UNH Stormwater Research –
Green Infrastructure Adaptations to Intensifying Rainfall

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Abstract

In order to address localized urban flooding events that have happened on the University of New Haven (UNH) campus in recent years, temporary measures have been put in place while more long-term solutions are being sought. Projections that precipitation events in Connecticut will continue to increase significantly in intensity as a result of climate change require urgent action be taken to prevent future flooding occurrences. The goal of this study was to identify the best green infrastructure options to aid in the development of effective long-term solutions. It is our recommendation that UNH should incorporate green infrastructure that minimizes virgin resource inputs during construction and maintenance. To reduce stormwater volume on campus, it is recommended that UNH replace some turf areas with native plantings that can serve as infiltration locations, as well as replacing impervious parking and sidewalk areas with pervious surfaces overlaying infiltration beds; runoff gathered by roof downspouts should be directed to these new infiltration areas or useful water harvesting devices as feasible. Once installed, on-going analysis needs to be carried out at these new green infrastructure applications to discern whether net economic, social, and environmental impact goals are being attained and balanced for UNH's campus.

Introduction

As microcosms of society, university campuses such as the University if New Haven are interesting and valuable locations for research into sustainability challenges that are shared by the campus and surrounding communities. This research, conducted over the summer of 2014, had the following UNH-specific goals:

- Create awareness on campus about the significance of and relations between stormwater, climate change, and localized urban flooding issues.
- Investigate and compare alternative solutions to UNH's localized flooding issue, using a life cycle approach to address economic, social, and environmental implications.
- Propose feasible options that UNH may use to both minimize campus flooding while additionally taking advantage of green infrastructure's ancillary benefits.

Localized urban flooding at UNH has caused and threatens to continue causing damage to property, health and safety risks, and environmental damages. A main culprit of this flooding is extensive amounts of impervious surface that generate stormwater runoff during rain events. Stormwater runoff not only results in dangerous and costly urban flooding, but also contributes to point and nonpoint source pollution that degrades local and downstream environments and poses health risks and economic costs to residents.

Paying to expand sewer system and wastewater treatment capacity, however, is easier said than done. Furthermore, as some regions of the U.S. experience changing climate patterns, the already dire circumstances are worsened by increasingly severe precipitation events that overwhelm existing infrastructure more and more frequently. In tandem with necessary improvements to traditional sewer infrastructure, investments in green infrastructure (GI) work toward reducing stormwater volumes by capturing and treating rain where it falls as opposed to routing it to centralized facilities. GI has many ancillary benefits beyond stormwater management that are making it an increasingly popular option that maximizes the return on investment dollars. This research seeks to investigate GI approaches that UNH may find effective for addressing campus stormwater issues. The questions addressed by this research are:

- What is the current state of UNH's stormwater situation?
- How is local precipitation projected to behave in light of climate change?
- What green infrastructure practices are currently being used to address stormwater management and how effective are they?
- Which of these green infrastructure practices could be considered feasible solutions to UNH's stormwater issues?

Understanding the answers to these questions will enable UNH to make informed decisions about how best to manage stormwater in the long term.

Background

Storm water picks up pollutants such as heavy metals, oils, pathogens, litter and sediments when it washes over impermeable surfaces that are typically found in urbanized residential, commercial, and industrial areas. Impermeable surfaces are those that do not allow water to pass through, such as traditional concrete or asphalt used to pave parking lots and roads, as well as surfaces such as rooftops. It is mostly characterized by the built environment and therefore storm water management remains to be an important challenge in urban locations. In addition to pollutants picked up on impermeable surfaces, stormwater can also pick up excess nutrients, herbicides and pesticides from landscaping and agricultural areas and wash these substances into nearby surface waters, where they degrade aquatic ecosystems. Stormwater run-off is the main pollutant to U.S. waterways today (EPA, 2014). Stormwater that flows over impermeable urban surfaces is usually collected in one of two sewer types; combined sewers or sanitary sewers. Combined sewers collect both stormwater and sewage from residential, commercial, and industrial buildings while sanitary sewers collect sewage from buildings only without collecting stormwater. Therefore, in areas that use sanitary sewers, a separate system called a stormwater sewer is required to collect rainwater run off to prevent urban flooding. In most cases, when stormwater is collected separately from sanitary wastes, it is released untreated or with minimal treatment (perhaps straining to removed large debris) to nearby surface waters (Primer for Municipal Wastewater Treatment Systems, 2004).

During heavy or prolonger precipitation events, stormwater volume sometimes overwhelms combined sewers (and even sanitary sewers that allow stormwater in through leaks), causing overflows. These overflows release the untreated or minimally treated mixture of sewage and stormwater at designed system overflow points which results in contamination of nearby surface waters and/or lands. Stress to combined sewers during intense rain events can also cause sewage to back up in basements and yards. Such contamination threatens the health and safety of local and downstream life, both natural and urbanized alike (Delleur, 2003). Economic damages also often result from such overflows given the necessary closure and cleanup of recreational or fishing waters or other attractions. As an example, it is reported that approximately 27 billion gallons of sewage and stormwater overflows from combined sewers near New York Harbor and the Hudson River estuary each year as a result of about 460 separate overflow events. Given such negative outcomes, water regulatory agencies and activists are putting effort into the reduction of such overflows (Combined Sewer Overflows, 2014). Aging and overburdened sewer systems are getting no help from mother nature in some areas of the world where it is predicted that climate change will result in more frequent and more severe precipitation events. USGS models project increasing precipitation patterns for the eastern seaboard of the United States, indicating that stormwater runoff and sewer overflows could become more prevalent if water infrastructure is not improved (Climate and Land Use Change Research and Development Program, 2014).

During a rain event in August 2012, localized flooding on the UNH campus inundated one building's classrooms with stormwater, resulting in excess of $400,000 worth of property damage. Localized urban flooding, unlike large-scale flooding, is usually the result of stormwater runoff from one square mile or less of impervious surfaces that has built up and overflowed nearby sewer or stormwater systems (Types of Floods and Floodplains, 2006). Both the stormwater sewers for the campus and those connecting the campus to West Haven were insufficiently sized to handle the volume of runoff generated during the rain event, causing overflow of the system and the subsequent flooding of Kaplan Hall (Aninno, 2014 powerpoint). The rainfall that caused the August 10th, 2012 flooding at UNH was documented at the Tweed New Haven Regional Airport weather station as a 2.36 inches event (NOAA, 2014). According to the 2004 Connecticut Stormwater Quality Manual, it is typical for New Haven County to experience one rain event per year consisting of 2.7 inches of rainfall per 24-hour period; this is termed a 1-year design rainfall event (Connecticut Stormwater Quality Manual, 2004). UNH's stormwater sewers were built to handle a 25-year design rainfall (Lou Annino), which is 5.6 inches of rainfall in a 24-hour period for New Haven County. Following the August 2012 flooding event, an on-site evaluation was done to better understand the causes of UNH's campus flooding. It was discovered that 29 acres of watershed to the northwest of the UNH campus drains their stormwater directly into UNH's stormwater sewers (Annino, 2014). The application of G.I. on the UNH campus as well as in the area northwest of the campus could help slow the flow of runoff into the sewers, reducing overflow. As a temporary relief measure, a section of the stormwater sewer line near Kaplan was replaced with piping doubled in diameter, and an overflow riprap was built to allow excess water to flow down the adjacent hillside. These fixes offer some time for UNH to work out more permanent solutions with the city of West Haven (Annino, 2014).

The University of New Haven's compact urban setting in West Haven, Connecticut and specific hill-top location are other reasons that strategically placed green infrastructure could go a long way toward minimizing local flooding risks. The 82-acre campus is the living, learning and/or working environment for 6,555 combined undergraduate and graduate students as well as 823 combined faculty and staff as of Fall 2013 (Cai, 2014). Most of the staff and faculty commute by car, as do many students, adding to demand for parking areas on campus that in most cases are constructed of traditional impervious pavement. The 35 buildings and accompanying non-porous paved surfaces result in about 65% impervious land area (Annino, 2014). The UNH campus and the City of West Haven utilize separate sewers for stormwater and sanitary wastes. The amount of impervious surface area on the UNH campus leads to a considerable amount of stormwater runoff volume to be handled by the stormwater sewers. Moreover, the pollutants picked up by runoff on campus are then delivered by UNH's and West Haven's stormwater sewers to nearby Club Creek. The health of this stream is highly questionable, given that impervious cover greater than 25% is documented as being severely degrading to stream and watershed health (Pazwash, 2011).

Figure 1: UNH's hillside riprap, installed after the 2012 campus flooding event in Kaplan Hall.

Literature Review

With human populations increasingly shifting to dense urban areas, the need for reliable, efficient, and multi-purpose infrastructure is growing. Urban areas in the northeastern United States are being overwhelmed by a greater increase in intense rainfall events as compared to all other region of the U.S. (Horton et. al, 2014). From 1958 to 2012, very heavy precipitation events in New England have increased by 71%, and this trend is predicted to continue (Walsh, J., et. al., 2014). G.I. can address these urban stormwater issues and provide additional benefits such as: groundwater recharge, reduced heat island effect, water quality treatment for sediment, pollutants, and excess nutrients, increased habitat, carbon sequestration, aesthetic green-space, potential for water harvesting and reuse, as well as energy savings from roof insulation, and protecting water habitats against erosion and heat pollution. Some G.I. types perform better than others in any one of these benefits, thus choosing which G.I. type to utilize depends upon local and downstream goals. What follows is a brief description of some of the most popular types of G.I.

For developed areas, G.I. such as rain gardens, bioswales, and retention ponds can be added, as well as returning certain areas to pre-development native tree and prairie growth zones. Rain gardens, bioswales, and retention ponds are generally depressions in the ground that can route and/or hold water during a rain event and infiltrate that water into the ground in the hours following the rain event. Plants and their soil communities in these features often treat pollutants such as excess nutrients and sediments. Rain gardens usually are made in pockets at low points on a property, whereas bioswales tend to be used in linear applications, such as running alongside a roadway. Most rain gardens and bioswales dry out between rain events, while retention ponds may remain wet continuously. Apart from being good for rainwater treatment and infiltration, rain gardens, bioswales, and retention ponds with native plantings also provide habitat for local and migrating species.

Some G.I. types that involve more construction materials include green roofs, green walls, permeable paving, rain barrels, and cisterns. These types of G.I. work well in denser urban settings where there may not be space enough for gardens, bioswales, and ponds. Green walls, green roofs, and permeable paving take advantage of urban spaces that are usually otherwise impervious by creating permeability. Green roofs capture rainwater falling on their own surface and/or rain routed from other nearby roofs using varying depths of plant media. Given that nearly 50% to 75% of urban impervious area constitutes roofs and driveways, volume reduction strategies focused here can yield substantial results. Green walls can be incorporated onto most vertical surfaces by reorienting horizontal planting media. Both green roofs and green walls can provide pockets of habitat that may be heavily used by migrating species. Permeable paving can consist of porous concrete or asphalt, or loose stone or pavers that allow water to percolate through. In urban settings, green roofs and walls, as well as pervious paving, can serve to reduce the heat island effect, and green roofs and walls can insulate buildings, lowering heating and cooling costs. Rain barrels and cisterns are used to store rainwater for uses either indoors or outdoors. Rain barrels are generally used in small residential settings whereas cisterns, which may be above or below ground, store volumes of water associated more so with large facilities or expansive impervious areas (Pazwash, 2011).

As indicated above, different types of G.I. come with their own sets of benefits as well as construction requirements. Life cycle assessments (LCAs) about G.I. practices are proving very useful in deciding which practice is most appropriate for a given site, as well as estimating the net impacts of the practice. A review of several LCAs has resulted in the following aggregation of findings, which could be used to inform some planning and decision making about G.I. utilization. Several studies found that G.I. options could address stormwater quality and quantity issues while resulting in less net pollution, energy use, and cost. For example, one such LCA concluded that bioretention basins (which fall on a spectrum between rain gardens and retention ponds) improve water quality to the level of some grey infrastructure options while resulting in less net CO_2 emissions and less monetary costs. However, creating enough bioretention basins to serve as the sole means of stormwater treatment would require amounts of land not typically available in urban areas. Therefore, it was found that the joint approach of routing stormwater into bioretention basins which connect to traditional separated stormwater sewer systems would result in the most water quality improvement at the least cost. Additionally, the LCA found that expanding only traditional infrastructure to try and improve water quality would be a failing tactic, given the negative environmental impacts of such construction (Wang, et. al., 2013) By combining green and grey infrastructure, the positive environmental impacts of G.I. can help offset some or all negative impacts that result from construction and maintenance of such systems.

Many LCA studies concluded that the bulk of emissions and environmental degradation associated with G.I. came into play during site construction and maintenance (Kirk, 2006). The materials required in site construction were usually the main culprit, with transportation associated emissions coming into play when materials were not sourced locally or if maintenance crews drove many miles every year to maintain the site. However, unlike traditional infrastructure, GI's incorporation of plants has the ability to sequester more emissions than are produced by its construction and maintenance, resulting in a carbon-neutral site, or even a carbon sink. To improve the ability of a GI site to be a net emissions capturer, it is important to source materials carefully. This can include using recycled materials, local materials, as well as vegetation that require less up-keep such as watering, pesticides, and fertilizers. Similarly, if annual maintenance of a site requires additional crews, trucks, equipment, and other materials to travel to campus, the emissions associated with such activities will negate the GI site benefits. Therefore, sites should be designed to require low maintenance and necessary maintenance activities should be coupled with other maintenance tasks on campus to consolidate the work of crews, supplies, and equipment.

Methodology

To carry out this research, the first task undertaken was a thorough investigation of past and current stormwater issues, much of which was found in U.S. Environmental Protection Agency (EPA) resources. These EPA resources were also rich in information about GI's emerging role as a stormwater management measure. To gather details about the specific nature of UNH's stormwater events, correspondence was carried out with UNH's Associate Vice President of Facilities, Mr. Louis Annino. Understanding the unique makeup of UNH's soil and water table required the use of the Natural Resources Conservation Service's soil mapping tool. Studies about current and projected climate for the northeastern U.S. were obtained from the 2014 National Climate Assessment. The National Oceanic and Atmospheric Administration provided historical data about local annual rainfall averages, as well as historical rainfall typical for each month of the year. An in-depth survey of available LCAs dealing with green and grey infrastructure was carried out as well.

Results and Discussion

When considering G.I. solutions for UNH's stormwater issues, it is important to know about site specifics such as area geology and soils. The soil types present affect water infiltration speeds. Water table specifics are also important in understanding how much additional water the soil may absorb, and where it will travel after being absorbed. The perched water table beneath the UNH campus is relatively high due to the presence of bedrock at an average depth of 6 to 10 feet beneath the ground's surface (Annino, 2014). This high water table means that depressions as shallow as 6 feet may have continual standing water; therefore, any infiltration sites on the campus that are intended to dry out between rain events will need to be shallower than this perched water table. The soils around the West Haven area are generally sandy loam derived from granite, schist, and/or gneiss. Much of the land in West Haven and on the UNH campus is characterized as urban land, meaning the ground is compacted and may have imported soils that were brought in for construction, landscaping, etc. Where there is naturally occurring, uncompact soil on campus, it should be finer in texture near the surface, growing stonier or gravelly with depth, giving it the property of being well drained. According to information provided by the Natural Resource Conservation Service, the bedrock is confirmed to be 29 to 80 inches deep, most likely perching the water table in some areas. The main water table is reportedly more than 80 inches deep in the soil; however, the shallow lithic bedrock results in a perched water table closer to the surface (NRCS, 2014). This perched water table can lead to quick soil saturation in a rain event, which is important to note for certain G.I. practices. The naturally occurring sandy loam soils infiltrate water at 4 inches per hour (Pazwash, 2011). This infiltration rate may need to be altered for an installed GI site depending on the anticipated amount of runoff the site will receive. Adding certain soil types to the GI site soil mix can serve to alter infiltration rates.

Considering that Connecticut is projected to receive ever-greater intensity precipitation events, an investment in GI to unburden the existing infrastructure is advisable. The urban setting of the UNH campus does not provide much space for large GI sites, therefore GI sites are going to need to be incorporated into settings that serve multiple purposes. One great option for such GI sites is the use of permeable pavers or pavements that allow stormwater to seep through the paving and be contained beneath in infiltration beds that gradually release the stormwater into the soil. These pavements and pavers require maintenance to ensure that their pore spaces do not become clogged, usually in the form of regenerative sweeping. In place of infiltration beds, below ground cisterns can be placed beneath the pavement to harvest water that can later be used for irrigation or other uses. Research at the University of New Hampshire has shown that certain permeable paving systems work well in the variable New England climate (UNH Stormwater Center, 2014). However, paving construction is known to have negative environmental implications of its own, so it is usually best to carry out the installation of such a GI site when the existing paved area would be due for resurfacing, replacement, or other work, to minimize unnecessary negative impacts. Carrying out the construction of GI sites in tandem with other planned construction also helps to decrease the cost of the GI site installation.

As another GI option, UNH could consider converting some of its lesser-used turf areas to natively planted infiltration areas, most notably on steep hills where the turf struggles to survive resulting in erosion of the soil into nearby storm drains. Not only are these areas potential eyesores, but soils washed into sewers and later delivered to water bodies are a major detriment to water quality for stream, lake, and coastal environmental health. These areas could have their non-native grasses replaced with native groundcover that will survive in such a location, creating an area of garden that serves many benefits, such as reducing or eliminating the need to mow, water, apply fertilizers or pesticides, as well as reducing soil erosion and increasing site infiltration capability due to the deeper root systems typical of many native species. If sites had sufficient infiltration capability, stormwater from nearby impervious surfaces could be routed to these areas. In particular, if infiltration and/or storage features could be placed conveniently in relation to campus buildings, the roof downspouts of these buildings could route roof runoff away from storm drains, helping to reduce the burden on campus sewer pipes. Green roofs could capture this water on roofs, however these GI features require considerable material inputs that create long pay-off times in terms of their net benefit to the environment. Less material intensive green roof systems could be investigated as a viable alternative though. Green roofs serve to reduce building heating and cooling demands, not to mention extending the lifespans of the roofing material. Planting additional trees near building also serves to reduce the energy demands of the building. Furthermore, trees use large quantities of water, making them a useful addition where water withdrawal following a rain event is preferred.

Project Recommendations and Continuation

Given the limited space on the urban campus of UNH, it is recommended that permeable paving infiltrations sites be investigated in order to reduce the volume of stormwater being directed into campus sewers. Also, any roofs that are routing stormwater to campus sewers should have their downspouts rerouted to either infiltration or storage features. Converting some turf areas to native vegetation will have the added benefits of campus beautification, reduced soil erosion and lawn care needs in addition to improved area infiltration.

Once GI sites are installed on the UNH campus, they should have metrics tracked annually to determine their effectiveness in the areas of cost, flood minimization, environmental protection, habitat creation, campus beautification and social benefits, as well as any savings related to reduced mowing, watering, weeding, fertilizing, herbicide treatments, building heating and cooling needs, etc. Analysis of such metrics will allow UNH to determine whether the GI sites are providing optimum benefits for the campus, or if adjustments should be made to the practices for improved performance against these goals. GI sites at UNH could serve as valuable case studies for the local area as others work to contend with stormwater issues as well.

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Biography

Jessica Zielinski is a senior majoring in Sustainability Studies at UNH. Upon graduation, she may pursue graduate studies prior to entering the field of urban sustainability. Jessica was awarded an EPA Research Fellowship that will support her research for the next year. This past summer she carried out an internship with the EPA Region 5 Water Division investigating the efficacy and long term costs of different green infrastructure practices. She looks forward to continuing this type of work in the coming years to help humanity and nature live more harmoniously within their shared biosphere.