SUMMARY

FLOOD RISK REDUCTION BENEFITS of Green Stormwater Infrastructure

GSI Impact Hub

WHAT YOU NEED TO KNOW

By reducing localized and riverine flooding, GSI-based approaches to stormwater management can provide a range of benefits to property owners, communities, and local governments. The flood risk reduction effect of GSI can:

- Reduce property damage and risk to human health and life
- Promote climate change resilience
- Extend the lifetime of aging gray infrastructure assets by expanding the capacity of existing drainage networks and/or reducing life-cycle wear on elements of these networks
- Help to address flooding-related equity concerns

This is a summary of a full guide produced as part of the GSI Impact Hub, a larger project that provides resources and support related to specific GSI co-benefits. Please visit the GSI Impact Hub website to explore these resources including:

- Compendium of GSI Co-benefits Valuation Resources
- GSI Impact Calculator, a block-level tool for quantifying and monetizing co-benefits
- Full-length guides related to flood risk reduction, green jobs and economic development, heat risk reduction, habitat and biodiversity, and transportation.

The GSI Impact Hub is a collaboration between The Nature Conservancy, Green Infrastructure Leadership Exchange, One Water Econ, government agencies and technical partners.

Please see the full guide to "Understanding and Quantifying the Flood Risk Reduction Benefits of Green Stormwater Infrastructure" for citations to the sources referenced in this summary.

GSI FLOOD RISK REDUCTION BENEFITS: WHAT'S THE EVIDENCE?

Green stormwater infrastructure (GSI) practices, including green roofs, trees, bioretention areas, and permeable pavement, can help to mitigate urban flooding in several ways:

- At the site, block, or sub-catchment level, targeted GSI can reduce localized flooding. This in turn reduces related impacts such as basement backups and so called "nuisance flooding" that occurs when stormwater inundates backyards, streets, and other public areas.
- GSI practices distributed throughout a watershed or catchment can reduce total runoff and peak flows, helping to mitigate downstream riverine flooding and associated damages.
- GSI-based solutions can provide a more flexible, cost-effective, and adaptive approach to reducing flood risk in the face of uncertainties surrounding future climate, rainfall patterns, and level of urbanization.

Research and real-world experience indicate that targeted GSI can eliminate localized flooding associated with up to the 10-year storm event at the site, block, or sub-catchment level. Recent projects in New York City and Detroit demonstrate these benefits. Sufficient storage is needed to manage flooding from moderate storm events.

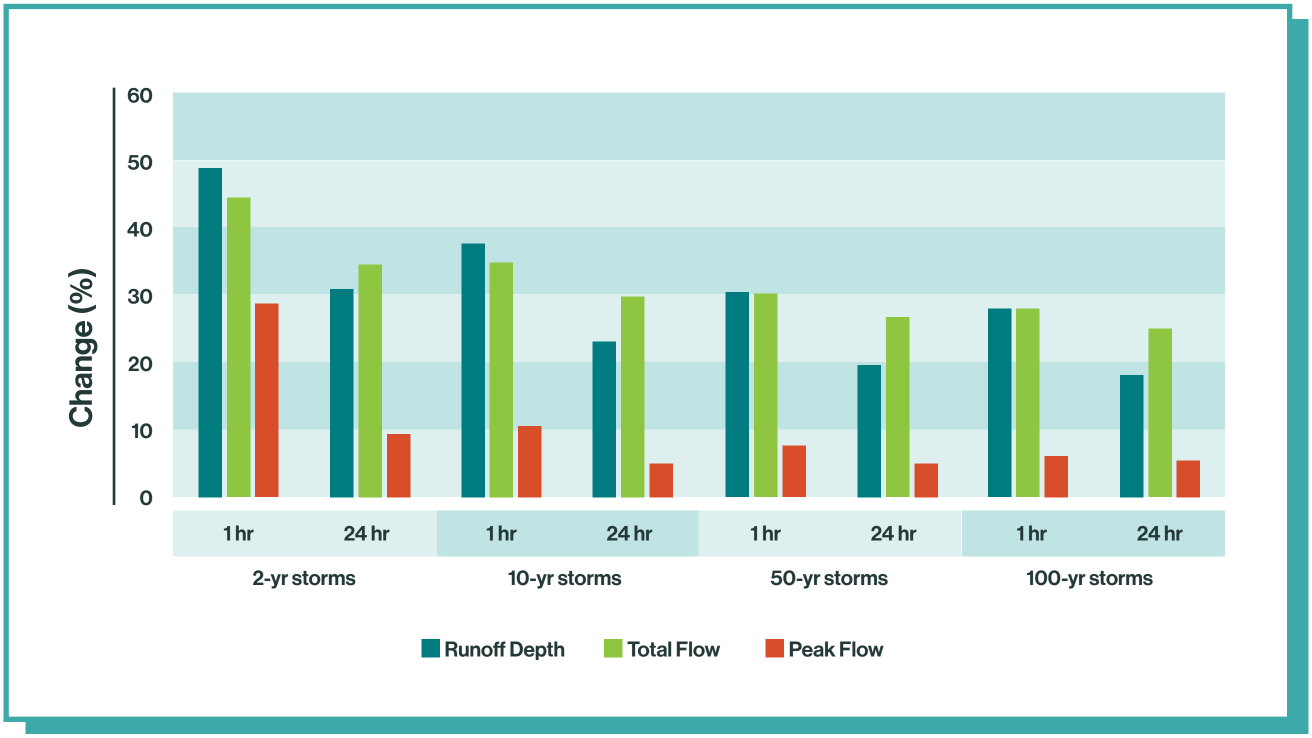
Urban Flooding: What Is It and How Does GSI Help?

Municipalities experience several different types of flooding. Prolonged or intense rain events that generate large volumes of stormwater cause waterways to overflow their banks, resulting in **riverine flooding. Localized flooding** occurs when runoff overwhelms drainage systems and waterways in direct proximity to a precipitation event. Many severe urban floods are caused by **coincident flooding**, where an area is impacted by multiple types of flooding at the same time.

Credit: Kahlil Kettering/TNC

In many areas, the effects of climate change will result in more frequent and intense rain events. To address this challenge, cities across the globe are rethinking and adapting their approach to flood risk management, transitioning from traditional engineered "flood defense" strategies to incorporate the concept of flood resilience, "where urban spaces are designed to make space for water and adapt to the increasing threat of urban flooding while providing wider improvements to the environment and society." GSI can be an important and effective component of a community's flood resilience strategy.

Figure 1. Flood risk reduction performance of distributed GSI (reducing effective impervious cover from 30% to 10%) and other BMPs in 185-acre Berry Brook watershed, Dover, NH



Source: Hastings 2018.

GSI strategies can effectively target flood prone areas and reduce localized flooding associated with small to moderate storm events.

When distributed throughout a watershed or catchment, GSI can reduce riverine flooding caused by smaller precipitation events (e.g., typically less than 1.3 inches); however, the effect of GSI on downstream flows decreases for larger storm sizes. The impact of GSI at the watershed or catchment level varies based on existing land uses (including total impervious area), scale of application, and placement within the watershed, among other factors. Figure 1 shows the decrease in peak flows (5 to 29%), runoff depth (19% to 49%), and total flow volumes (25 to 45%) modeled across a range of storm event sizes for a watershed in New Hampshire where GSI practices reduced effective impervious cover from 30% to 10%.

Credit: Green Infrastructure Leadership Exchange

MAXIMIZING FLOOD RISK REDUCTION BENEFITS

To maximize flood risk reduction benefits of GSI, it is important to target high priority locations, understand the effectiveness of various GSI practices, and incorporate key design elements. Stormwater programs should optimize the location and type of GSI to achieve flood volume, duration, and damage reductions.

A wide range of GSI practices can measurably reduce urban flooding

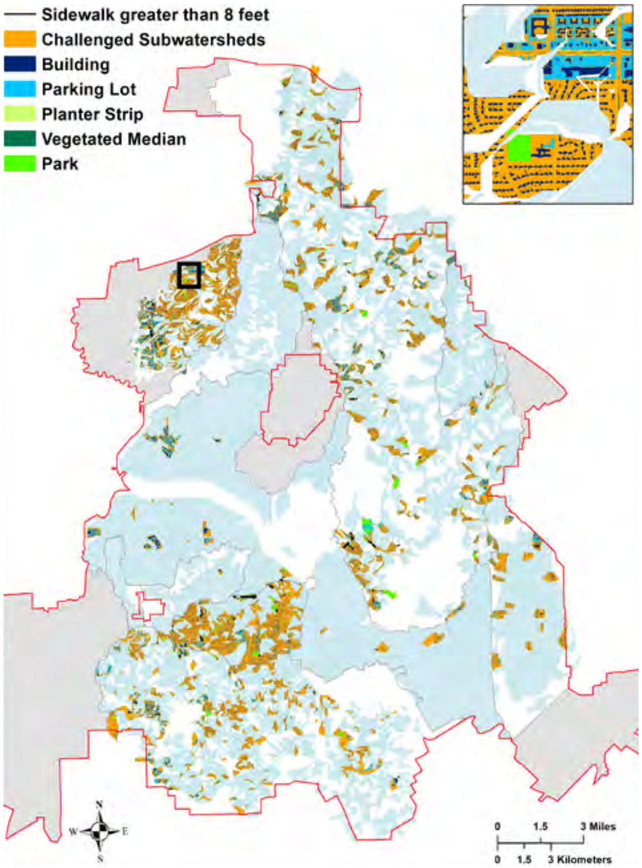
Many GSI practice types can have a beneficial effect on flood volume and duration impacts. Table 1 summarizes several academic studies evaluating these practices and their corresponding flood risk benefits.

Location matters

Flood risk reduction benefits can be maximized through a tailored review of spatial data to identify high priority areas for flood management. For example, data and reports detailing flood damage claims, basement backups, road closures, or complaints about street flooding can illuminate problem areas. Prioritizing interconnection between GSI practices and complementary "gray" infrastructure, particularly where traditional drainage networks exceed capacity during storm events, is also beneficial. For example, in Dallas, TX, The Nature Conservancy (TNC) identified "challenged watersheds" where existing drainage is limited/undersized and contributes to inlet overflows and areal flooding. TNC modeled GSI opportunities based on land use and other spatial constraints to assess how GSI could reduce flooding (Figure 2).

Research indicates that when many relatively small GSI installations are interconnected and designed to operate synergistically as a stormwater treatment train, they can be more effective than a single centralized asset. The effectiveness of different practices can depend on the hydrological zone in which they are located. For example, capturing and retaining stormwater in the upper contributing zone of a watershed can help to prevent flooding lower in the watershed.

Figure 2. Challenged watersheds (all levels of severity) and GSI opportunities (based on land use and other spatial constraints), Dallas, TX.



GSI-based practices can reduce localized flooding and contribute to improved hydrologic performance downstream, helping to mitigate the impacts of riverine flooding in many cases.

Table 1. Summary of recent studies on the effectiveness of GSI interventions for flood risk reduction

GSI Practice	Location	Description	Storm Size	Scale	Results
Rain gardens	Philadelphia, PA	Simulated rain garden performance with large amount of precipitation at a sustained high intensity. Results were combined with monitoring of actual performance in average rainfall years.	1.65"-5"	Site-scale	Rain gardens designed to manage a 1.65" storm can treat runoff volume from a 5" event.
Green street-downspout disconnects and vegetated swales	Montgomery County, MD	Compared runoff volume and peak flows under a range of storm events for green street and to traditional curb and gutter drainage.	Monitored across a range of storm events	Site-scale/ localized flooding	Up to ~ 0.8" rainfall event, green street produced less runoff. Peak runoff from green street was less than from gray street for all but the most infrequent, extreme events.
Permeable pavement & bioretention	LaCrosse, WI	Modeled the effectiveness of three green street designs. One added bioretention along 30% of local roads, while two added permeable pavements (with varying storage capacities) along 80% of major roads and 90% of local roads.	3-month, 24-hr (0.83") 10-yr, 2-hr (2.86")	Small catch-ment/ localized flooding	All systems would eliminate flooding from 3-month, 24-hour event. Permeable pavement was the most effective in reducing flooding from 10-year, 2-hour storm. Full implementation of permeable pavement (4' of storage depth) would reduce flooding by 87%.
Bioretention, rain gardens, rainwater harvesting systems	Dallas, TX	Used hydrological modeling and spatial analysis to identify how GSI can reduce flooding in areas where existing drainage network is undersized, considering capacity, cost, and future climate change scenarios.	models run for 2-, 10-, and 100-yr, 24-hr storms.	Catchment scale/ local-ized flooding	GSI can reduce inlet overflows by 31%, 25%, and 17% under 2, 10, and 100- year storms. Combined green/gray alternative managed more stormwater under 100-year conditions at a lower $/gallon cost than gray alone.
Infiltration, permeable pavement, bioretention, undisturbed cover	New Market, NH	Examined downstream hydrologic performance in extreme events under GSI and conventional buildout scenarios. Land use conditions were modeled for historic, current, and future climate change scenarios.	100-yr, 24 hr (8.5")	Watershed/ subwatershed	In highly developed subwatersheds, GSI had substantial impact. Conventional build-out increased runoff from 29-36% relative to baseline, while GSI build-out had increases of 2-7%.
Recharge chambers, infiltration trenches, trees	Montgomery County, MD	Compared two treatment watersheds to a reference (forested) watershed and an urban control watershed with centralized detention facilities. Comparing three treatment watersheds to a reference (forested) watershed and an urban control watershed with centralized detention facilities	Monitored across a range of storm events	Watershed	Runoff yields in treatment watersheds were lower than in urban control watershed for up to ~0.8" storm. Except for most extreme events, peak runoff in treatment watersheds fell between the peaks from the forested and urban control watersheds. GSI can replicate reference conditions in small events.
GSI at new and redevelopment sites	20 HUC 8 watersheds across U.S.	Modeled GSI practices in 20 sample HUC8 watersheds across the country to estimate avoided costs from GSI practices between 2020 to 2040. Practices designed to capture 85th – 90th percentile storms.	Models run for 2-, 5-, 10-, 25-, 50-, and 100-yr events	Watershed	GSI implementation can reduce floodplain area by 3%-8% up to 20-year return interval. Effectiveness of GSI tapers off as storm size increases.
GSI retrofits, identified through community input and land use assessments.	Silver Creek in Toledo, OH & Chester Creek in Duluth, MN	Modeled flooding and property damage under current and projected future precipita4on levels under climate change.	100-yr event	Watershed	Implementing GSI to reduce peak discharge by 10% would reduce economic damages in Silver Creek watershed by 39% and 46% under current and future precipitation conditions. In less developed Chester Creek watershed, implementing GSI to reduce peak discharge by 20% would reduce economic losses from a 100-year storm by 27% and 16% under current and future conditions.
Impervious area reduction	Baltimore, MD	Compared hydrologic responses in three suburban watersheds with various amounts of impervious cover. Two drained to detention facilities, third had no stormwater controls.	3.5" – 16.1" storms, with peak rates between 0.47 and 3.5 in/hr	Watershed	Stormwater detention basins did not significantly reduce peak runoff rates for larger storms. Reduction in impervious cover has a larger impact on runoff volume than detention alone.

QUANTIFYING AND MONETIZING FLOOD RISK REDUCTION BENEFITS

Federal agencies and others have developed well-established methods and tools for assessing avoided flood damages to capital assets. These approaches are generally applied to riverine flooding and involve estimating the amount of flood losses that will be avoided over the life of a flood risk reduction project or suite of investments. Key steps include:

- Define and inventory the area over which flooding will be mitigated.
- Conduct hydrologic and hydraulic (H&H) modeling.
- Estimate damages with and without project implementation.

Figure 3. Guidelines for GSI system selection based on location within the watershed or sub-watershed

	Location in the Watershed		
GSI Practice	Contributing Zone (Upper)	Collecting Zone (Middle)	Conveyance Zone (Lower)
Retention basins	**	**	-
Rainwater harvesting	**	**	-
Constructed wetlands	*	*	*
Detention basins	**	**	-
Bioswales	-	**	*
Rain gardens	-	**	**
Green roofs	-	**	*
Permeable pavement	**	**	**

Key: ** Very appropriate * Moderately appropriate - Mildly or not appropriate

Source: McFarland 2019

Economists have developed alternative approaches for valuing flood risk reduction benefits that are more applicable to the type of localized flooding that GSI can be used to address, including:

- Willingness-to-Pay (WTP)
- Hedonic Pricing
- Avoided gray infrastructure costs

The available academic literature supports economic values that, especially when aggregated over time and multiple households, can represent substantial value (Table 2).

Table 2. Summary of findings from flood risk reduction valuation studies

Evaluation Method	Location	Findings (2022 USD)
Willingness to Pay	Champaign-Urbana, Illinois	Residents willing to pay $50/year to reduce basement flooding by 50%
Hedonic Pricing	Meta-analysis of studies across U.S. cities	On-site retention to mitigate flooding increases property values by 2-5% for all properties in the flood plain
Avoided costs of gray infrastructure at new and redevelopment sites	National	Average capital cost for stormwater management of $3 per square foot of impervious area managed. Represents the stormwater management allowance cost from RS Means for a typical gray infrastructure scenario, "absent further information" or specific cost detail.
Avoided costs of gray infrastructure upgrades	Dallas, TX	GSI was found to be 77% less costly than upgrading gray infrastructure alone to meet modeled overflows
Avoided costs of flood insurance payouts	Cook County, IL	Average payout per urban flood insurance claim for basement backups was $5,281

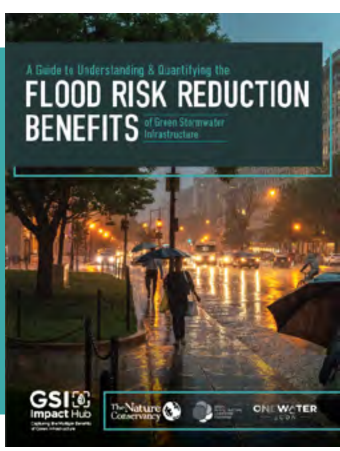
FUNDING GSI FOR FLOOD RISK REDUCTION

Federal and state agencies sponsor a range of grant programs which fund floodplain restoration and flood risk reduction projects and are likely to be very familiar to regional flood control districts and other flood management agencies. The American Flood Coalition hosts a web-based discovery tool that provides information about federal funding programs. Table 3 provides a sample of federal grant programs that may support funding for GSI projects that reduce flood risk.

While public agency grants are a well-trodden path for many stormwater and flood control agencies, they have significant constraints and limitations. Other approaches that can leverage grants and local revenue sources may provide attractive options for project funding and implementation. For example, the City of Evanston, Illinois requires that developers seeking Tax Increment Financing (TIF) funding either obtain a LEED Silver rating or implement a prescribed number of advanced stormwater reduction, retention, and treatment measures. A second pathway is to use TIF revenues to directly install GSI and other flood mitigation measures. The City of Milwaukee, for example, used TIF revenues and grant funding to construct the 45-acre Menomonee Valley Stormwater Park, a unified stormwater system that utilizes permeable surfaces, constructed wetland areas, and natural vegetation to reduce stormwater pollutants and volumes.

Table 3. Sample of federal grant programs that may support funding for GSI projects that reduce flood risk

Funding Agency	Grant Program	Notes
Federal Emergency Management Agency (FEMA)	Flood Mitigation Assistance Grant Program (FMA)	Projects must be located in NFIP communities; 25% non-federal match required for most projects. Program is typically passed through to states which then administer applications and awards.
FEMA	Hazard Mitigation Assistance Grant Program (HMA)	Funds hazard mitigation plans; acquisition of hazard prone homes and businesses; drainage improvement projects to reduce flooding (flood risk reduction projects), and more.
FEMA	Pre-Disaster Mitigation Program (PDM)	Administered by State Hazard Mitigation Offices.
FEMA	Building Resilient Infrastructure and Communities Program (BRIC)	Provides funding for public infrastructure projects and mitigation efforts that bolster a community's flood resilience before a disaster strikes. Non-federal match required.
Department of Housing and Urban Development	Community Development Block Grant - Disaster Recovery	Funded through HUD and administered by state agencies.
Natural Resource Conservation Service (NRCS)	Watershed and Flood Prevention Program	Federal-state-local cooperative efforts to mitigate erosion, floodwater, and sediment damage, as well as to further watershed conservation.
National Fish and Wildlife Foundation	National Coastal Resilience Fund	Eligible entities include: local and municipal communities, nonprofit 501c3 organizations, educational institutions, state and territorial government agencies and Tribal governments. 50% non-federal match required.



For more information visit:
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