THE CARE AND FEEDING OF A LONG-TERM INSTITUTIONAL COMMITMENT TO GREEN STORMWATER INFRASTRUCTURE: A CASE STUDY AT THE UNIVERSITY OF CONNECTICUT

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INTRODUCTION

In 2007, the Connecticut Department of Energy and Environmental Protection issued the first Total Maximum Daily Load (TMDL) in the country based not on a specific pollutant or pollutants, but on impervious cover (IC) (Arnold et al., 2010). The water body in question was Eagleville Brook, a small tributary of the Willimantic River in eastern Connecticut that drains a majority of the University of Connecticut campus. The university is in effect a small city within a largely rural area. Partly as a result of this, there has been a history of "town-gown" tension and controversy with regard to the university's impact on the water resources of the area. This tension reached a climax in September 2005, when a quarter-mile stretch of the Fenton River, which drains the part of campus not in the Eagleville watershed, ran dry (Merritt, 2005). Water quantity concerns were frequently joined by water quality concerns, with area residents complaining about the pollution of their drinking water (Morse, 2002).

Although the Fenton incident precipitated increased efforts on the part of the university to conserve water, efforts to improve the way that campus addressed stormwater issues lagged behind until the advent of the impervious cover TMDL. In the intervening eight years since the issuance of the "IC-TMDL" - practically the wink of an eye in the deliberate world of land use decision making - the University of Connecticut campus has become a showcase for green stormwater infrastructure (GSI) practices, also known as low impact development (LID) practices.

While the IC-TMDL served as the catalyst, an environmental regulation, no matter how innovative, cannot in itself produce such dramatic change. For this to occur a number of interconnected efforts have to come together, including leadership, research, monitoring, coordination, and education both within and without the

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university community. This paper is an attempt to capture these key elements, consider why they worked (or didn't), and provide a status report on green stormwater infrastructure on the University of Connecticut campus.

KEYWORDS
green stormwater infrastructure, low impact development, university

HISTORY AND STATUS OF GSI ON CAMPUS

Early efforts

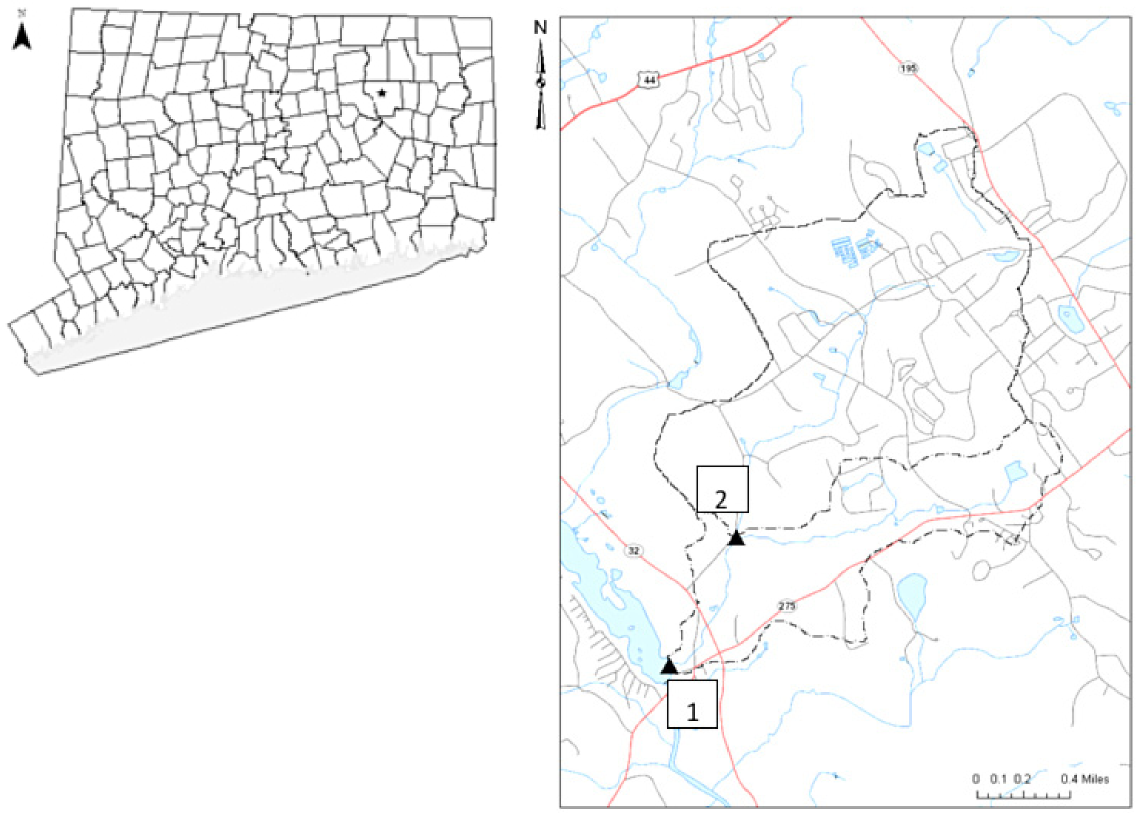
Substantial changes in infrastructure were implemented on the University of Connecticut campus over the last 20 years as part of the "UConn 2000" and "UConn 21st Century" programs. Although the new buildings and upgrades to existing buildings have been a benefit to members of the campus community, the impacts on Eagleville Brook have been less than positive. The addition of IC from new buildings and parking lots increased the discharge of stormwater to Eagleville Brook. As a result, the Brook has suffered from high sediment loading, scouring during large rainfall events, and decreased water quality. Many faculty members attempted to get the University administration to take action on reducing stormwater pollution on campus, due to the fact that research on GSI practices was beginning to show significant potential for bioretention, rain gardens, pervious pavements, and green roofs to reduce stormwater pollution from urban areas. However progress was slow at best.

The Connecticut Department of Energy and Environmental Protection routinely monitored Eagleville Brook as part of its responsibility to report to Congress on the quality of waters in the State (section 303d of the Clean Water Act). Two segments of the stream were found to be impaired for aquatic life (Figure 1), with the cause listed as "unknown", although siltation and copper loading were suspected (CT DEEP, 2004). Land development and urban runoff were cited as two potential sources of the problems. This is not surprising given the large amount of developed land that drains to Eagleville Brook (Figure 2).

Shortly after this in 2007, a Total Maximum Daily Load (TMDL) for Eagleville Brook was developed using impervious cover (IC) as a surrogate pollutant (CT DEEP, 2007). Although surrogate pollutants such as volume have been used before, no TMDL had ever been established using IC as the surrogate (Arnold et al., 2010). In 2005 and 2006, statewide research was conducted on the relationship between IC and stream health, as indicated by state aquatic life standards; these standards are based primarily on assessments of the benthic macroinvertebrate community. Of the 125 research sites, no stream with IC greater than 12% met the state standard for a healthy aquatic system (CT DEEP, 2005; Bellucci, 2007). Therefore, total IC was proposed by Connecticut Department of Energy and Environmental Protection, and eventually approved by the U.S. Environmental Protection Agency, as a surrogate pollutant for the Eagleville Brook TMDL, and the target was set at 11% IC in the watershed.

Prior to the establishment of this goal, the University of Connecticut had implemented several GSI practices on campus, with the goal of reducing stormwater runoff in general.

FIGURE 1: a) Location of project area in Connecticut, b) Watersheds of upper (location 1) and lower (location 2) impaired stream segments.



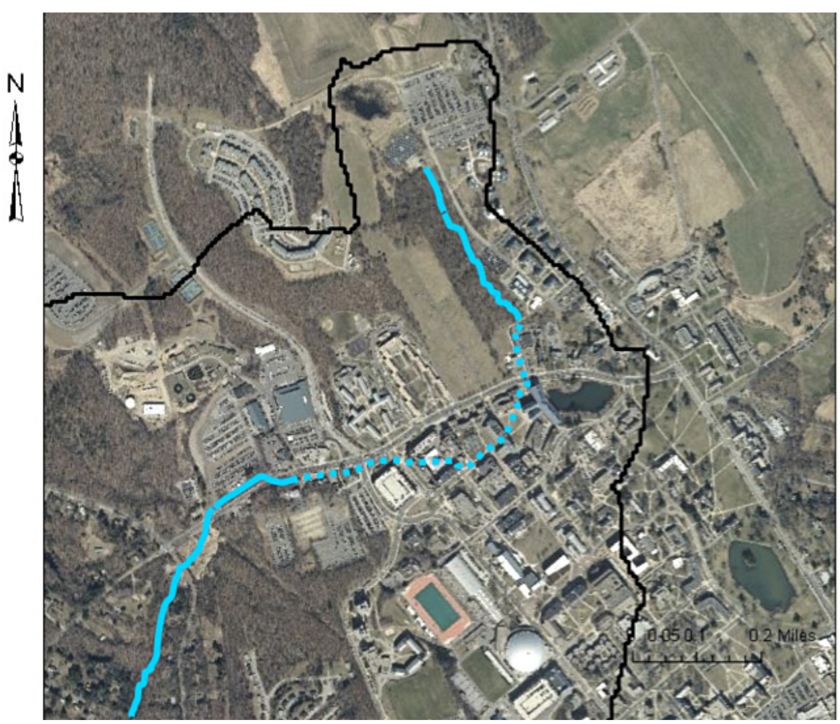


FIGURE 2: University of Connecticut campus in Storrs, with Eagleville Brook in blue (dashed blue line is where Eagleville Brook is in a concrete conduit beneath campus). Solid black line is watershed divide.

However, with the advent of the IC-TMDL, GSI implementation on campus has grown substantially since 2005 (Figure 3), with pervious pavements (Figure 4), bioretention (Figure 5), and green roofs (Figure 6) becoming commonplace on campus. More detailed information about these installations can be seen online through a virtual GSI tour at http://s.uconn.edu/virtualGSItour. The initial university response to the TMDL, in the form of a study, technical report and watershed plan, was led by the University of Connecticut's Center for Land Use Education and Research through its longstanding "NEMO" (Nonpoint Education for Municipal Officials, http://nemo.uconn.edu) stormwater effort. Documents and information related to the study can be found at http://clear.uconn.edu/projects/tmdl. Implementation has been primarily the responsibility of the University of Connecticut Office of Environmental Policy, with input from the Center for Land Use Education and Research, and other University faculty.

Around the same time, a Flood Management Certification analysis for the Brook recommended a 55 acre diversion from Eagleville Brook watershed to the Fenton River watershed, due to high peak flow rates noted for Eagleville Brook. This proposal generated strong local opposition, as the Fenton River drains to Mansfield Hollow reservoir, a drinking water supply system. Due to the opposition, the University of Connecticut held off on the diversion while exploring other alternatives to meet flood management requirements. Steady GSI implementation had been occurring on campus since 2005, and the potential for GSI practices to provide at least some mitigation for flooding was discussed. Design for flood control typically considers runoff from large events (i.e., the 100-year, 24-hour event) whereas water quality

FIGURE 3: Cumulative area treated with LID practices, University of Connecticut Storrs campus.

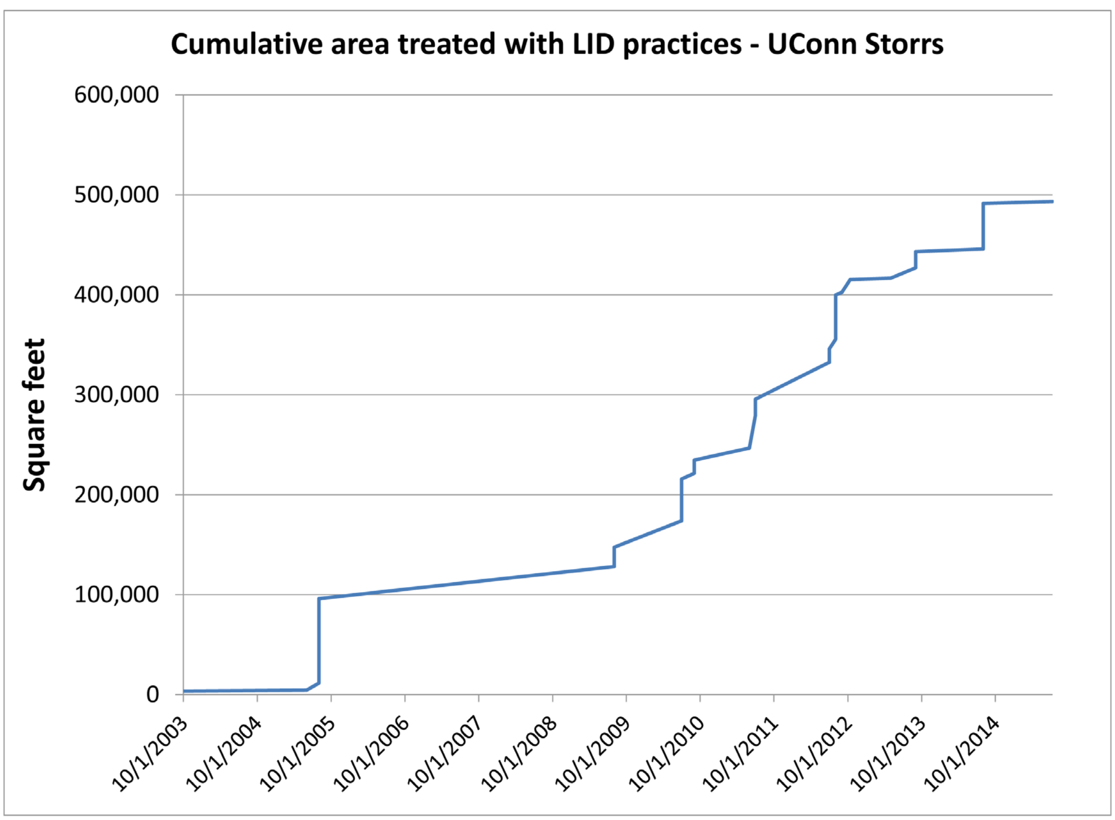


FIGURE 4: Pervious pavement in the "snow shelf" between the sidewalk and street, University of Connecticut, Storrs.

FIGURE 5: Bioretention area by Oak Hall, University of Connecticut, Storrs.

FIGURE 6: Green roof on Storrs Hall, University of Connecticut, Storrs.

considerations typically focus on runoff from a smaller event such as a one inch storm. There may be ways to achieve both of these goals by integrating these two designs. For example, one large bioretention on campus is designed to contain a 10-year 24-hour event. While this won't solve all flooding issues, this extra capacity will certainly help to reduce impacts downstream.

The University of Connecticut hired a consulting firm in 2012 (URS) to determine what effect, if any, the recently installed LID practices had on peak discharges in Eagleville Brook. The main goal was to determine whether these practices would have a large enough impact on the peak discharge in Eagleville Brook to negate the need for the 55 acre diversion that had been proposed in 2006. Key findings from the URS (2013) report were the following: modeled peak discharge for current conditions (2011) met flood management recommendations (this included projects that were constructed between 1993 and 2005) for a 2-year, 24-hour event. Peak discharges for the 10-year and 100-year events were lower than the "pre-1993" condition that was modeled, but they were not low enough to meet the flood management requirement for 10-year or 100-year events (Table 1). However, the analysis also included a hypothetical implementation of 10 "priority projects" identified in the pre-implementation IC-TMDL field survey of the Eagleville Brook watershed (CWP & HWG, 2010), along with water harvesting on a water reclamation plant that was installed in 2012. If these projects were implemented, hydrologic impacts would include maintenance of peak discharges below flood management levels for the 2- and 10-year events, but not for the 100-year event (Table 1),

TABLE 1. Peak flow rates (cfs) for 2-year, 10-year, and 100-yr events. Location 1 is immediately downstream of the University of Connecticut campus; location 2 is where Eagleville Brook drains into Eagleville Lake.

location	pre-1993	FMC goal	current (2011)	w/ water harvest	w/ top 10
	2-year				
1	**53**	**52**	**49**	**46**	**43**[1,2]
2	**161**	**157**	**154**	**149**	**143**[1,2]
	10-year				
1	**195**	**174**	**187**	**174**	**173**[1,2]
2	**519**	**501**	**506**	**493**	**488**[1,2]
	100-year				
1	**430**	**377**	**417**	**407**	**406**[2]
2	**1205**	**1137**	**1189**	**1185**	**1178**[2]

[1]Top Ten scenario reduces peak flow below FMC modeled criteria

[2]Top Ten scenario reduces peak flow below pre-1993 estimates

with an estimated annual stormwater volume reduction of roughly 5.9 million gallons (CWP & HWG, 2010).

Because of these findings and the existence of a reliable tracking system (next section), the Connecticut Department of Energy and Environmental Protection agreed in 2015 to create a new Memorandum of Understanding with the University of Connecticut, acknowledging the hydrologic benefits of the LID practices on campus. The 55 acre diversion was no longer required, but the University is now responsible for installing GSI practices that remove an amount of stormwater equivalent to that which would be removed by implementing the 10 priority projects proposed in the TMDL analysis. The terms of the agreement, signed in 2014, must be completed by 2021. The agreement further requires regular maintenance of all GSI practices, and continued monitoring/tracking of the impact of GSI features in the Eagleville Brook watershed.

Importance of keeping track: impact tracking system

As part of the reporting requirements for the IC TMDL, impervious cover additions and subtractions were recorded, to assess progress towards the goal (Table 2). Hydrologic monitoring has historically been used in other locations to obtain detailed performance data, such as the volume of water reduced by GSI installations. However, this type of monitoring is not practical on a large number of installations such as on the University of Connecticut campus, due to the high equipment and labor costs. Faculty from the Center for Land Use Education and

TABLE 2. Additions and subtractions of IC in the Eagleville Brook watershed from March 2010 to July 2014 (from Dietz, 2014).

Location	Practice	Date installed	IC added (ft^2)	IC disconnected (ft^2)
Northwoods apartments	Bioretention	7/1/2010		23,808
Northwoods apartments	Pervious asphalt	7/1/2010		42,000
Hillside Rd. snow shelf	PICP sw	6/1/2011	3,100	12,055
Laurel Hall	Bioretention	7/1/2011	27,125	27,125
Laurel Hall	PICP	7/1/2011	3,420	3,420
Laurel Hall	Green roof	7/1/2011		
Water reclamation facility	Bioretention	7/1/2012	36,975	36,975
Water reclamation facility	Water harvest	7/1/2012	13,600	13,600
Hillside Rd. snow shelf	PICP se	8/1/2012	6,280	9,355
Oak Hall	Bioretention n	8/1/2012		
Oak Hall	Bioretention s	8/1/2012		
Oak Hall	PICP	8/1/2012	3,150	3,150
Hillside Rd. snow shelf	PICP n	10/12/2012	6,550	12,750
Sundial	PICP	5/1/2013	1,450	1,450
D-Lot	Tree filter	6/9/2014		13,550
Hilltop apartments	Tree filter	6/16/2014		10,245
Basketball practice	PICP	8/1/2014	2,785	2,785
Basketball practice	Bioretention	8/1/2014	16,770	41,248
Klinck	Bioretention	7/10/2015		1,660
		Total	**121,205**	**255,176**
			Net change (ft^2)	**133,971**
			Net change (ac)	**3.1**

Research team decided to estimate runoff reductions for the University of Connecticut green infrastructure sites by using some basic parameters of each installation, and daily precipitation totals from a nearby National Oceanic and Atmospheric Administration (NOAA) station. For bioretention/rain gardens, the watershed area and capacity of the system were measured. For pervious pavements, the area of pavement plus the area of impervious surface that drained on the pervious area was measured. For green roofs, the area of the green roof was measured. For all installations, a performance rating between 0 and 1 was estimated. This value was used to

TABLE 3. Summary of stormwater volume reductions based on daily precipitation totals, University of Connecticut Storrs campus.

Location	Watershed	Type	Date Installed	Stormwater treated to date (ft3)	Stormwater treated to date (gal)
Towers dorms	Eagleville	Bioretention	Oct-03	119834	896479
Towers dorms	Eagleville	Pervious asphalt	Aug-09	613456	4589267
Lakeside apartments	Eagleville	PICP	Jun-05	36562	273519
Hilltop dorms	Eagleville	Bioretention	Aug-05	191417	1431989
Burton-Shenkman	Eagleville	Bioretention	Aug-05	2808079	21007240
Field House	Eagleville	Pervious concrete	Aug-09	91985	688140
MSB	Eagleville	Green roof	Sep-09	33198	248353
Northwoods apartments	Eagleville	Bioretention	Jul-10	208680	1561137
Northwoods apartments	Eagleville	Pervious asphalt	Jul-10	635959	4757607
Hillside snow shelf SW	Eagleville	PICP	Jun-11	170036	1272041
Hillside snow shelf SE	Eagleville	PICP	Aug-12	99582	744976
Hillside snow shelf N	Eagleville	PICP	Oct-12	112051	838251
Laurel Hall	Eagleville	Bioretention	Jul-11	417301	3121829
Laurel Hall	Eagleville	PICP	Jul-11	54814	410064
Laurel Hall	Eagleville	Green roof	Jul-11	1805	13505
Water reclamation facility	Eagleville	Bioretention	Jul-12	346648	2593275
Water reclamation facility	Eagleville	Water harvest	Jul-12	160525	1200890
Sundial	Eagleville	PICP	May-13	12724	95186
			Total	**6,114,657**	**45,743,750**
Mansfield apartments-E	Fenton	Bioretention	Sep-10	44957	336322
Mansfield apartments-W	Fenton	Bioretention	Sep-10	134316	1004817
Storrs Hall	Fenton	Pervious asphalt	Aug-12	88439	661612
Storrs Hall	Fenton	Green roof	Sep-12	15304	114487
Oak Hall N	Fenton	Bioretention	Aug-12	78872	590044
Oak Hall S	Fenton	Bioretention	Aug-12	66769	499500
Oak Hall	Fenton	PICP	Aug-12	35587	266227
Whetton W	Fenton	Bioretention	Sep-13	15625	116888
Whetton E	Fenton	Bioretention	Sep-13	69999	523662
Whetton	Fenton	Pervious asphalt	Sep-13	31523	235822
Basketball Practice	Fenton	Bioretention	Aug-14	143278	1071865
Basketball Practice	Fenton	PICP	Aug-14	8789	65754
			Grand Total	**6,696,047**	**51,230,748**

assess how well each unit was functioning, and account for installations that had known clogging or poor infiltration. For the green roofs, a value of 0.52 was used, since monitoring data for one of the green roofs on campus have indicated this was the annual precipitation retention (Gregoire & Clausen, 2011). The date of installation was also noted for each practice. Then, daily precipitation totals were used to calculate the amount of precipitation that was treated by each practice. This allows for an estimated cumulative total of gallons of stormwater treated to date by all of the practices on the University of Connecticut campus. As of July 2015, a total of 52,050,000 gallons of stormwater have been treated by LID practices on the University of Connecticut campus (Table 3).

Monitoring

In addition to the tracking system, actual water quantity and quality monitoring has also been performed on Eagleville Brook. In collaboration with the Department of Natural Resources and the Environment at the University of Connecticut, equipment to measure discharge in the Brook was installed in 2010, at an existing weir in the stream. Funding was obtained from the Connecticut Sea Grant program to add more sophisticated equipment to the site, and in 2012, real-time measurements of discharge, temperature, conductivity and precipitation were initiated. These measurements are updated every 30 seconds and posted to the Web (http://clear.uconn.edu/projects/eagleville) (Figure 7). These data are helping to build a long term record of discharge and other water quality parameters in Eagleville Brook (Figure 8),

FIGURE 7: Eagleville Brook real-time dashboard at http://clear.uconn.edu/projects/eagleville.

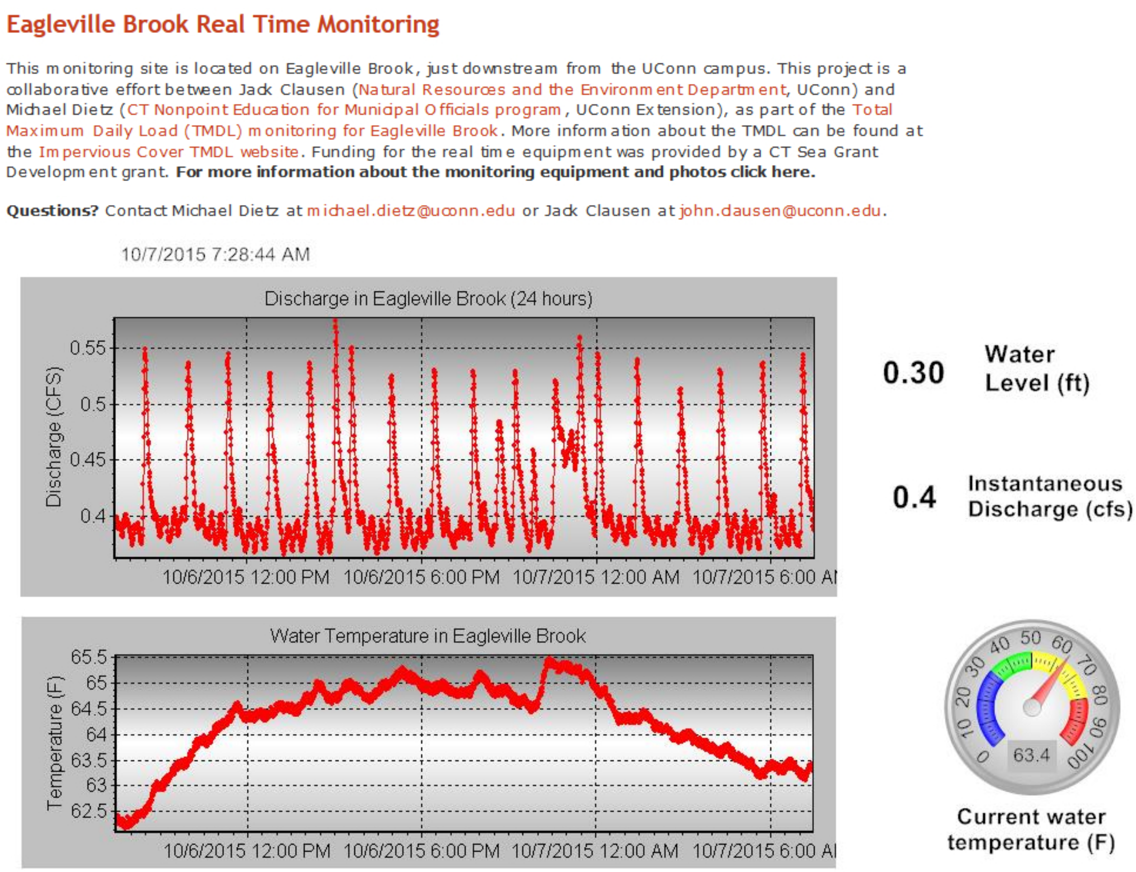
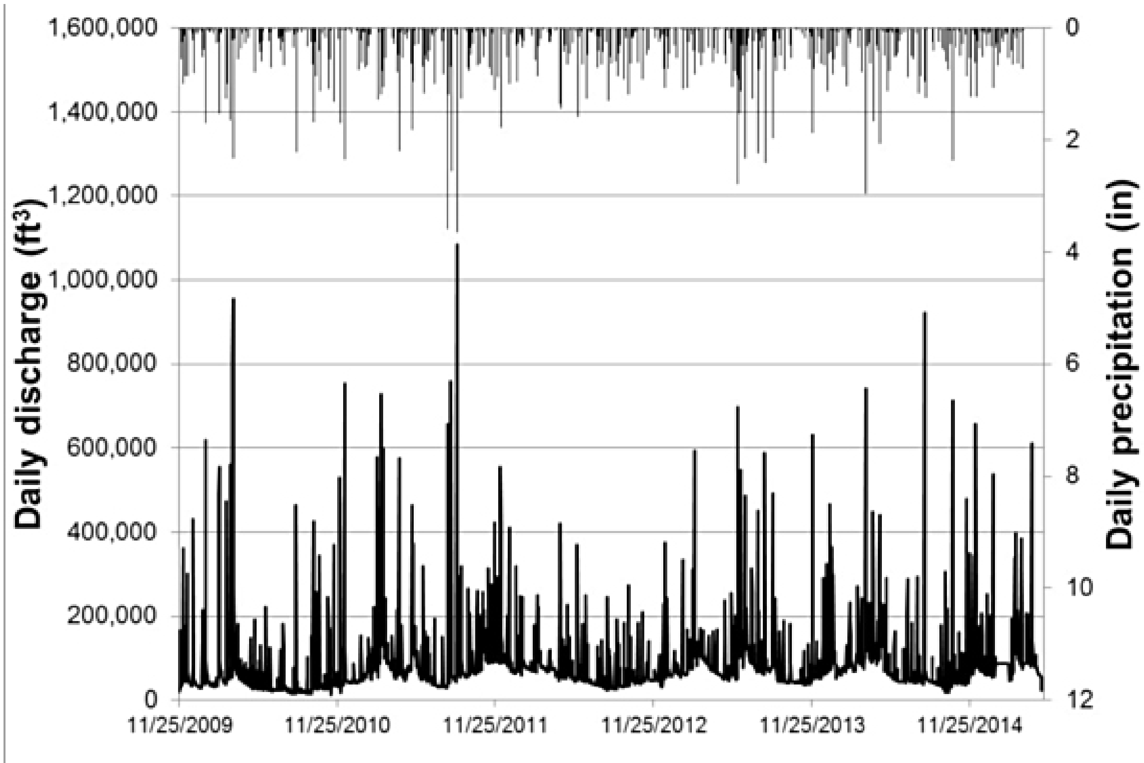


FIGURE 8: Daily discharge and precipitation totals, Eagleville Brook, Storrs CT.



that will hopefully help to document improvements in the condition of the brook over time. In addition, the results may uncover additional problems that are not strictly related to the stormwater volume focus of the IC-TMDL and the new agreement. For instance, a year of weekly water sampling indicated high levels of both chloride and copper in Eagleville Brook, with 80% of samples above chronic water quality criteria for chloride and copper. These findings are leading to additional studies, both on campus and in the lab, to learn more about the sources for both pollutants.

The tracking system and the water quantity/quality measurement site are helping to provide valuable information to support the implementation efforts that have been occurring on campus. These data provide hard evidence for regulators and administrators to prove that the investments that have taken place are providing tangible benefits.

COORDINATION AND MAINTENANCE

Advisory Committee

Funding for the initial IC-TMDL efforts on campus was provided by the University of Connecticut, the Connecticut Department of Energy and Environmental Protection, and the Town of Mansfield. Continued support from Clean Water Act Section 319 through the Connecticut Department of Energy and Environmental Protection has provided for part-time coordination and oversight of activities related to TMDL and implementation efforts. As was suggested in the Watershed Management Plan for Eagleville Brook (Dietz and Arnold, 2012), a Watershed Advisory Committee was formed. The Committee meets 2-3 times per year, and has representation from the University of Connecticut's Center for Land Use Education and

Research, the Office of Environmental Policy, Facilities, Architectural, Engineering and Building Services, and the Town of Mansfield. Although GSI has become part of the "fabric" of campus activities, the committee has helped to keep implementation and planning efforts coordinated and focused.

Maintenance Challenges

The maintenance of GSI practices is critical to ensuring their proper long-term function. Sedimentation, compaction, invasive plants, and over-mulching all have the potential to cause premature failure of GSI features. In an institutional setting such as the University of Connecticut, education (and ongoing retraining) of maintenance personnel is critical. To the untrained eye, a rain garden can appear to be a typical landscaped area. Without personnel trained to recognize the differences, rain gardens will be maintained like a regular landscaped area. They will have a good appearance, but flow paths can become blocked, they can end up getting filled up with mulch, and function becomes greatly reduced. For pervious pavements, clogging of the surface with fine organic material or sediment can lead to reduced infiltration. Again, to the untrained eye, the integrity of the lot surface can look fine, with no heaving and cracking. However, infiltration will be greatly reduced if surface clogging becomes extreme. The improved longevity of the pervious pavements on campus has stood out as an unintended benefit. Due to the highly pervious base, frost heaving does not occur, and the surface of the pavement remains in good condition. For example, there is a pervious asphalt lot on campus that was installed in 2009, and there are no cracks or heaves in the entire lot. The adjacent traditional pavement/base shows cracking and heaving in some areas.

At the University of Connecticut it has been difficult to integrate maintenance of GSI features into the regular work schedule of Facilities and Landscape operations. Overburdened and under-staffed, any request to add more (and different) tasks to their daily lists is understandably unpopular. As noted, however, the recent agreement between the University of Connecticut and the Connecticut Department of Energy and Environmental Protection requires that campus GSI features be properly maintained. The Watershed Advisory team is spearheading efforts to train facilities staff on how to maintain certain practices (rain gardens, bioretention, green roofs) or hire outside contractors (pervious pavements).

Ongoing work with Facilities Department

To ensure compliance with the agreement, the Watershed Advisory team meets frequently to provide support, guidance and status updates on our GSI features. It was critical for the University of Connecticut to get buy-in from the Facilities and Landscape departments because the maintenance of these GSI features relied heavily on their involvement, and some initial internal resistance was encountered. One of the major concerns was the additional maintenance costs for GSI features. To address these cost concerns (e.g., maintenance requirements, cost, equipment) a GSI summary document was created. The summary presented a maintenance comparison of GSI features (e.g., green roofs, bioretention, pervious lots) and conventional drainage structures, landscape beds, roofs, and impervious parking areas. Each GSI feature and/or conventional feature included recommended frequency and best management practices and/or maintenance items. Conventional maintenance costs were estimated from University of Connecticut records, while GSI costs were estimated from the literature. The summary also included the size of each feature, estimated hours it would take to complete the maintenance item (based on the size) and a cost estimate. The cost estimate was based on the time and size of the GSI feature and it was further broken down to include costs expected to be incurred by University of Connecticut staff or contractors, if necessary.

The comparison showed that the costs for GSI features were similar and in many cases less expensive than the maintenance costs for conventional alternatives. The GSI summary helped gain the support of University of Connecticut staff and Administration, once all stakeholders had an understanding of the maintenance requirements and our obligation to the agreement between the University and the Connecticut Department of Energy and Environmental Protection.

An additional unforeseen hurdle was the turnover in Facilities and Project Management staff at the University of Connecticut. Just when it seemed that GSI had truly become part of the fabric of the University, staff turnover in these departments necessitated some re-education of new staff on GSI efforts on campus. Fortunately the Office of Environmental Policy and Center for Land Use Education and Research faculty are available to "carry the torch" for these efforts.

CONCLUSIONS

For the extended project team, the University of Connecticut experience has demonstrated the power of the old aphorism on the use of "the carrot and the stick". In this paper we have focused primarily on the "sticks" of the IC-TMDL and the flood management agreement, which continue to be the major motivating forces behind GSI implementation at the University of Connecticut. However, the "carrots" are gaining ground as the many benefits of GSI beyond regulatory compliance emerge. The large bioretention cells, many rain gardens, and green roofs are helping to transform the look of this "small city" into a greener place. In addition, many students now consider a university's environmental record as a factor in their decision on where to go to school; 60% of students and parents report that a college's commitment to environmental issues has an impact on their choice (The Princeton Review, 2015). The GSI features are a visible and in some cases dramatic demonstration of the University of Connecticut's commitment to environmental protection. The GSI focus has been a solid part of a greater environmental initiative at the University of Connecticut that has led to its being named by the Sierra Club in four consecutive years as one of the 10 "greenest" universities in the U.S. (Sierra Club, 2015). Faculty from the Center for Land Use Education and Research now field a steady stream of requests to lead tours of the campus GSI features for a wide variety of groups including municipal staff, nonprofit environmental organizations, researchers and regulatory staff.

As this paper has attempted to capture, there are many interconnected key factors that have combined to create this ongoing success story. Regulatory pressure was needed to get the ball rolling, and is needed to help keep up momentum and to provide a measuring stick with quantitative goals. A tracking system is needed to assess progress against these goals, and to survive the tracking effort has to be scientifically defensible yet affordable – a tough combination. Expertise, in this case both internal (faculty/staff) and external (consultants) is needed to establish priorities and guide implementation. And an internal champion, in this case the Office of Environmental Policy, needs to take ownership of the effort and continually insert the GSI agenda into the constant stream of day-to-day land use decisions made at the university. This agenda needs to be presented in the context of a realistic assessment of the cost/

benefits of GSI, particularly with regard to maintenance of these features. Finally, the positive, non-regulatory benefits of GSI need to be communicated to leadership (in this case university administration) in order to develop a loop that serves to continually reinforce the initiative. When these factors come together as they have at the University of Connecticut, the results can be dramatic.

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