

 <https://doi.org/10.71573/enpems27>

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# Stormwater Modelling Coupled to Field Monitored Storm Data – Lessons Learned

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## Abstract

This research presents the results of field monitored green infrastructure Stormwater Management Practices (SMPs) constructed to mitigate stormwater runoff from an elevated highway in the urban environment. The SMPs were designed to capture and remove the first 3-5 cm of rainfall that falls on the highway and allow it to infiltrate rather than enter the combined sewer network, and to mitigate peak flows from larger events. Since 1997, Villanova University in partnership with Temple University has developed and is continuing a fundamental and applied research program using field monitored data coupled with calibrated computer USEPA Storm Water Management ModelSCOMPAR (SWMM) model to advance the knowledge base of the profession, and to assist and inform stormwater management design and maintenance practices implemented as part of the project. The research team includes geotechnical and environmental researchers, though this presentation will focus on the lessons learned from field hydrologic monitoring coupled with the SWMM Computer Model.

Recommendations derived from this research address the stormwater capture and transport system, design of infiltration SMP's, addressing design and construction challenges, and use of continuous simulation for design to meet regulatory requirements.

## Highlights

- Coupling stormwater models with monitored storm event data advances understanding of Stormwater Management Practice (SMP) performance.
- Model Comparison to data supports identification of SMP limitations and subsequent improvements.
- The capture and transport of runoff has been found to be an unexpected challenge as runoff from the drainage areas partially bypasses the intended collection system.

## Introduction

The United States Pennsylvania Department of Transportation (PennDOT 2018) is incorporating extensive green stormwater infrastructure into the reconstruction of the I-95 highway corridor in Philadelphia. The Green Stormwater Infrastructure (GSI) is designed to capture the first 3 - 5 cm of rainfall that falls on the highway and allow it to infiltrate rather than enter the combined sewer network. The use of GSI to manage stormwater runoff stems from requirements of the Pennsylvania Department of Environmental Protection and the Philadelphia Water Department's Green City, Clean Waters program (2012), which were designed to address combined sewer overflow problems in Philadelphia. Since 1997, Villanova University in partnership with Temple has developed and is continuing a fundamental and applied research program to advance the knowledge base of the profession, and to assist and inform PennDOT and its consultants on stormwater management design

and maintenance practices implemented as part of the I-95/GIR project (PennDot 2015). The research team includes geotechnical and environmental researchers, though this presentation will focus on the lessons learned from field hydrologic monitoring coupled with the USEPA SWMM Computer Model (Rossman 2015).

## Methodology

### SCM Monitoring

Each SMP is monitored for flow, depth and meteorological conditions. Figure 1 shows photos of several sites receiving runoff from the elevated highway. SMP A is a fenced, long linear bioswale, roughly 146 m long and 8 m wide. The bioswale has three culvert inlets (N8, N9, N10) and two outlet structures (B1, B2) that overflow into Philadelphia’s combined sewer system which connects to the Delaware River PWD (2015). Figure 2 presents the as-built drawing with corresponding inlet and outlet structures for SMP A.



Figure 1 SMP Locations and Weather Stations (Google 2017, 2018 Annual Report)

SMP A is a fenced, long linear bioswale, roughly 146 m long and 8 m wide. The bioswale has three culvert inlets (N8, N9, N10) and two outlet structures (B1, B2) that overflow into Philadelphia’s combined sewer system which connects to the Delaware River PWD (2015). Figure 2 presents the as-built drawing with corresponding inlet and outlet structures for SMP A.

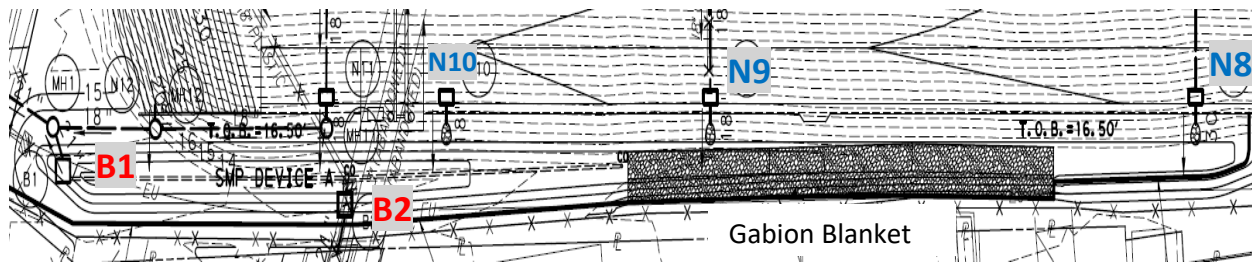


Figure 2 Inlet (Blue) and Outlet (Red) Structures (AECOM/URS 2015)

### Hydrologic Modelling

Environmental Protection Agency (EPA)’s SWMM (Rossman 2015) was used to gain a better understanding of the SMPs. It considers Combined Sewer System performance, which is critical in older cities, such as Philadelphia that rely on this outdated drainage infrastructure. This model was created using storage units for the upstream, gabion, and downstream basins of SMP A. Infiltration and ponding were simulated by using seepage loss through each storage node. The Modified Green-Ampt model for infiltration was used. The Green-Ampt model for infiltration predicts the cumulative infiltration as a function of time and available soil parameters. A simulated runoff test conducted using hydrant flow was used to initial calibrate the model (VCRWS 2017).

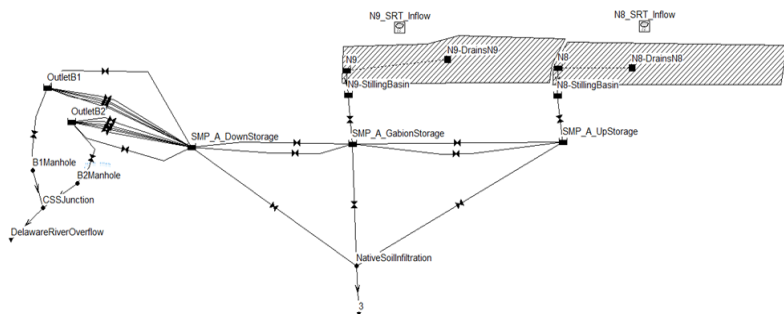


Figure 3-Calibrated SWMM Model

## Data Set

Figure 4 below from the 2019 project report is a good example of data used in the study. Note that by comparing the rainfall, to the ponding and outflow depths you can review whether the expected flows are captured and transported to the SMP, and the overall performance of the SMP.

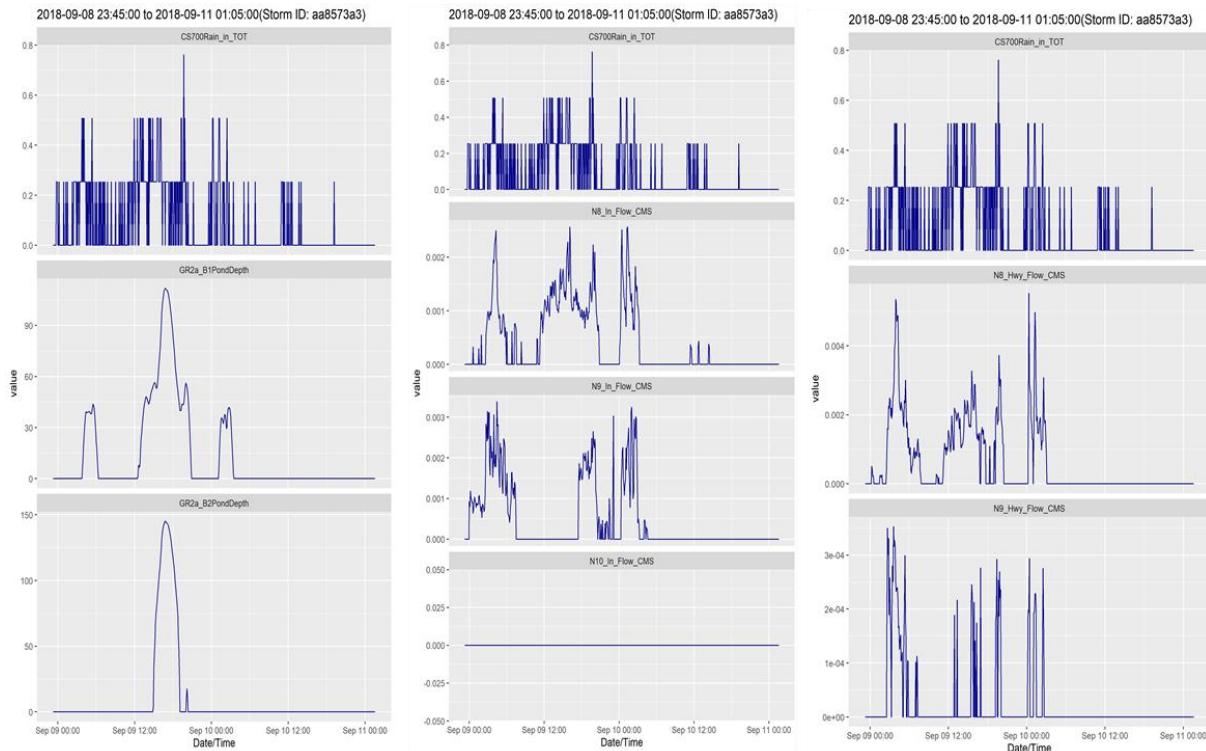


Figure 4 (a) Ponding depths, (b) Inlet Flow, and (c) Highway Flow for the September 9, 2018 storm (VCRWS 2018)

## Results and discussion

The presentation will focus on the lessons learned comparing collected storm data to the SWMM model. A selection of the main results are listed below (VCRWS 2019):

- The capture and transport of runoff has been found to be an unexpected challenge. It has been found that some runoff from the drainage areas may bypass the intended collection system. This can result in SMP erosion, over/underloading, and possible ponding on the travel surface.
- It is recommended that the infiltration SMPs be designed as an ecosystem, that is to use all components of the hydrologic cycle, soil, and vegetation. This can be easily achieved by raising outlet orifices and the use of check dams to support infiltration. Dense vegetation with deep roots that can thrive in the SMP environment are significant in maintaining performance. This approach will have a significant positive effect on infiltration SMP performance and longevity.
- Transitioning from construction to operational performance is the cause of many of the challenges that are faced by PennDOT and is a significant challenge for long term construction projects. It is recommended that protection of the SMP, when the contributing drainage area is unavoidably expected to change due to construction activities and associated increase in sediment, be built into the construction sequence. It is further recommended that all infiltration SMPs undergo post-construction Simulated Runoff Test; when a water source is available to demonstrate that the SMP is built to design expectations.

- The use of continuous simulation models for smaller (2-year or less) design storms is recommended when permitted by the regulatory agency for water volume events that match precipitation patterns to infiltration, evapotranspiration, and soil physics. This is expected to result in more appropriate footprints, particularly for areas with moderate to good infiltration rates, and can allow designs that separate rate and volume control that are more resilient when space is available.

## Conclusions and Future Work

The challenges of understanding the performance of green stormwater infrastructure requires long term monitoring to understand the performance over time. The value of comparing performance to model expectations is invaluable to advance our design, construction, and operation practises.

## Acknowledgement

First the authors want to thank the many Villanova professors and graduate researchers that have worked on this project, and our AECOM partners.

The authors would like to thank the Pennsylvania Department of Transportation District 6-0 for their support and funding. The opinions presented in this article/publication are those of the authors and do not necessarily express the opinions of the Pennsylvania Department of Transportation. Reference in this report to any commercial product, process, or service, or the use of any trade, firm, or corporation name is for general informational purposes only and does not constitute an endorsement or certification of any kind by the authors.

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