Growing Resilience: Advancing Green Stormwater Infrastructure in Environmental Justice Neighborhoods

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Highlights

- With an eye on workforce development, green jobs, and climate resilience, a bilingual stormwater management operation and maintenance training was hosted at Esperanza to help address the need for Spanish-led training.
- This implementation model is being expanded throughout Philadelphia by The Nature Conservancy and others to prioritize green stormwater infrastructure projects that maximize community and environmental impact.
- Site selection for green stormwater infrastructure has been analyzed to optimize co-benefits to neighborhoods that may benefit the most.

Introduction

Esperanza is a faith-based nonprofit organization in North Philadelphia that works to strengthen Hispanic communities through education, economic development, and advocacy. In partnership with Esperanza, The Nature Conservancy (TNC) and AKRF implemented a green stormwater infrastructure (GSI) retrofit project on their headquarters site in Philadelphia using grant funding from the Philadelphia Water Department and William Penn Foundation.

Methodology

With construction of the stormwater retrofit completed in 2023, the site now manages over 5.6 million gallons of stormwater annually and has added new water quality vegetated areas and trees to the Hunting Park neighborhood, which has limited tree canopy and is consistently hotter than the majority of Philadelphia. With an eye on maintenance, workforce training and resiliency, a bilingual stormwater management operation and maintenance training was hosted at Esperanza to help address the need for Spanish-led training. This implementation model is being expanded throughout Philadelphia by TNC and other partners to prioritize green stormwater infrastructure projects that maximize community and environmental impact.

Additionally, TNC and AKRF (and other partners) are finding new locations in environmental justice neighborhoods of Philadelphia for stormwater retrofits that will have the most benefit to the community. Methodology of the selection process will be discussed.

Key Findings

Maintenance is key to operational continuity and a ‘low-hanging fruit’ method to increase resiliency. There is a need for bilingual GSI maintenance training in the Philadelphia area.

There are approaches to quantify the numerous co-benefits of GSI and TNC and their partners have been combining this analysis with stakeholder engagement to make progress in neighborhoods, site by site.

Recommendations

Expand capacity for training, job opportunities and maintenance documentation.

References

None at this time but training materials can be provided.

Managing stormwater can be challenging in communities facing economic hardships. However, with determined leadership, federal and state support, and efficient program management, communities can realize success in their program. Highlights of the journey of one such Stormwater Authority located in the City of Chester; PA are presented in this session.

The City of Chester is located about 20 miles south of Philadelphia, PA. Once a booming industrial/ manufacturing hub, the City has been experiencing an economic downturn and significant environmental justice issues since the 1960s. Today, the City has a population of about 35,000 with a median household income of $35,000. With the City's ongoing economic challenges, stormwater management was ignored for a long time. Since 2016, HDR has directly assisted the newly formed Stormwater Authority of the City of Chester (SAC) with the implementation of its Stormwater Utility Rate Study, Infrastructure Mapping and Condition Assessment, Catch Basin Repair and Retrofit Program, City-wide Green Stormwater Infrastructure (GSI) Feasibility Study, Flood Assessments, MS4 Stormwater Management Program Development, and Regional Stormwater Facility Design. HDR Inc. was responsible for the planning, design, bid support, construction management, and inspections associated with the above projects, and for supporting SAC to obtain over $40 million in PENNVEST State Revolving Fund (SRF) loans and grants for project implementation. Since the inception of the program, over 1,200 catch basins within the City have been cleaned, inspected, and retrofitted with water-quality insert filters or hoods. Additionally, in the areas along the Chester Creek Corridor that were prone to frequent inundation, separate storm sewer systems have been constructed. Green Stormwater Infrastructure (GSI) including porous panels, stormwater tree boxes, curb bump-outs, and bioretention areas have been installed at multiple locations within the City.

Another key aspect of the stormwater management program was fostering local workforce development and job creation. The construction bids advertised required a minimum of 15% local resident and union participation by work hours. Additionally, multiple GSI maintenance training events were held for local landscaping and maintenance construction companies.

This presentation will include information about the program's background and impetus, the project team's organizational structure, and related processes that were instrumental in getting projects "in the ground" and securing the funding to do so in a timely manner for the program. Descriptions of specific projects implemented as part of the program will be presented to demonstrate how the initial goals of the program including the goals most important for this environmental justice community were successfully achieved.

Comparing Community Approaches to Flood Mitigation in Pennsylvania

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Highlights

- Presentation evaluates a cross section of flooding concerns and causes in three types of Pennsylvania communities: rural, suburban, and urban.
- The Fishing Creek Watershed Flood Mitigation Study identified 75 total problem areas, each visited and evaluated with conceptual mitigation solutions and prioritized for use in aiding potential implementation.
- The Lewisburg Flood Mitigation Study included the identification of a green stormwater infrastructure demonstration project as a tool to promote flood mitigation awareness.
- The Bethlehem Township stormwater and flood mitigation program seeks to utilize projects to meet MS4 permit requirements while increasing flood resiliency through project optimization.

Introduction

Many communities throughout Pennsylvania with a variety of development densities deal with flooding issues stemming from a wide range of historical causes. Regardless of cause all of these flooding situations are being exacerbated by changing weather patterns. As changing weather patterns bring these problems to the front of communities agendas many are in various steps of preparing and mitigating the associated risks. Location and situation, land use and management, local climate, and geology are each factors that effect a community's specific flood issues. This presentation will review three case studies and compare the variety of flood issues, each community's status in the path to resiliency prior to and after each study, and a review of communication approaches. Each study summarized problems and projects for flood mitigation, identified recommended areas and issues for further study, and summarized the evaluation of prioritized options. Recommendations were developed to provide officials with the information to prioritize next steps for increasing flood resiliency.

Background

Communities that are aware of stormwater problems and flood hazards and plan approaches to address these issues are more resilient than those who downplay stormwater and flooding threats. Each of these communities have taken a proactive approach by funding through various mechanisms, studies to better understand both flooding risk, flooding causes, and potential mitigation actions.

- The Fishing Creek Watershed Flood Mitigation Study was a comprehensive effort to identify flooding and wet weather issues within the Columbia County portion of the Fishing Creek Watershed.
- The Lewisburg Flood Mitigation Study was an extension of previous flood mitigation planning and projects and sought to move the Borough towards achieving flood resiliency and mitigating adverse impacts from flooding events of the future.
- The Bethlehem Township stormwater and flood mitigation program is a comprehensive approach to meeting MS4 requirements while reducing flood risks. This presentation will review these case studies and compare the stormwater capture approaches to deal with flooding issues and each approach and path to resiliency.

Fishing Creek, Columbia County, Pennsylvania

The Fishing Creek Watershed Flood Mitigation Study was a comprehensive effort to identify flooding and wet weather issues within the Columbia County and to investigate the mitigation options available from the site to watershed scale. Fishing Creek Watershed is primarily a rural and agricultural area with up to 79% of individual municipal populations lying within the floodplain. The study yielded conceptual solutions that supported goals of achieving Chesapeake Bay TMDL requirements while capturing stormwater and reducing flood issues.

Borough of Lewisburg, Pennsylvania

The Lewisburg Flood Mitigation Study was an extension of previous flood mitigation planning and projects, with goal of the study to identify actionable steps and recommendations towards achieving flood resiliency and mitigating adverse impacts from flooding events. This study incorporated a green stormwater infrastructure demonstration project to engage the community in stormwater and flood awareness.

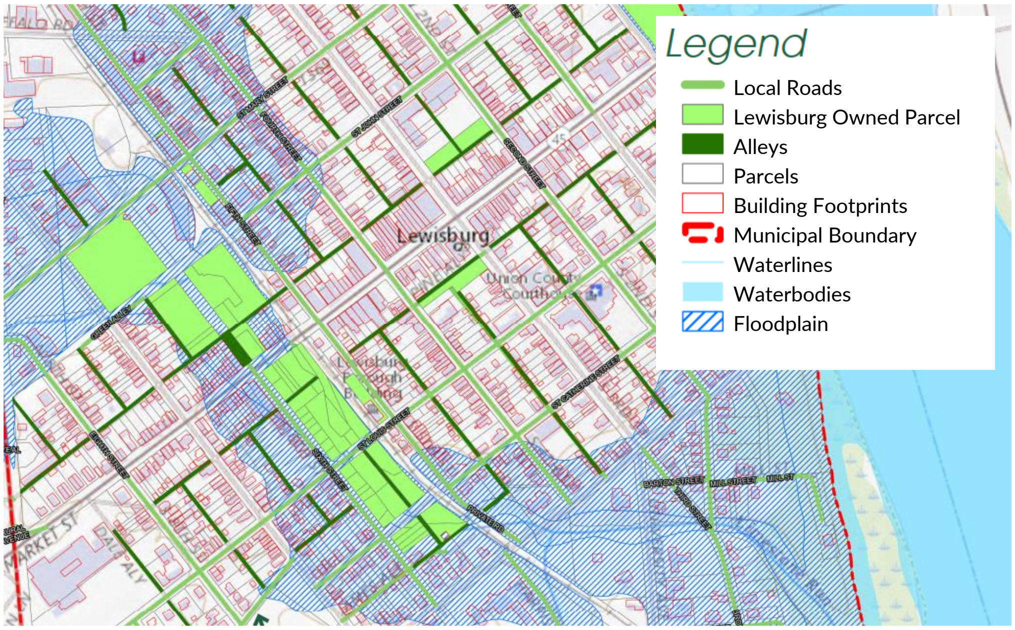

Figure 1. Lewisburg Green Stormwater Infrastructure Demonstration Project Opportunities.

Bethlehem Township, Pennsylvania

The Bethlehem Township stormwater and flood mitigation program was initiated to develop a comprehensive approach to meeting MS4 requirements while reducing flood risks. The Township completed a flood mitigation study that reviewed the potential to utilize existing and potential stormwater management basins for decreasing flood peak flows and event volumes.

Key Findings and Recommendations

For each Study, a consideration of project prioritization was included to address issues of highest impact or benefit to the community. The project teams developed a system to prioritize projects that considered technical analysis, engineering judgment, and input from public officials and interest groups that participated in the process. For each, a set of criteria were developed to determine the priority of each problem area. Criteria to assess each problem area and potential mitigation concept project included items such as frequency of problem, property vs public impacts, problem reduction, resiliency, cost, community preference, and operations and maintenance requirements. The presentation reviews the use of how stormwater management policies, requirements, and solutions aid in addressing flooding issues from individual site and municipal scales to full watershed impacts.

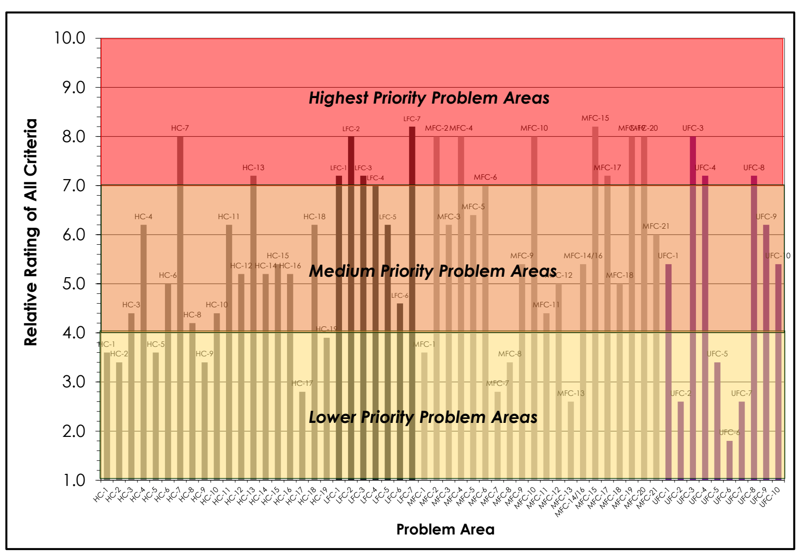

Figure 2. Fishing Creek Watershed Relative Problem Area Prioritization Rating.

Little Creek, DE: A Case Study in Coastal Community Resilience

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Highlights

- Verdantas performed flood mitigation feasibility studies for the town of Little Creek, DE.
- Several solutions were recommended, including sewer, ditch, and wetlands improvements.
- Little Creek serves as a case study for the unique flooding challenges faced by small coastal communities.

Introduction

Little Creek is a small, rural town in Kent County, Delaware, with only 0.10 square miles of incorporated area and a population of 195 as of the 2020 census. It is situated to the east of Dover and is bordered to the south by the tidal Little River. Intertidal estuarine marshes lie within and near town, as well as upland patches of freshwater wetlands. Multiple buildings in town feature on the National Register of Historic Places.

The town experiences frequent flooding events during which Main Street (Delaware Route 9) is impassable (Figure 1). This hinders access in and out of town and impacts public safety with the Little Creek Fire Station inaccessible during many flood events. Several factors contribute to the flooding, which has both pluvial and tidal influence. Portions of the aging storm sewer network are undersized, and settling of the network components as well as daily submergence by high tides contribute to reduced system capacity and standing water in pipes and catch basins. Flooding is expected to be exacerbated by continued settling, as well as sea level rise and increased precipitation caused by a changing climate. Additionally, funding of flood mitigation measures is challenging for resource-constrained coastal communities like Little Creek when they are both so small and so severely affected; it generally requires a combination of funding sources for both design and construction, including state and/or federal grant funds.

Figure 1. Flooding on Main Street (DE-9), looking northward toward Lowe Street, the night of September 27, 2023.

Verdantas was hired to evaluate the feasibility of flood mitigation measures for both the northern and southern drainage areas of the town. Currently, the feasibility study for the northern drainage area has been completed and has now progressed to the detailed design stage, with design and construction funds secured through the FEMA Hazard Mitigation Grant Program. The southern drainage area study was completed in March 2024.

Methodology

Verdantas was contracted by the town of Little Creek, initially to evaluate flood mitigation feasibility in the northern drainage area of town, and now also to carry out design of the flood mitigation measures. A drainage system model was constructed in HydroCAD to evaluate existing conditions for the 1-, 10-, and 25-year rainfall event. Investigated flood mitigation solutions were storm sewer network improvements, implementation of green infrastructure, and restoration of tidal wetlands.

Verdantas was also contracted by Delaware Department of Natural Resources (DNREC), on behalf of the town, to evaluate flood mitigation feasibility in the southern drainage area of town. A dual-drainage 1D SWMM model was developed to replicate existing conditions flooding for the 1-, 5-, 10-, and 25-year rainfall event. Investigated solutions were drainage network improvements (surface and subsurface), tide gates, detention storage, and pumping.

Key Findings

The recommended flood mitigation measures for the north project were a combination of upgrades to the existing storm drainage infrastructure and restoration of tidal wetlands. Upgrades to the storm sewer were recommended to add capacity and efficiently drain surface flow. Wetlands and ditch restoration were additionally suggested to enhance conveyance, add sufficient detention storage between the upstream drainage network and a tidal tributary channel of the Little River, and to provide ecosystem benefits. The town sought and won $2 million in funding from FEMA's Hazard Mitigation Grant Program to fund design, permitting, and construction of the proposed flood mitigation improvements. Obtaining this federal grant is an accomplishment for Little Creek as a small, under-resourced community and required extensive efforts to obtain not only the federal grant, but also the required local match.

The recommended flood mitigation measures for the south project included subsurface and surface drainage network improvements, as well as potential restoration of a drainage ditch along Bell Street to the west of town. The storm sewer network draining to wetlands east of town is suggested to be entirely replaced, which will correct settling and promote positive drainage toward the wetland outfalls. Some existing pipes, which flow beneath private properties and possibly structures and are of unknown condition, would be abandoned and replaced with new pipes and junction structures in the public right-of-way. Portions of the network should be upsized to convey the 10-year event, and due to shallow cover, some locations may need to have double-barrel pipes instead of increased diameter pipes. Surface drainage improvements may include construction of a gutter section along the Main Street curbline, increased pavement cross-slope in Main Street, and/or increased capacity inlets or additional inlets. Ditch restoration to convey the 10-year storm would divert flow around town by carrying it directly to Little River riparian wetlands, which in turn would reduce the need for pipe upsizing in the storm sewer network; however, ditch restoration is dependent on the acquisition of private property through which it runs. Restoration of the ditch will also provide water quality and ecosystem benefits.

Recommendations

Recommended solutions included a combination of storm sewer maintenance improvements, street surface and ditch drainage improvements, and wetlands restoration. A variety of solutions are needed due to the flooding challenges as well as practical and budgetary constraints.

Additionally, hydrologic and hydraulic (H&H) modeling to support these projects was challenging due to the combination of pluvial and tidal influence. We also found during the southern flood study that we were pushing the limits of 1D modeling to predict surface flooding; if the southern project progresses to the detailed design phase, we are considering moving to coupled 1D-2D modeling in a software package such as PCSWMM (1D storm sewer network coupled with 2D surface grid modeling).

Lessons Learned

- Coastal communities are at the intersection of multiple flooding challenges, with both rainfall- and tide-driven causes, both of which are getting worse along the Eastern Seaboard due to climate change. The effects of sea level rise are also exacerbated by land subsidence.
- Small communities face additional difficulty in addressing flooding, due to funding and resource constraints.
- A wide variety of site-specific solutions must be considered to effectively address routine flooding, given these constraints.

Exploring determinants of residents' behavior in green stormwater infrastructure adoption: an extension of the theory of planned behavior

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Highlights

- Knowledge and past experiences play a substantial role in residents' behavior of GSI adoption.
- Educational programs and interventions aimed at promoting positive attitudes and social norms are required.

Introduction

Climate change and increasing imperviousness levels are causing urban areas around the world to experience larger volumes of rainfall runoff. This requires effective management to protect property, and infrastructure, and prevent environmental pollution. The traditional grey stormwater infrastructure is often outdated and incapable of controlling the increased runoff volumes. Green Stormwater Infrastructure (GSI) can complement grey infrastructure, but public land for its installation is limited. As a result, municipalities often rely on residential properties to install GSI at the lot level. Despite governmental efforts to promote GSI, local residents sometimes lack the motivation to implement individual GSI practices on their properties or contribute to the development of GSI within their communities. Even when provided at no cost or with incentives, resident participation remains low, potentially due to factors such as insufficient information, knowledge gaps, and other social-psychological and socio-demographic influences (Venkataramanan et al., 2020). Currently, there is limited understanding of how these factors influence residents' behavior in GSI adoption. Our study aims to address this gap by identifying the social and psychological determinants impacting GSI implementation within the residents' immediate surroundings, contributing to a more comprehensive understanding of this critical area.

The theoretical foundation of the Theory of Planned Behavior (Ajzen, 1991) guides our exploration, positing that attitudes, subjective norms, and perceived behavioral control collectively determine behavioral intentions, ultimately shaping actual behaviors. We extend this framework by incorporating the mediating role of demographic characteristics, as well as knowledge and past experiences. We hypothesize that individuals with greater knowledge and exposure to stormwater issues and GSI practices are more likely to exhibit positive intentions and behavior toward GSI implementation and maintenance. Figure 1 indicates the hypothetical model used for this study.

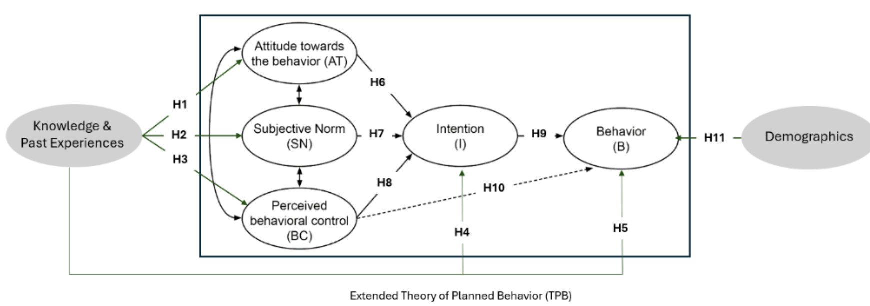

Figure 1. Research hypothetical model based on the Theory of Planned behavior

Methodology

This study employed a questionnaire survey conducted online via the Qualtrics platform. Dynata, a first-party data and survey platform, facilitated sampling and recruitment, ensuring a diverse pool of participants. Screening strategies were employed to gather data from individuals residing in Baltimore, Pittsburgh, and Portland, selected based on varying stages of Green Stormwater Infrastructure (GSI) implementation in these cities. A total of thirty-seven questions were organized into five sections, including an introduction, screening questions, sections on past experience and knowledge, TPB constructs, and demographic information. A total of 354 complete responses were collected and the IBM SPSS and SmartPLS 4 were utilized for data analysis. Partial Least Squares Structural Equation Modeling (PLS-SEM) was chosen for data analysis due to its suitability for small sample sizes, non-normal data distributions, and predictive analysis objectives. The analysis comprised measurement model assessment and structural model assessment to evaluate reliability, validity, and interrelationships among variables. Additionally, a multi-group comparison was conducted to explore geographic variations in responses across the three cities.

Key Findings

Results reveal that Knowledge and Past Experiences significantly influence behavior directly ($\beta = 0.643$, $p < .001$), emphasizing the importance of prior experiences and education in GSI engagement. Perceived Behavioral Control strongly predicts intention ($\beta = 0.654$, $p < .001$), indicating individuals' perceptions of their capability to implement GSI affect their willingness to engage. However, the direct influence of attitude on intention was not significant ($\beta = 0.075$, $p > .001$), suggesting a nuanced relationship. Demographic factors had minimal impact on behavior, reinforcing the dominance of theoretical determinants. Moreover, the Multi-group analysis comparing the results across the three cities revealed that no path coefficients showed significant differences, suggesting that the relationships modeled by the Theory of Planned Behavior are consistent across the different geographic regions studied for this particular context. The paths involving demographics control variables, and their impact on Behavior, generally do not differ significantly across the three locations, with all p-values being non-significant. This indicates a consistent lack of direct effect of these control variables on Behavior across the different geographic groups.

Recommendations

Based on the findings of the study, several lessons were learned:

1. **Tailored Educational Interventions**: Given the significant influence of knowledge and past experiences on GSI adoption, educational interventions should focus on increasing public awareness and understanding of stormwater issues and GSI benefits.
2. **Enhancing Perceived Behavioral Control**: Strategies aimed at enhancing individuals' perceived behavioral control, particularly regarding the installation and maintenance of rain gardens, are crucial for promoting GSI adoption. This could involve providing resources, guidance, and support to address perceived barriers such as time constraints, financial concerns, and lack of knowledge or space for GSI implementation.
3. **Leveraging Social Norms**: Recognizing the influence of subjective norms on intentions towards GSI adoption, efforts should be made to leverage social networks and community dynamics to promote environmentally responsible behaviors. Peer-led initiatives, community collaborations, and incentivized programs could help create a social environment that encourages and reinforces GSI practices.
4. **Addressing Attitudinal Ambiguities**: The study's findings suggest a nuanced relationship between attitudes and intentions towards GSI adoption, warranting further exploration of attitudinal components. Future research should delve deeper into understanding the specific factors shaping individuals' attitudes towards GSI, considering aspects such as aesthetic preferences, functional benefits, and maintenance concerns.
5. **Context-Specific Interventions**: Recognizing geographic variations in the relationship between knowledge and subjective norms, interventions should be tailored to local contexts and community characteristics. Strategies that resonate with the unique socio-cultural and environmental landscapes of each city can enhance the effectiveness of GSI promotion efforts.
6. **Policy Implications**: Policymakers and urban planners can use these findings to inform the design and implementation of GSI policies and initiatives. Incorporating educational components, community engagement strategies, and targeted incentives into GSI programs can facilitate widespread adoption and long-term sustainability of green infrastructure practices.

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