

Watershed-Scale Flood Mitigation by Green Stormwater Infrastructure: Current Evidence and Future Directions

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What I will be presenting:

Green stormwater infrastructure (GSI) has become a widely adopted approach for managing urban runoff, improving water quality, and reducing localized flooding. Practices such as bioretention systems, permeable pavement, infiltration trenches, and distributed storage features have been extensively studied at the site scale, where they often demonstrate measurable reductions in runoff volume and peak discharge. However, a critical question remains for stormwater practitioners and planners: to what extent do these localized benefits translate into meaningful reductions in watershed-scale flood response during large and extreme storm events? This presentation will summarize findings from an ongoing structured literature synthesis focused on watershed-scale hydrologic performance of GSI. Studies are being evaluated based on watershed characteristics, impervious cover, GSI type, treated drainage area, storm magnitude, rainfall characteristics, and modeling or monitoring approaches. Preliminary findings indicate that GSI can contribute to watershed-scale peak flow reduction across a range of storm magnitudes, including events represented by 2-year to 100-year return periods. However, reported performance varies substantially among studies, suggesting that watershed-scale effectiveness is highly dependent on local watershed conditions, storm characteristics, and GSI implementation strategies.

What the audience will learn:

Attendees will gain an overview of the current state of knowledge regarding watershed-scale flood mitigation provided by GSI systems and the factors that influence their effectiveness during extreme storms. The presentation will highlight emerging evidence that GSI-treated areas alone may not fully explain watershed-scale performance and that other factors, including watershed size, imperviousness, drainage connectivity, soil conditions, GSI placement, storm intensity, and design characteristics, play important roles. The presentation will also identify key knowledge gaps limiting current stormwater planning and design, particularly the lack of long-term watershed-scale monitoring data and the limited number of studies evaluating performance during extreme precipitation events. Finally, future directions will be discussed, including opportunities for integrated monitoring and modeling approaches that can better quantify watershed-scale benefits of distributed GSI systems. These insights can help practitioners, municipalities, and researchers make more informed decisions regarding stormwater investments and urban flood resilience planning.

Evaluating the Climate Resilience of an Interconnected Green Stormwater Infrastructure System Using PC-SWMM Model

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What I will be presenting:

As research on Green Stormwater Infrastructure (GSI) and its implementation in cities has increased, we can move beyond understanding of the performance of individual systems to how multiple GSI function as a system. This study evaluates the performance of an integrated GSI network consisting of ten rain gardens, two cisterns, a detention basin, three infiltration systems, and one bioswale, constructed as part of a redevelopment project on a nine-acre former parking lot at Villanova University.

A PCSWMM model for both pre and post construction conditions were developed and compared across multiple storm events shows that total discharge volumes decreased by approximately 35–78%, depending on rainfall intensity. The calibrated PCSWMM model was used to simulate 25 storm events from 2022, and future climate scenarios were analyzed using the SWMM-CAT tool with CMIP5/CMIP6 projections under RCP and SSP pathways. Results indicate that projected near- and long-term climate scenarios may increase peak flows by up to 18.6% and total runoff volumes by up to 16.9%. While the system effectively manages current runoff, overflow events in rain gardens increased in 2023, indicating the need for adaptive maintenance.

What the audience will learn:

The audience will learn how the integrated GSI system works and how it performs at a site scale under different intensities of rainfall. The study will show how calibrated hydrologic modeling can provide a more reliable assessment of system performance than design assumptions alone. The study will also highlight use of tools such as PCSWMM along with SWMM-CAT to evaluate the effect of climatic conditions on GSI and evaluate future risks.

Participants will learn how to identify the performance metrics of the GSI system and make adjustments to improve GSI practices that are overflow-prone or underperforming such as increasing storage capacity, improving system connectivity, altering soil media with better conductivity and enhancing maintenance strategies. Key takeaways include practical approaches for optimizing GSI networks and designing more resilient green stormwater systems in the context of changing climate conditions. The findings offer practical insights for municipalities and engineers designing and managing climate-resilient stormwater infrastructure systems.

Assessing Flood Mitigation Performance in Urban Landscapes with Compacted Soils

Vanaskie, Matthew: HRG

Severe urban flooding is becoming increasingly common worldwide, causing substantial damage to infrastructure and communities. Rapid urbanization reduces pervious surfaces and soil infiltration capacity, increasing flood risk. In older, already-developed urban areas where land for conventional flood control infrastructure is limited, low-impact development (LID) practices offer a practical and space-efficient alternative. This study evaluated the performance of an existing stormwater system while accounting for rainfall variability, soil compaction, and selected LID practices, including permeable pavement, infiltration trenches, and cisterns, chosen based on their suitability and practical applicability. The stormwater system was modeled hydrologically and hydraulically using PCSWMM under two rainfall conditions: an SCS Type II design storm and a historical extreme rainfall event. Runoff volume and peak flow were analyzed to assess LID effectiveness, runoff control, and the influence of soil compaction and rainfall input selection. Results showed notable differences between scenarios that excluded soil compaction and LIDs and those that incorporated them, with similar trends observed under both rainfall events. Accounting for soil compaction depths of 1–3 inches reduced system totals by 17–22%, depending on storm type, while adding LIDs produced further consistent reductions of 3–5% in total discharge. For peak flows, soil compaction reduced maximum discharge by 5–6%, and LIDs provided an additional reduction of approximately 2%. Overall, the findings indicate that soil compaction level and rainfall input selection can substantially influence predicted design flows. Targeted, space-efficient LID practices can further reduce excessive loads on existing stormwater networks in already-developed urban areas.

Symbiotic Subsurface Bioretention

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What I will be presenting:

To unlock the co-benefits and maximize the impact of urban greening we must focus on subsurface stormwater infrastructure that simultaneously supports robust canopy growth and large-volume stormwater retention.

This session presents a conceptual model for integrating structural soil cell technology, traditionally focused on creating uncompacted root zones for urban tree health, with high-capacity modular storage units, typically used solely for stormwater volume management.

We explore the engineering and environmental potential of this symbiotic subsurface approach. By designing a system where the stormwater management structure also houses and passively irrigates the deep, uncompacted soil cells, we achieve several key climate resilience outcomes:

1. **Maximum Canopy:** Trees gain significantly larger root zones and consistent water access, resulting in larger, healthier, and longer-living canopies, directly supporting the Philly Tree Plan's goals.
2. **Enhanced GSI Performance:** The system acts as a decentralized basin, maximizing stormwater volume managed, reducing peak flow, and enhancing stormwater quality.
3. **Space Efficiency:** It provides a singular, highly efficient solution for subsurface space utilization beneath hardscapes that can be leveraged in a multitude of scenarios (e.g., parks & sidewalks). This proposal offers a cutting-edge vision for integrated GSI design that moves beyond siloed solutions to deliver true, dual-benefit climate resilience.

What the audience will learn:

Upon completion of this session, attendees will gain a comprehension of the benefits expected with multi-functional subsurface GSI design. We will begin by critically evaluating the spatial and functional limitations of traditional "siloed" systems, where tree pits and stormwater detention tanks compete for limited underground space. The audience will learn why these separate approaches often lead to compromised tree root soil volumes and limited tree growth.

Moving into the "how-to," the session will provide an analysis of the foundational design principles required to conceptualize a unified system. We will detail the technical requirements for integrating

structural soil cells directly with modular storage units, focusing on spatial efficiency in the public right-of-way to achieve stormwater volume goals while adding valuable soil volume for tree health.

Finally, we will articulate the economic case for integration. By analyzing the "cost-per-benefit" of an integrated system that solves for both tree canopy goals and GSI volume requirements, attendees will leave equipped to advocate for integrated infrastructure that maximizes both project ROI and long-term municipal climate resilience.