Urban Flood Monitoring and Watershed Response to Reduced Impervious Cover through Implementation of Green Infrastructure

Background

The City of Madison, like many communities, has seen a recent increase in extreme flood events. This increase has occurred most notably in Madison since 2016, when a large and intense rain event in late July caused extensive flooding of public and private property on Madison's west side; large events in July 2017 and June 2018 caused similar flooding, again largely focused on Madison's west side.

In response to the damage incurred due to recent extreme rainfall events as well as the likely increasing frequency of such events due to global climate change, the Madison Common Council authorized the City of Madison Engineering Division to develop watershed models and plans for watersheds of greatest concern in the Madison area. Additionally, the city has initiated a campaign to minimize stormwater runoff entering storm drains through implementation of green infrastructure (GI) practices. Although much is known on the stormwater volume reduction benefits of individual GI practices, very little is known about the watershed response to a collection of practices. In addition to facilitating a basic data collection program for the City of Madison, this study hopes to answer the following questions:

- How much effective impervious cover needs to be converted to pervious cover before hydrologic changes can be observed downstream?
- Can a waterbody impaired by urban land use ever be able to revert to pre-settlement conditions through implementation of GI alone?
- What temporal scale should municipal officials expect when developing plans for watershed and ecosystem restoration?
- Are hydrologic models that make use of GI simulations accurate or misleading towards long-term watershed health?

Approach

In 2019, The UMid WSC was selected by the City to implement a data-collection platform using real-time sensors and cloud-based data delivery services to help consultants calibrate watershed models to measured data. Instrumentation used to measure water level, flow, and precipitation originally deployed in 2019 will be relocated to other urban watersheds within city boundaries each year over the next five years to provide additional calibration opportunities. In addition to providing information necessary to calibrate hydrologic models, data will be used to assess stormwater volume reduction through implementation of GI in one of the modeled watersheds.

<u>Basic Data Collection</u>

This portion of the project covers the time needed for annual removal, storage, and redeployment of 41 equipment sets (8 discharge, 20 stage, 13 rain). Removed equipment will be cleaned, checked for calibration drift, and readied for redeployment each year in preparation for the next modeled watershed. Redeployment includes scouting of new sites, installation, setup and initial calibration checks of equipment. USGS will also provide technical assistance for the general operation and maintenance of each data collection platform. This budget also includes battery replacements costs, materials costs for reinstallation, and equipment replacement costs for data loggers, rain gauges, stage sensors, flow meters, and antennas. This budget does not include the yearly remote monitoring basic subscription to be paid by the City of Madison to Telog/Trimble.

Assessment of Green Infrastructure

Assessment of the cumulative hydrologic impact of GI will be done primarily through before-after-control-impact (BACI) statistical design at the catchment level. The basis behind the BACI approach is that there is a quantifiable relationship between paired hydrologic data and that this relationship is valid until a major change (i.e. green infrastructure) is made in one of the catchments while the other remains the same. At that time, a new relation will develop. The strength of this approach is that it does not require the assumption that the control and test catchment are statistically the same. If the timing and location of the impact are known and adequate pre-data are collected, BACI design is considered optimal to help isolate the effect of development from natural variability.

An example can be seen from a recent study in the Berry Brook watershed, Dover, NH (figure 1). Compared to the lesser developed Isinglass watershed (black dashed line in figure 1), flows in Berry Brook had greater separation in unit hydrograph response before any stream restoration occurred. A shift towards predevelopment hydrologic conditions was gradually observed over time as restoration was done in the Berry Brook watershed. Much of the change attributed to flows in Berry Brook was due to reductions in effective impervious cover through implementation of GI.

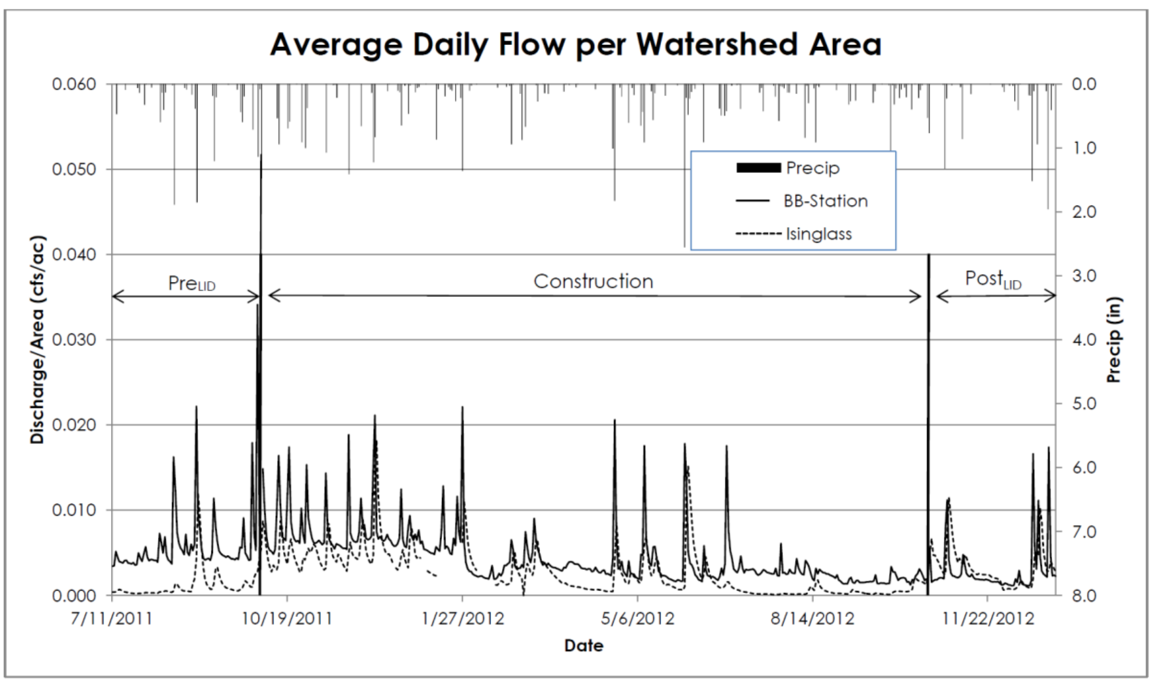

Figure 3. Example of how stream hydrology in the Berry Brook watershed, Dover, NH shifted from developed to undeveloped over time as stream restoration was coupled with reduction of effective impervious cover through implementation of GI. Adapted from Hlas (2013).

In addition to facilitate transition of instrumentation into unmonitored catchments, this study will:

1. Leverage instrumentation and resulting hydrologic data already collected by the City to create a nested monitoring approach for GI assessment. The USGS will work closely with City Engineering to locate urban catchments that are well-suited for GI. The city will then embark on an accelerated plan to implement as much GI as possible within the selected catchment over the next five years.
2. A USGS monitoring site will be installed at the furthest downstream location within the catchment to track hydrologic changes over time.
3. An inventory of GI practices will be maintained by use of GIS to track the reduction of effective impervious cover in the catchment.
4. Develop rapid assessment methods to frequently measure average infiltration rates of GI practices in the study catchment over time.
5. Develop an urban hydrologic model to simulate predicted outcomes of planned GI installation. Compare these outcomes to observed values.

The time required to detect measurable changes at the downstream monitoring point could take several years depending on how quickly and to what extent conversion of impervious to pervious cover occurs; however, because the study area will already have a network of sensors to measure storm flow in sewers and channels throughout the sewershed, changes on a smaller spatial scale could potentially be observed at a much shorter timeframe. Although the research is specific to Madison, results can be transferred to any urban area in the U.S. that is developing a strategy to potentially reduce urban flooding, maintain or replenish baseflow in urban streams, and improve water quality and ecosystem health.

Benefits and Relevance:

This study advances the national mission of the USGS by providing high-resolution water-quality data critical to understanding the urban component of the hydrologic cycle. Furthermore, although green infrastructure has been proven at the individual practice level, little is known about the level of investment required to detect changes at the sewershed. This study will also provide information that could be useful toward urban hydrologic models as part of the IWAA program of the Water Mission Area. Results of this study are transferable to any and all communities dealing with the challenge of mitigating urban stormwater pollution through implementation of green infrastructure.

Products:

Results of the study will be summarized in a USGS series publication or peer-reviewed journal article as well as presented at one or more professional conferences such as the International Low Impact Development conference.

Budget:

The table below provides an estimate of the first five-year commitment. The study could extend beyond 5 years depending on construction milestones for GI in the watershed or sewershed.

Table 1. Proposed budget for basic data collection and assessment of green infrastructure.

Fiscal Year	City of Madison	USGS
2020	$65,000	$22,000
2021	$53,500	$18,000
2022	$54,000	$18,500
2023	$55,000	$18,500
2024	$56,500	$19,000
TOTAL	**$284,000**	**$96,000**

References:

Hlas, V., 2013. An examination of the reduction of effective impervious cover and ecosystem and watershed response, Master thesis, University of New Hampshire, Department of Civil Engineering. Available at http://gradworks.umi.com/15/23/1523794.html, last accessed June 20, 2017.