pavement expansion of the largest parking lot on campus; vegetated swales adjacent to residence halls, enhanced bioretention areas and rain gardens at one of the most heavily traversed locations in the heart of campus; and stream daylighting to decrease the impact of northern campus stormwater runoff into the surrounding village.

An interpretive map and walking tour of the project’s elements was constructed; including educational and interpretive signage to highlight green infrastructure practices on campus and in the village for residents, visitors, and students. Learning modules about climate change, flooding, and green stormwater practices for middle school environmental curriculum were developed by School of Education faculty member Rosemary Millham to accompany field trips to the walking tour. Interdisciplinary watershed management educational activities and materials with a focus on climate change, flooding, and stormwater management were created and implemented for infusion into college curriculum, including hands-on field work components. Both natural and social science elements of sustainable water, policy development, planning, implementation, and assessment were addressed. Biologist David Richardson led a faculty-student research team monitoring water quality, establishing baseline data and ongoing measurement processes of progress toward achieving water quality goals in the Saw Mill Brook watershed.

SUNY New Paltz is a signatory to the American College and University Presidents’ Climate Commitment, a national program that facilitates the expansion of environmental education and research and to improve environmental performance on college campuses. This demonstrated commitment to sustainability throughout the institution enhances our attractiveness as a showcase for sustainable water quality practices and watershed management for institutions of higher education in the Hudson Valley and throughout New York State.

Green Infrastructure Practices
Various Green Infrastructure (GI) practices have been constructed and implemented as a result of this funding (or in conjunction with this funding) both at the SUNY New Paltz and in the Village of New Paltz. The permeable (porous) parking lot addition to the Route 32 campus parking lot is complete and open to parking (Fig. 1).

Fig. 1. Original signage at the Route 32 lot

The Lenape Bioswales are also complete and draw water from the parking lots surrounding Lenape dorms. The Crispell bioretention raingardens enhancement plantings were installed with some of the extra plants serving critical spots across campus.
The stream daylighting project in Peace Park in the Village of New Paltz has been completed (Fig. 2). Several other projects that were not funded under this project but will contribute to the overall GI list on campus include a rain harvesting system that was installed as part of the Wooster Science building renovation. Further, funded with a NEIWPCC/Hudson River Estuary Program grant, a rain water harvesting system was included in the recent LeFerve Hall dorm renovation.

Fig. 2. Stream daylighting in the Village of New Paltz, across from village hall and adjacent to campus

Water quality monitoring
Water quality monitoring took place over 16 months with two complete summers (2013 and 2014). In collaboration with several other faculty members including KT Tobin and Shafiul Chowdhury (Geology), Richardson (Biog) directed student driven research and outreach. The students came from multiple disciplines. In 2013, there were five student researchers detailed by their major and then contribution to the project in parentheses: Alex LeTourneau – Computer Science (Buoy), Caitlyn Maceli – EGS (Biology/Chemistry sampling), Alison Uhrlass – Geology (Mapping), Bill O’Connell – Geology (Precipitation/Hydrology), Kevin Kolvenbach – EGS (support). In 2014, there were five students researchers: Caitlyn Maceli – EGS (Biology/Chemistry sampling), Steven DiMeglio – EGS (Biology/Chemistry sampling and hydrology), Kelsey Hillerud – Communications/Media (Documentary), Lindsay Muir – Graphic Design (Infographics). Each summer, the students worked June and July and presented their results from the summer to their faculty mentors and KT Tobin. Alex and Caitlyn continued working on their respectively pieces beyond the summer as independent study students for credit under Dr. Richardson’s supervision.

We longitudinally sampled the ponds on campus from the upstream most pond to the spillway on a weekly to biweekly basis and analyzed biological, physical, and chemical metrics including temperature, pH, conductivity, chlorophyll, total suspended solids, and fecal coliform bacteria. We found that the four inlet pipes that feed the pond system have conductivity that varies over an order of magnitude and likely comes from different storm water drain and surface water sources. We also found high densities of fecal coliform bacteria, especially after storms (Fig. 3). Based on total phosphorus concentrations (Fig. 4) and chlorophyll a concentrations (Fig. 5), the Gunk has a trophic state index that ranges from 46 to 86 indicating the Gunk progresses from mildly eutrophic to hypereutrophic conditions as the summer daylight hours increase. Surprisingly, herbicide treatments (Copper Sulfate) for the algal blooms in 2013 saw minimal effects on algal biomass, likely because of increasing

Fig. 3. Fecal coliform bacteria in the Gunk outflow over summer through fall 2013.
Herbicide applications were replaced by an infrequent manual removal and composting of the algae in 2014. Clearly, there are other mechanisms that regulate the algal biomass in the campus ponds including high background concentrations of phosphorus, possibly as a legacy of high water fowl density around the ponds, past inorganic nutrient treatments of the lawns or other storm related P inflow.

In 2013, we first launched the Environmental Monitoring Buoy (Fig. 6); we relaunched the buoy in late spring 2014. The buoy had to be assembled and calibrated and now, every 15 minutes, data is transmitted via cell phone signal, to a server and is posted to the web for anyone to see (buoy.newpaltz.edu). The buoy monitors pH, temperature, conductivity, dissolved oxygen, and turbidity. Following each sampling season, the buoy was removed during the first cold weather in October/November. There are some interesting patterns of dissolved oxygen dynamics related to the application of algaecide to the campus pond and diel cycles of oxygen due to primary production and photosynthesis (Fig. 7). We wanted to note that during late August and early September, the buoy went anoxic. There may have been fish kills or major fish movement during that time period.
We worked on developing maps of campus and the watershed. Watershed delineations were established for the Saw Mill Brook including the SUNY New Paltz campus based on digital elevation models. These maps revealed that the headwaters of Saw Mill Brook were not on campus, as we had surmised, but continued across Route 32 uphill into the Cherry Hill neighborhood. Second, we developed a map of the bathymetry of the pond system using systematic measurements of water depth while kayaking.

We deployed several environmental sensors to measure the hydrologic flow from the spillway and a tipping bucket precipitation gauge near the South Classroom building. We installed a pressure transducer at the outflow of the large pond and completed weekly manual measurements of discharge. Storm sampling was completed with hourly collection during and following large rain events using ISCO samplers, we did not experience the intense storms like 2011 & 2012, but we did have some heavy rains, especially a significant storm in late June 2013.

Finally, in summer 2014, we measured the effectiveness of the bioswale and porous pavement in improving water infiltration into the soils and ground water. We measured adjacent locations as controls for the GI projects. For example, we measured nearby lawns to match with the bioswales and found that the infiltration rates were 11 times higher in the bioswale than typically campus lawns with high foot and vehicle traffic. We also found
that the pervious pavement was effective in promoting infiltration, up to 130 times faster than in older impermeable pavement and 2.5 times faster than new, freshly laid impermeable pavement (Fig. 8).

**Mapping, signage, and walking tour**

Professors KT Tobin and David Richardson, and undergraduate research student, Caitlyn Maceli, have all led guided tours of our GI and water quality monitoring projects. Tour attendees include Vassar College professors and students, classes from campus (Sociology, Art, and Biology departments), campus administrators, members of the NY Rising committee, and others. We have compiled all the existing and planned practices for the walking tour and include the water bodies, GI sites (rain gardens, bioswales, pervious parking lot, stream daylighting), and new building constructions. Josh Simons (CRREO) along with student interns, has led mapping efforts to create campus base maps with multiple layers of related to green infrastructure and campus function as a whole including walking paths, water bodies, our GI sites, trees, and the master facilities plan. Educational and interpretive signage, led by Lisa Mitten, our campus sustainability coordinator, have been staked and will be installed as soon as snow melts and the ground thaws this spring (Fig. 9).

**Curriculum development and infusion**

In the fall of 2013, we recruited faculty from across multiple disciplines at SUNY New Paltz (Table 1) representing every school – Fine & Performing Arts, Education, Liberal Arts & Sciences, Business, Science & Engineering. For the cross-course collaboration, the general topic of water, water use, and green infrastructure was woven into each course with at least in one project/lab/paper assigned based on this project. The projects are described in more detail below.

At the end of the semester, December 11, 2013, we held a large poster session and symposium to present student projects, discuss the GI projects, and have a panel discussion of the cross curricular enhancement. The student poster session included posters from all the below courses. Some of the major results from the student work, as highlighted in this article: [http://oracle.newpaltz.edu/students-soak-up-science/](http://oracle.newpaltz.edu/students-soak-up-science/) were sociological surveys of students at this campus and administrators across different campuses, field experiments that determined the infiltration rates across different campuses, and connecting students to local ecology. This event was well-attended and included about 50 student posters and a panel discussion with Emily Vail (DEC, HREP, WRI), KT Tobin, David Richardson, Brian Obach, Eric Keeling, and others all presenting.

In Friday’s Graduate Art seminar class, the focus was on the question of how humans relate to regional watersheds (additional collaborators included: Clearwater, the Poughkeepsie High School, SPURSE LLC and the Children’s Media Laboratory). The class began with a series of lectures on political ecology, new urbanism and ecological art that included readings such as Ivan Illich’s *H20 and the Waters of Forgetfulness*, *The Hudson River Primer* by David Strayer and *Water: A Natural History* by Alice Outwater. For the “A Day in The Life of The Hudson River” on October 10th, students also developed a series of maps and physical projects that directly address water quality issues and sharing these during
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Obach’s Environmental Sociology class read Postel’s “Water: Adapting to a New Normal” from *The Post Carbon Reader*. They took a campus tour focusing on the green infrastructure projects and visited the Village of New Paltz wastewater treatment plant. Lisa Mitten, Campus Sustainability Coordinator was a guest speaker about what our campus is doing about water conservation, and the class will conduct a project related to what campuses can do about water-related issues.

Table 1. Participating majors, faculty, and courses

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<thead>
<tr>
<th>Major</th>
<th>Faculty</th>
<th>Course</th>
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<tbody>
<tr>
<td>Art</td>
<td>Matthew Friday</td>
<td>Graduate Art Seminar</td>
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<tr>
<td>Biology</td>
<td>David Richardson &amp; Eric Keeling</td>
<td>Ecology</td>
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<tr>
<td>Business</td>
<td>Pom Jiraporn</td>
<td>Consumer Behavior</td>
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<tr>
<td>Education</td>
<td>Ro Millham</td>
<td>Middle School Science Enrichment Program + Teaching Science in Secondary Schools</td>
</tr>
<tr>
<td>Environmental Geochemical Sciences</td>
<td>Meghan Ferguson</td>
<td>Environmental Geochemical Science</td>
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<tr>
<td>Sociology</td>
<td>Brian Obach</td>
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<tr>
<td>Sociology</td>
<td>KT Tobin</td>
<td>Research Methods</td>
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Tobin’s Research Methods class integrated varied articles on water-related social research (e.g. Marshall and Jones – *Citizen Participation in Natural Resource Management*, Sadalla et al – *Priorities in Residential Water Use*). They have taken the campus walking tour, and, and also met with Lisa Mitten. Students developed and conducted a survey research project about SUNY New Paltz students’ awareness, attitudes, and behaviors related to water issues on campus.

In Jiraporn’s Consumer Behavior class, one assignment was a sustainability campaign targeted towards college students. One group focused on a promotional campaign with key messages about water conservation. Students used theories in the consumer behavior course to justify their campaigns.

Rosemary Millham’s Science Enrichment Middle School students played a water usage game and the green stormwater practices lesson from her MS curriculum (see below). In her Teaching Science Secondary Ed class, students were taken into the field to discuss green infrastructures and take notes during a campus walk. After discussion and the purpose for green infrastructures were identified by the students, they created a lesson plan to teach a lesson about water resources, climate change, and how we can mitigate flooding. Several of her students were at the "Day in the Life of the Hudson" event with Millham testing the waters.

In Richardson, Ferguson, and Keeling’s Ecology and Environmental Geochemical Science courses, students spent one lab examining the pathways of water flowing through campus and the effect of development on water quality and quantity. They mapped the different land use/land cover on campus based on different criteria and did an experiment to determine the infiltration rates of storm events to recharge groundwater (Fig. 10). The students focused on the new pervious surface Route 32 parking lot.

Fig. 10. Students in Ecology class working in measuring infiltration rates into compacted soils.
In collaboration with NASA, Rosemary Millham (Elementary Ed) prepared middle school curriculum for classroom use of the campus as a field trip location, to walk the tour and complete associated lesson plans. She has completed 9 lessons for MS teachers to choose from including “Watch Your Storm Drain!!,” “How Much Water Do You Use?,” and others.

Presentations and media coverage

SUNY New Paltz students created this short documentary video highlighting the project: https://vimeo.com/105768848

The following is a list of presentations, conferences, and other events that have stemmed from this project.

- Tobin presented at the “Green Infrastructure for Water Quality and Neighborhood Revitalization” conference at SUNY Orange on May 28, 2013
- John McEnrue presented on SUNY New Paltz’s Green Infrastructure at the Vassar College Green Campus Infrastructure conference on May 28, 2013
- Tobin & John McEnrue presented on SUNY New Paltz’s Green Infrastructure to a visiting contingent of Chinese government officials on July 8, 2013
- Tobin presented the project with Emily Vail/DEC at the annual meeting of the Environmental Consortium of Colleges and Universities on Nov 9, 2013. See http://www.environmentalconsortium.org/news/annualmeet.html
- Tobin presented the project on Nov 11, 2013 at the Mohonk Consultations & Hudson River Watershed Alliance conference “A Watershed Moment: Changing Climate & the Future of Our Water Resources” See http://hosted-p0.vresp.com/1035369/c711f5a99e
- Water Symposium Dec 11, 2013, 2:00-4:40 LC 100 presentations from multiple professors and students
- Richardson and students put up posters for Watershed Roundtable at SUNY New Paltz on Mar. 28, 2014.
- Richardson’s students presented posters of their research at the Hudson River Symposium, SUNY New Paltz Student Research Symposium, and Joint Aquatic Sciences Meeting (national conference in Portland, Oregon) all in spring and early summer 2014.

As additional outreach, we have included photos and information on our CRREO Facebook page and on the SUNY New Paltz website. Emily Vail from DEC did some historical research about the Saw Mill at our local library, as did Richardson’s students, and we now have a portfolio of photos and associated with the project.

This project received mention in the recently released NYSERDA funded Mid-Hudson Regional Sustainability Plan (page 8-21).

Select media coverage of the project:

- http://oracle.newpaltz.edu/ floating-along-the-live-stream/
- http://oracle.newpaltz.edu/students-soak-up-science/

Future plans

Related to this project, Tobin and Richardson are interested in publishing in journals focused on pedagogy, e.g. Teaching Sociology; and articles about engaging the public and other stakeholders. We are currently writing a scientific manuscript about this research, with Vail and Maceli as co-authors, to Urban Ecology in 2015.

When the walking tour signage is in place this spring, we plan to have a ribbon cutting and celebratory event.