



SCAN TEAM REPORT

NCHRP Project 20 68A, Scan 16-02

Leading Landscape Design Practices For Cost-Effective Roadside Water Management

Supported by the

National Cooperative Highway Research Program

The information contained in this report was prepared as part of NCHRP Project 20-68A U.S. Domestic Scan, National Cooperative Highway Research Program.

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The purpose of each scan, and of Project 20-68A as a whole, is to accelerate the integration of innovative ideas into practice by information sharing and technology exchange among state transportation agencies. Experience has shown that personal contact with new ideas and their application is a particularly valuable means for sharing information about practices. A scan entails peer-to-peer discussions between practitioners who have implemented practices of interest and who are able to disseminate knowledge of these practices to other peer agencies. Each scan addresses a single technical topic that is selected by AASHTO and the NCHRP 20 68A Project Panel. Further information on the NCHRP 20-68A U.S. Domestic Scan program is available at <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1570>.

This report was prepared by the scan team for Domestic Scan 16-02, *Leading Landscape Design Practices for Cost-Effective Roadside Water Management*. The members of the scan team are listed below. Scan planning and logistics are managed by Arora and Associates, P.C. Harry Capers served as the Principal Investigator. Melissa Jiang provided valuable support to the team. NCHRP Project 20-68A is guided by a technical project panel and managed by Andrew C. Lemer, PhD, NCHRP Senior Program Officer.

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Disclaimer

The information in this document was taken directly from the submission of the authors. The opinions and conclusions expressed or implied are those of the scan team and are not necessarily those of the Transportation Research Board or its sponsoring agencies. This report has not been reviewed by and is not a report of the Transportation Research Board or the National Academies of Sciences, Engineering, and Medicine.



Scan 16-02

Leading Landscape Design Practices For Cost-Effective Roadside Water Management

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Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ADOT	Arizona Department of Transportation
ASCE	American Society of Civil Engineers
BMP	Best Management Practice
DOT	Department of Transportation
EPA	Environmental Protection Agency
FAHP	Federal Aid Highway Program Programmatic Biological Opinion
FHWA	Federal Highway Administration
GI	Green Infrastructure
GIS	Geographic Information System
GSI	Green Stormwater Implementation
LID	Low-Impact Development
M&O	Maintenance and Operations
MPO	Municipal Planning Organization
MDOTSHA	Maryland State Highway Administration (One unit of Maryland Department of Transportation)
MS4	Municipal Separate Storm Sewer System
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NDOT	Nevada Department of Transportation
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
ODOT	Oregon Department of Transportation
PennDOT	Pennsylvania Department of Transportation
PNW	Pacific Northwest
PWD	Philadelphia Water Department
SEMCOG	Southeast Michigan Council of Governments
SMP	Stormwater Management Program
STTC	Stormwater Technology Testing Center
SWM	Stormwater Management
ROW	Right of Way
TMDL	Total Maximum Daily Load
TRB	Transportation Research Board
TU	Temple University
VU	Villanova University
WSDOT	Washington State Department of Transportation

Executive Summary

This report summarizes findings of Domestic Scan 16-02 on leading landscape design practices for cost-effective roadside water management within transportation agencies and other organizations. The purpose of this scan was to investigate how transportation agencies are applying principles and practices of green infrastructure (GI) for roadside water management to mitigate adverse impacts of flooding, drought, and temperature extremes affecting their infrastructure.

Scan Purpose and Scope

Although a great deal of information is published by environmental and national highway agencies, there appears to be a limited number of state Department of Transportation (DOT) agencies that are fully implementing these practices and recommendations. The intent of the published information is largely to help agencies deal with regulatory requirements to provide clean water to receivers of their locale. This scan proposed to discover those agencies that were successfully utilizing GI in their practices, what was and was not successful, and how to assist agencies to more fully, cost-effectively, and successfully provide cleaner water while simultaneously providing more environmental, social, and economic benefits.

General Findings and Observations

After a peer-to-peer exchange and discussions of what were considered significant findings from 12 agencies meeting over four days, participants agreed that eight categories were required for successful GI implementation. Not all these categories or findings are necessarily being exercised in more than one or two jurisdictions. Nevertheless, the team determined that by using all the approaches and solutions combined would provide successful, long-term results, despite varied climates, geographies, and topographies.

Team Recommendations

These findings and subsequent conclusions and recommendations fall into eight categories:

- Definition of GI
- Maintenance
- Watershed Approach Versus Project Site Approach
- Information Development and Sharing
- Public Outreach
- Asset Management
- Design
- Construction Inspection of Temporary and Permanent Best Management Practices (BMPs)

The team recognized that these eight categories were those that had a significant impact on the challenges presented by implementing GI practices for roadside water management within transportation agencies. One of the first challenges is that there is no standard definition of GI. All of these challenges would be greatly reduced by recognizing the challenges agencies confront and incorporating the recommendations provided for national, state, and local entities.

The team discovered a curious paradox when looking at the state of GI in state DOTs. Local, state, and federal regulators nationwide promote, encourage, and require low-impact development (LID) stormwater measures.

- Comprehensive design guidance is widely available.
- Applied research programs continue to develop the technique.
- Regional bodies and nongovernmental organizations promote and apply LID and GI.
- Private consultants are well versed in the methods.
- LID and GI are routinely employed by private owners and their consultants.
- FHWA and the American Association of State Highway and Transportation Officials (AASHTO) promote and encourage GI.

Yet GI practice across state DOTs is inconsistent and seems to be employed only when required. GI is not yet a part of the DOT stormwater management toolbox and is not routinely employed as a standard stormwater management method.

The scan team's conclusion was that successful management of stormwater and GI is best accomplished by using a holistic approach. Planning, asset management, maintenance, and a watershed approach are inter-related and impact each other. Long-term success in both regulatory compliance and environmental stewardship is greatly improved when GI is approached as an entire system rather than segmented on a project-by-project basis.

GI's many benefits, such as environmental, economic, social, aesthetic, and habitat improvements, are worth the effort of communities and agencies to look beyond the stormwater functions.

Introduction

Background

Transportation agencies seeking ways to mitigate the adverse impacts of flooding, drought, and temperature extremes on their infrastructure have been exploring principles and practices of green infrastructure (GI) for roadside water management. Techniques such as water harvesting, landform grading, rain gardens, micro-catchment basins in arid climates, and large-watershed actions have been used as components of transportation development projects and operations. The fundamental intent of these techniques is to work with natural processes and “build with nature.” While the details of applications are often determined by geography, many of the project development approaches are transferrable to other climatic and landscape settings. The principles and practices being developed for designing, developing, and managing GI are generally applicable.

Historically, the focus of design has been on controlling the peak flow of water and moving this water off roads to nearby waterways as quickly as possible. Often, we use gray infrastructure, including culverts and pipes, to move the water offsite quickly; however, this approach is no longer efficient or cost-effective. The infrastructure needed now requires a more holistic design approach.

As investments required to maintain aging gray infrastructure and environmental pressure from expanding urbanization increase, the value of ecosystem services is entering more prominently into local, state, and regional planning and management equations. Compounded by increasing regulatory pressure to address water and air quality, by the need to anticipate and adapt for climate change impacts, and by the drive for economic competitiveness, all with ever more constricted finances; communities, cities, and regions across the U.S. are increasingly assigning higher priority to their GI systems¹.

Transportation corridors often convey significant amounts of runoff from surrounding areas to local streams and rivers. Often, developments along major transportation corridors convey stormwater into existing state, county, and local stormwater systems, ultimately shifting the burden of stormwater management to transportation agencies. This challenge is exacerbated by the aging stormwater infrastructure within road right-of-way (ROW) areas.

The Environmental Protection Agency (EPA) has multiple websites and links related to stormwater, GI, transportation, and related topics. **Figure 1-1** shows information regarding the National Pollutant Discharge Elimination System (NPDES) Stormwater Program taken from the EPA website

1 Greening the Grey: Green Infrastructure for Sustainable Development, U.S. Forest Service, U.S. Department of Agriculture, December 2013, http://cligs.vt.edu/wp-content/uploads/2014/01/CLiGS-NARC_GI2013_final.pdf

NPDES stormwater program areas:

- Stormwater Discharges from Construction Activities
- Stormwater Discharges from Industrial Activities
- Stormwater Discharges from Municipal Sources
- Stormwater Discharges from Transportation Sources
- Oil and Gas Stormwater Permitting
- EPA's Residual Designation Authority
- Stormwater Maintenance
- Long-Term Stormwater Planning

Problems with Stormwater Pollution

Stormwater runoff is generated from rain and snowmelt events that flow over land or impervious surfaces, such as paved streets, parking lots, and building rooftops, and does not soak into the ground. The runoff picks up pollutants like trash, chemicals, oils, and dirt/sediment that can harm our rivers, streams, lakes, and coastal waters. To protect these resources, communities, construction companies, industries, and others, use stormwater controls, known as best management practices (BMPs). These BMPs filter out pollutants and/or prevent pollution by controlling it at its source.

The NPDES stormwater program regulates some stormwater discharges from three potential sources: municipal separate storm sewer systems (MS4s), construction activities, and industrial activities. Operators of these sources might be required to obtain an NPDES permit before they can discharge stormwater. This permitting mechanism is designed to prevent stormwater runoff from washing harmful pollutants into local surface waters.

Authorization Status for EPA's Stormwater Construction and Industrial Programs – Most states are authorized to implement the stormwater NPDES permitting program. EPA remains the permitting authority in a few states, territories, and on most land in Indian Country.

Population growth and the development of urban/urbanized areas are major contributors to the amount of pollutants in the runoff as well as the volume and rate of runoff from impervious surfaces. Together, they can cause changes in hydrology and water quality that result in habitat modification and loss, increased flooding, decreased aquatic biological diversity, and increased sedimentation and erosion. The benefits of effective stormwater runoff management can include:

- Protection of wetlands and aquatic ecosystems,
- Improved quality of receiving waterbodies,
- Conservation of water resources,
- Protection of public health, and
- Flood control.

Traditional stormwater management approaches that rely on peak flow storage have generally not targeted pollutant reduction and can exacerbate problems associated with changes in hydrology and hydraulics.

Figure 1-1 NPDES Stormwater Program²

Much infrastructure in our country needs replacement or repair but it is chronically underfunded. Now, more resilient and affordable solutions that can meet multiple objectives are needed. GI is one solution that can help create more livable and resilient communities by alleviating the stress on our storm sewer systems, addressing localized flooding, and creating infrastructure that is able to withstand more-intense weather events.

² NPDES Stormwater Program, National Pollutant Discharge Elimination System, U.S. Environmental Protection Agency, <https://www.epa.gov/npdes/npdes-stormwater-program>

Additionally, regulatory requirements are the impetus for delivering GI strategies and solutions. Many of the GI practices used today were incorporated due to the various regulatory requirements for clean water/clean air imposed by agencies such as the EPA and state departments of environmental protection/quality. However, regulatory agencies (typically at the state level) often included barriers that hindered a DOT's ability to fully or successfully implement the best approaches to GI. There is an example of this in Watershed Approach Versus Project Site Approach by Maryland DOT.

The Federal Highway Administration (FHWA) has multiple links and websites regarding GI³. Interestingly, despite the plethora of information and after researching agencies, especially state DOTs, it does not appear from website searches that many DOTs are implementing GI practices in a comprehensive and systematic fashion. This lack of implementation continues, despite these resources continuously reporting on the social, economic, and environmental benefits of GI. In addition, multiple habitat and aesthetic improvements accompany GI. In this report, we will also review obstacles the various agencies discussed and why they are occurring.

Additionally, the EPA has other requirements under Section 401, Certification, of the Clean Water Act⁴ with which DOTs also must comply with under certain circumstances: Some of the requirements are shown in **Figure 1-2**.

(a) Compliance with applicable requirements; application; procedures; license suspension
(1) Any applicant for a Federal license or permit to conduct any activity including, but not limited to, the construction or operation of facilities, which may result in any discharge into the navigable waters, shall provide the licensing or permitting agency a certification from the State in which the discharge originates or will originate, or, if appropriate, from the interstate water pollution control agency having jurisdiction over the navigable waters at the point where the discharge originates or will originate, that any such discharge will comply with the applicable provisions of sections 301, 302, 303, 306, and 307 of this title. In the case of any such activity for which there is not an applicable effluent limitation or other limitation under sections 301(b) and 302 of this title, and there is not an applicable standard under sections 306 and 307 of this title, the State shall so certify, except that any such certification shall not be deemed to satisfy section 511(c) of this title.

Figure 1-2 *Partial requirement, Clean Water Act, Section 401, Certification*

Thus, the NPDES permit is not the only regulation/permit enforcing requirements for stormwater. Clean Water Act 401 certifications and the Endangered Species Act also have considerable authority over stormwater discharges and can extend regulatory authority beyond “municipalities” and into rural areas.

State and local laws and permits create an additional layer of regulatory requirements. This leads to additional impacts and challenges due to the lack of consistency between the different programs. These differing regulations often cause confusion, with resultant delays or blockages to the DOT's attempts at beneficial GI efforts.

3 Search results for “green infrastructure,” Federal Highway Administration, U.S. Department of Transportation, <https://search.usa.gov/search?utf8=%E2%9C%93&affiliate=dot-fhwa&query=green+infrastructure&commit.x=9&commit.y=13&commit=Search>

4 Clean Water Act, Section 401 Certification, U.S. Environmental Protection Agency, <https://www.epa.gov/cwa-404/clean-water-act-section-401-certification>

Multiple federal agencies have declared support for GI⁵ and seven federal agencies released a federal letter of support for the Green Infrastructure Collaborative⁶. Each agency committed to taking specific actions to promote GI. Joining EPA, the cooperating agencies are the:

- U.S. Department of Agriculture
- U.S. Department of Defense
- U.S. Department of Energy
- U.S. Department of Housing and Urban Development
- U.S. Department of the Interior
- U.S. Department of Transportation



Figure 1-3 *Federal buildings, representation of the federal GI Collaborative*

The Green Infrastructure Collaborative includes more than 20 academic, nongovernmental, and private sector organizations committed to advancing the implementation of GI strategies. Nevertheless, there are still mixed messages and confusion about GI and its regulation, benefits, strategies, and implementation.

Despite this federal support, much of the leading-edge experience is coming from local and regional (i.e., sub-state) agencies. An important feature of this scan was consideration of how those exemplary applications might be scaled up to intercity, corridor, and statewide systems. Thus, the scan's peer-to-peer exchange included regional, state, and local agencies that discussed their experiences, regulatory actions that activated policies, and the subsequent required actions. These considerations ranged from planning, funding, design, construction, and short- and long-term maintenance.

5 Green Infrastructure Collaborative, Green Infrastructure, U.S. Environmental Protection Agency, <https://www.epa.gov/green-infrastructure/green-infrastructure-collaborative>

6 Federal Agency Support for the Green Infrastructure Collaborative, July 16, 2014 (Amended October 8, 2014), https://www.epa.gov/sites/production/files/2015-10/documents/federal-support-for-green-infrastructure-collaborative_508.pdf

There is a great deal of information on GI but it is difficult to find consolidated approaches used by larger agencies, such as state DOTs. Smaller scale agencies, such as municipalities, appear to have utilized more GI techniques. However, with the continued instances of climatic extremes, a toolbox of approaches and solutions would be highly valuable for larger agencies to use as they implement GI. Hotter, drier summers; warmer, wetter winters; and more frequent extreme weather events are confronting transportation agencies with increasingly frequent and intense floods, droughts, and temperature extremes that adversely affect the transportation infrastructure.

In the past, solutions have been more limited to traditional approaches using gray infrastructure typically made from hardscape materials of concrete or stone, such as pipes, pumps, ditches, and detention ponds engineered to manage stormwater. It is becoming clearer that these approaches are not only expensive but can also contribute to the problems of flooding and stormwater pollution. A paradigm shift in large DOT agencies in considering such solutions as low-impact development (LID) and other GI will become an imperative as well as a cost-saving benefit. Other agencies have been investigating and providing information on GI, such as the Transportation Research Board (TRB), EPA, U.S. DOT, American Association of State Highway and Transportation Officials (AASHTO), FHWA, and others.

In 2005, the EPA and FHWA initiated the Green Highways Partnership⁷ out of realization that building safe, sound transportation systems and protecting and sustaining a clean and healthy environment were not mutually exclusive. This was particularly true considering the common denominator: serving the public good. Some of the agencies, such as FHWA and EPA, have provided funding mechanisms to be a catalyst to seek solutions and expedite implementation. Each has set up websites to disseminate information with links to other sites that carry related information.

Benefits of Green Infrastructure

Below is an example of the multiple benefits that the City of Philadelphia has realized from its Green City, Clean Waters⁸ partnership. This is a model other U.S. cities can use to implement GI to address sewer overflow. According to the City of Philadelphia, however, the benefits extend far beyond reducing sewer flow:

“Green City, Clean Waters: Philadelphia Water Department (PWD) continues its work outlined in the Green City, Clean Waters Partnership Agreement, a national model for U.S. cities to implement green infrastructure to address sewer overflow. This initiative saves the City billions of dollars by avoiding the need to construct and maintain additional traditional water and sewer infrastructure. These projects appear in the form of tree-lined streets, planted areas in sidewalks or streets, or as rain gardens or porous pavement at schools and recreation centers. Not only do these projects substantially increase the rate of greening, but they also improve the quality of our air and water and help reduce heat-related and air-related illnesses. Since the

7 Green Highways Partnership, <http://www.greenhighwayspartnership.org/>

8 Green City, Clean Waters, Philadelphia Water Department, City of Philadelphia, <https://www.phila.gov/water/sustainability/greencitycleanwaters/Pages/default.aspx>

start of FY14, PWD controlled the stormwater runoff from as much as 498 acres or more of the total area in the City through the use of green stormwater infrastructure, while also creating newly vegetated areas, better water and air quality, and improved human health conditions for residents. PWD has also restored two miles of local streams, created three and a half acres of wetlands and cleared area waterways for the safe passage of at least 3,500 migratory fish. PWD received the American Planning Association's 2015 National Planning Excellence Award for the implementation of Green City, Clean Waters.

"In the process, PWD has established strong partnerships with the community and the School District of Philadelphia for green infrastructure implementation on parks and schools. Through the Rain Check program, PWD installed over 7,000 rain barrels and over 150 other stormwater tools in residential homes. PWD is actively monitoring almost 50 green infrastructure sites and has installed low cost sensors at schools for Science, Technology, Engineering, and Mathematics (STEM) education. Through the Infill Soak It Up design competition, engaged 23,000 people in 20 events focused on accelerating the adoption, adaptation and implementation of green stormwater infrastructure. PWD also launched incentive grant programs to help commercial properties manage stormwater and reduce their stormwater bills.

*"In FY16, PWD will face the first five-year evaluation period set under the Consent Order with the Environmental Protection Agency regarding the Green City, Clean Waters program. By the end of FY16, 1,000 acres or more of the overall area of the city may be brought under control of green stormwater infrastructure, while creating newly vegetated areas, better water and air quality, and improved human health conditions for the residents. PWD will also seek to create a formalized network of municipalities and utilities with which to share best practices and data to help drive down costs, increase efficiency and find new financing mechanisms."*⁹

Scan Scope

This scan is for the first domestic scanning tour in the U.S. examining leading landscape design practices for cost-effective roadside water management. As no scan has been done that is similar to this one, it was determined it would be helpful for transportation agencies to have a resource of proven practices, as well as lessons learned.

This scan reviewed recent experience with GI practices for roadside water management to identify planning and design criteria, management practices, and exemplary applications that may be broadly useful in transportation agencies nationwide. Because much of the leading-edge experience is coming from local and regional (i.e., sub-state) agencies, an important feature of this scan was consideration of how exemplary applications might be scaled up to intercity corridor and statewide systems. The scan team hopes its work will contribute toward development of nationally useful guidelines and policies on effective GI practice.

⁹ Fiscal Year 2016 Budget Testimony, Philadelphia Water Department, City of Philadelphia, April 28, 2015, <http://phlcouncil.com/wp-content/uploads/2015/12/FY2016-Water-Department-Testimony.pdf>

Scan Team

The team consisted of representatives from various state Departments of Transportation (DOTs) and the FHWA staff formed to guide the scan and develop findings, recommendations, and dissemination actions. Scan team members brought to the table a diversity of research, planning, ecology, stormwater management and construction experience, along with an understanding of DOT management and workforce challenges.

The team members represented DOTs and FHWA from seven states: California, Nevada, Washington, Minnesota, Illinois, Maine and Louisiana. The team members' contact information and biographical sketches can be found in **Appendix A** and **Appendix B**.

Preparing for the Scan

The first portion of the scan is a desk scan, whose primary purpose is to help the scanning team select which agencies to consider as potential candidates to further investigate as participating agencies. After a conference call, the scanning team identified the most critical areas on which they wanted to focus. The team decided to study four to six agencies that have developed successful in-depth strategies to either document or develop more practices that would be useful/needed.

Amplifying Questions

The scan team members first met as a group for the desk scan in an organizational meeting to discuss potential agencies to study and to develop amplifying questions they felt would provide the most comprehensive set of responses to fully understand each selected agency's approach and practices regarding GI. The amplifying questions are provided in Appendix C, the agency responses in **Appendix D**. Although the team originally thought that between four and six agencies would be interviewed, 12 were eventually selected to participate in the scan based on further research and input from other agencies.

The format of the scan was a peer-to-peer exchange workshop; this format allowed the team to bring together all the selected practitioners and innovators in one location with the scan team to discuss their experiences in a workshop. Information was exchanged using presentations and roundtable discussions. This format was extremely effective, as more ideas and brainstorming could occur, and each participating agency had the ability to share and learn from each other and from the scan team's members.

The first challenge for the team was to develop a recognizable definition of what is considered GI, as there is currently no universally accepted definition. This was to help the selected agencies to have similar criteria with which to respond to the amplifying questions. For this scan, GI was defined as including roadside stormwater management, LID, hydromodification, or watershed actions that conserve water, buffer climate change impacts, improve water quality, water supply, public health, and restores and protects rivers, creeks and streams as a component of transportation development projects and operations.

The team developed six categories that they believed would provide the necessary information an agency could use to explain how the application of GI in stormwater management (or in other areas) resulted in the successful use of those applications:

1. **Agency information;** types of GI required to be implemented under regulatory programs (e.g., NPDES) versus voluntary GI initiatives (e.g., community rain gardens). Also, the team wanted to distinguish GI efforts from stormwater programs and, if the agency had distinct rules, designated staff, and other elements, for the two areas of practice.
2. **GI techniques,** lessons learned, best management practices, and emerging practices The why and wherefores of implementing GI, such techniques used, BMPs, and if the use of GI was a part of the agency's vision and mission or instead was a part of regulatory requirements or public demand.
3. **Performance Measures:** This included requirements imposed by regulatory agencies, programmatic agreements through GI, funding for GI, cost differences between GI and gray infrastructure, permanent vegetation establishment and plant establishment periods, and environmental outcomes, such as impact mitigation.
4. **Maintenance:** We wanted to determine how maintenance is handled; whether there is a dedicated staff and/or funding for GI; if specialized equipment is needed and purchased for GI; if regular maintenance is scheduled for GI components or projects; and if there are maintenance triggers and, if so, how they are identified.
5. **Miscellaneous Questions:** These questions entailed items that did not specifically fit into any of the preceding categories, such as design related to either project or regional approaches, partnerships developed with other agencies, soil testing, and site selection criteria. The team also asked if it missed an approach or technique that would bear further exploration.

Finally, a sixth category was included only for cities or municipal planning organizations (MPOs), as these local agencies could have different or additional resources and challenges.

6. **City/MPO:** Questions in this category related to additional considerations, such as zoning requirements established, special incentives for implementing GI, cost/benefit analyses, municipal bonds, plant establishment and required plant establishment periods (which could be different in an urban environment), and pushback from the public or from commercial entities.

All the amplifying questions encompass any varying criteria, such as environmental, climatic, regional, topographic, urban versus rural, too little versus too much water, regulatory agency influences, and long-term cooperative agreements.

Peer-to-Peer Workshop

The scan was conducted in one location in November 2017 as a peer-to-peer exchange workshop, with each host agency providing a PowerPoint presentation to share its practices. During the workshop, the scan team members and host agencies reviewed the amplifying questions and reviewed watershed management practices and activities from 12 states (see **Figure 1-4**). These included seven state DOTs (Arizona, Maryland, Michigan, Nevada, Oregon, Pennsylvania, and Washington) and five cities, counties, or regional agencies (Philadelphia, Pennsylvania; New York City, New York; Long Creek Watershed Management District, Maine; Southeast Michigan Council of Governments [SEMCOG], Michigan; and King County, Washington). The diversity of the invited agencies resulted in a comprehensive and complementary combination of experience, skill sets, and knowledge from multiple geographic and climatic regions.

At the end of each day, the group discussed its significant findings for the day. On the fourth day, after all presentations were completed, all participants discussed and mapped out the most significant findings and voted on those they found the most important. The last step on the last day was for the scan team to go over the results of the significant findings to determine those that most merited final conclusions and recommendations.

The workshop agenda and key contact information are provided in **Appendix E** and **Appendix F**, respectively.

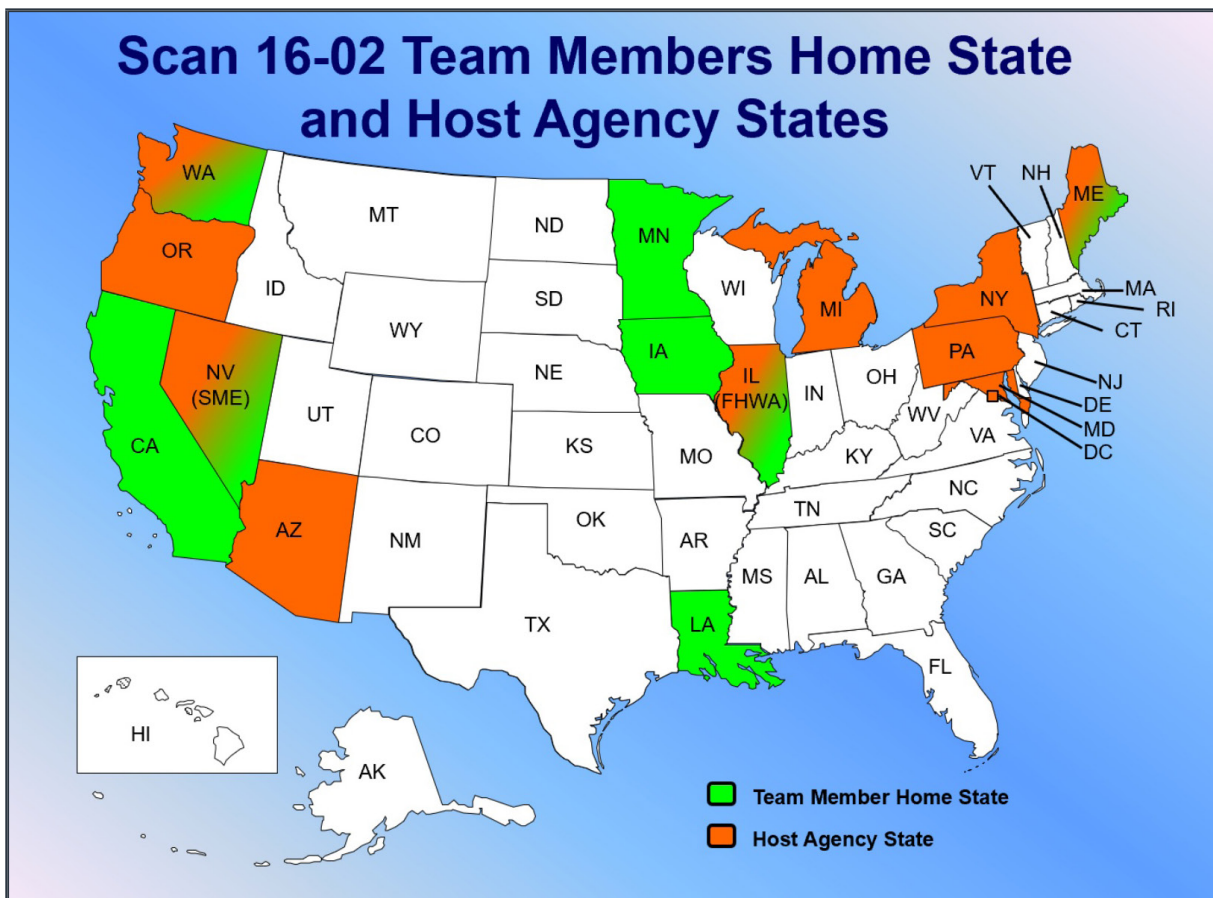


Figure 1-4 Team member and host agency states map

Primary Findings, Observations, and Typical Practice

After meeting over a four-day period and sharing agency experiences, practices, and results, both positive and negative, the team identified the eight critical categories that impacted the overall success of GI practices.

Host agencies presented information on their activities based upon amplifying questions they received. Each day ended with a group discussion focused on information shared by that day's presenting agencies. The group discussion included each participant sharing what he or she found to be particularly interesting from that day's presentations. Those discussions were tabulated in a list of findings described by participants as being significant. A sample of the daily findings is presented in **Table 2-1**.

Sample of Day One Significant Findings

"Intensity of regulations really affects what gets implemented."

"Technology matters, especially geospatial data management."

"Importance of training/education in implementing effective maintenance, such as Maryland's program and New York City's Blue Belt signs"

"Need to define green infrastructure, distinguish GI from stormwater management techniques in general."

Sample of Day Two Significant Findings

"Watershed approach is key."

"Planning level of DOT is important to coordinate stormwater needs and optimize opportunities."

"Maintenance is important; we could have an entire scan on maintenance of these BMPs."

"Asset management is critical; more information is needed on inspection frequencies and methodologies."

Sample of Day Three Significant Findings

"Standards, codes, policy, ordinances as important tools for driving/enabling green stormwater infrastructure"

"Ecological approach used on I-75 project highlights the importance of broad participation."

"Problems with maintenance are similar across the board - lack of staff with vegetation management background/skills."

"Importance of signage for communicating to the public and maintenance staff"

Table 2-1 *Sample of daily findings*

On the fourth day of the meeting, the scan team and host agency participants split into groups that were not agency-related to reexamine significant findings from the previous days and develop a list of those items they believed had the most impact or significance. After the teams posted their lists, each participant identified those elements they believed were the most important or significant in developing a successful GI program. Eight categories were identified as being critical in having such a program. Those eight categories of significant findings, as well as conclusions and recommendations, are discussed in detail in the following sections.

Categories of Importance

Definition of Green Infrastructure

The conclusion the team reached was that currently no nationally recognized standard definition of GI exists. Although multiple agencies and websites provide definitions, there is no standard. Below are some examples:

EPA

An adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspire, and/or recycle stormwater runoff. When used as components of a stormwater management system, green infrastructure practices such as green roofs, porous pavement, rain gardens, and vegetated swales can produce a variety of environmental benefits. In addition to effectively retaining and infiltrating rainfall, these technologies can simultaneously help filter air pollutants, reduce energy demands, mitigate urban heat islands, and sequester carbon while also providing communities with aesthetic and natural resource benefits.¹⁰

American Rivers

Green infrastructure is a term that can encompass a wide array of specific practices, and many definitions exist (see the EPA’s definition here¹⁰). In our view, green infrastructure is an approach to water management that protects, restores, or mimics the natural water cycle.¹¹

FHWA

Green infrastructure is strategically planned and managed networks of natural lands, working landscapes and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations. One common use in transportation of green infrastructure is as an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. Green infrastructure water management approaches and technologies infiltrate, evapotranspire, capture, and reuse stormwater to maintain or restore natural hydrologies.¹²

¹⁰ Green Infrastructure Glossary, Vocabulary Catalog, U.S. Environmental Protection Agency, https://ofmpub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details=&glossaryName=Green%20Infrastructure%20Glossary

¹¹ What Is Green Infrastructure?, American Rivers, <https://www.americanrivers.org/threats-solutions/clean-water/green-infrastructure/what-is-green-infrastructure/>

¹² Glossary, Planning for Operations, Federal Highway Administration, U.S. Department of Transportation, <https://ops.fhwa.dot.gov/publications/fhwahop12004/glossary.htm>

Wikipedia

*Green infrastructure or blue-green infrastructure is a network providing the “ingredients” for solving urban and climatic challenges by building with nature. The main components of this approach include stormwater management, climate adaptation, less heat stress, more biodiversity, food production, better air quality, sustainable energy production, clean water and healthy soils, as well as the more anthropocentric functions such as increased quality of life through recreation and providing shade and shelter in and around towns and cities. Green infrastructure also serves to provide an ecological framework for social, economic, and environmental health of the surroundings.*¹³

Most DOTs have the term green infrastructure on their web pages, but typically in reference to specific topics. Rather than a definition, these topics are under titles such as strategy, programs, preliminary investigation, adaptation planning, sustainability implementation, feasibility study, and map. Some DOTs use LID as a synonym for GI, even though it is a category of GI. Obviously, DOTs have GI in their programs; however, again, there is no clear definition of what GI really means, even to the individual agency. Clearly, GI is a common term, yet it has almost as many interpretations as there are different agencies.

An agreed-upon definition is needed for multiple reasons. These include grant funding consistency, federal eligibility, categorization of GI projects, design approaches, and recognition in the transportation realm. As many agencies identified in their responses to the amplifying questions, specific funding for GI is needed in most agencies. Funding sources such as grants, federal eligibility, and recognition in the transportation realm would aid not only with funding but would also further the cause and effectiveness of GI approaches and programs.

Further, there is a challenge to recognizing the various relationships between LID, constructed environments, and construction practices as they relate to GI. Having a clear definition of GI would help clarify these relationships and how they are separate yet inter-related.

Related to the missing definition of GI, there are also no nationally recognized subcategories of GI, such as biofiltration strips and swales, LID, and compost-amended vegetative filtration strip. Although many agencies use these various components of GI, they may have a different idea or use for each one. Having nationally recognized subcategories would also strengthen funding options and the exchange of information and practices between agencies.

Finally, there are other GI functions beyond stormwater, such as environmental, social, aesthetic and economic functions. As described in the Land Institute Position Statement¹⁴, GI has gone from a little recognized practice to a widely accepted one in public, private, and commercial enterprises. Now, the problems faced are different than recognition of the practice. “[Previously] we needed to address a lack of understanding and acceptance across a broad front, whereas now we face greater social, environmental and economic issues. The need is to demonstrate the contribution that GI

¹³ Green infrastructure, Wikipedia, https://en.wikipedia.org/wiki/Green_infrastructure

¹⁴ Green Infrastructure: An Integrated Approach to Land Use, Landscape Institute Position Statement, https://www.landscapeinstitute.org/wp-content/uploads/2016/03/Green-Infrastructure_an-integrated-approach-to-land-use.pdf

can make towards solving those problems, using the tools of planning policy and economic value in a world that requires facts and numbers to support what should be common sense. Business, land owners and the environment need each other more than ever, and can gain most for us all when planned, designed, built and managed for their mutual benefit.”¹⁵

This statement continues about the necessity for funding GI, with an explanation of the far-reaching consequences of implemented GI on a large scale: “The challenges we face today are too often approached as separate issues. There is insufficient consideration given to the complex interactions between, for example, housing, flood management, food growing and biodiversity. This approach prevents us from adopting more-dynamic, integrated and forward-thinking solutions. GI offers an alternative to this narrow-minded approach – a way not only of tackling specific challenges head on, but also of realizing multiple secondary benefits at the same time. It is this integrated approach that will unlock the potential of our landscape.”

Clearly, the interactions of GI and its many benefits, such as environmental, social, and economic, are worth the investment of communities and agencies beyond just looking at the stormwater functions.

In summary, the conclusions the team arrived at regarding the definition of GI are:

- No nationally recognized standard definition of green infrastructure exists.
- A standard definition is needed for grant funding consistency, federal eligibility, categorization of GI projects, design approaches, and recognition in transportation.
- A challenge exists in recognizing the relationships between LID, constructed environments, and construction practices as they relate to GI.
- No nationally recognized subcategories of GI exist, such as biofiltration strips and swales, LID, and compost-amended vegetative filtration strip.
- GI functions exist beyond stormwater.

The recommendations for defining GI are:

- A national-level standard definition of GI needs to be developed. That definition should explain the relationship between LID and GI, as well as the subcategories of those elements.
- AASHTO, in conjunction with FHWA, should be responsible for developing this definition as it relates to transportation for a consistent adoption throughout the country.
- Champions in AASHTO need to be identified or recruited to define and incorporate the term and practices into the book “A Policy on the Geometric Design of Highways and Streets,”¹⁶ more commonly referred to as the Green Book. Until that is accomplished, there will be continuous confusion and/or disagreement over both the need and the

¹⁵ Green Infrastructure: An integrated approach to land use, Landscape Institute Position Statement, <https://www.landscapeinstitute.org/PDF/Contribute/2013GreenInfrastructureLIPositionStatement.pdf>

¹⁶ A Policy on Geometric Design of Highways and Streets, AASHTO Store, American Association of State Highway and Transportation Officials, https://store.transportation.org/Item/CollectionDetail?ID=180&gclid=CjwKCAiAiuTfBRaAEiwA4itUqJPUb9pLmoyu4Xmk-weJhTIItLEeWt6mhXvSU5SZ7l6vUxjVQ3rGUmhoC6nIQAvD_BwE

implementation of GI practices, other than in response to regulatory requirements. Effective GI has far more impact and positive outcomes than what regulatory agencies would imply.

Maintenance

Maintenance was the most important project-related category to be identified. Not only is maintenance key, but it is critical to providing effective roadside runoff management.

Every agency identified numerous issues with maintenance. Few agencies had maintenance crews that were dedicated to GI. This created multiple problems, from GI having a low priority, as crews were also responsible for pavement condition, striping, lighting, snow removal, trash pick-up, sweeping, and other tasks to lack of training specific to GI, so crews were not maintaining GI components appropriately or adequately. Also, GI maintenance can be considered “invisible” from the roadway, so again it is made a lower priority for crews and management responding to the ire of the public. Invasive plant species or weeds are an issue, as maintainers were often not familiar with the desired native species the agency was typically trying to establish on the project site. Maryland State Highway Administration (MDOT SHA) has a Landscape Design Guide¹⁷ and a Preferred Plant List¹⁸; however, it also has issues with establishing native plants, partially due to lack of maintenance crews’ knowledge or training.

It is critical that maintenance as well as planning for maintenance is tied into all projects and is included as part of the early planning and design phases. Including maintenance staff as part of the planning and design teams and developing a maintenance plan during these phases will help ensure long-term sustainability of these techniques. Early planning with maintenance staff helps to create a sense of ownership, leads to identifying potential maintenance challenges or obstacles that could be avoided, supports recognition of proper equipment needs, and ensures adequate funding is dedicated to maintenance budgets. Often, lack of maintenance can be blamed on inadequate funding of maintenance budgets, especially given the lack of knowledge and proper equipment that is necessary to maintain GI successfully.

Maintenance training, then, is a necessary component of GI maintenance and needs to be implemented at tiered levels, from supervisors to inspectors to the ground crews. Correct training, planning at the supervisory levels, and adequate budgeting will provide better cost-effectiveness and long-term success.

Procuring the proper resources, such as equipment and personnel with the proper training, is essential. Having spent the funds to design and construct GI, if the correct planning and training takes place, the initial investment in these projects is more likely to succeed in both the short and long term. This would include maintenance plans and a plan for each asset being a necessary component of all programs. Some of the agencies have integrated GI into their overall

¹⁷ Landscape Design Guide, Maryland State Highway Administration, December 2016, <https://www.roads.maryland.gov/OED/SHALandscapeDesignGuide.pdf>

¹⁸ MDOT SHA Preferred Plant List (PPL), Maryland State Highway Administration, Version 05-09-2018, https://www.roads.maryland.gov/OED/Preferred_Plant.pdf

asset management system, allowing workflow tracking, which enables stormwater assets to be maintained at the proper time and to be a trigger for timely inspections.

Further, maintenance crews did not necessarily have the right equipment for correctly maintaining features, such as vacuum trucks to remove sand/debris buildup on permeable paver applications. Lack of the proper equipment reduces or eliminates the effectiveness of this treatment to infiltrate water, which instead becomes additional runoff.

As there is greater and ongoing attrition due to retirements, promotions, and outside firms hiring knowledgeable state employees, agencies need to have in place policies, procedures, and manuals with standard operating procedures and maintenance plans for long-term continuity. Then, having easy-to-use dashboard guides with maintenance procedures clearly denoted would contribute to proper maintenance of GI assets.

In conclusion, the aspects of maintenance that need to be considered are:

- Maintenance is critical to providing effective management of roadside runoff.
- Maintenance needs to be integrated into all projects that include GI elements.
- Training needs to occur at tiered levels (supervisors, inspectors, and crew). Planning for maintenance provides better cost-effectiveness and long-term success.
- Personnel with the right expertise and equipment are essential.
- Maintenance plans for each asset are a necessary component of all programs.
- Workflow should be tracked by including stormwater assets in an asset management system. Workflow tracking is necessary for assessing resource and staffing needs, budgeting, and efficiency tracking and improvement.
- Policies, procedures, guidance, and manuals with standard operating procedures and maintenance plans are necessary for long-term continuity.
- Costs continue to increase and thus require a lifelong funding commitment.

Recommendations

Due to the overriding and continuous problems with funding of maintenance activities, which then impacts the success of installed GI components, the state DOTs and local agencies should work with the project sponsors, including FHWA at the beginning of the project, to develop a plan to support future maintenance activities. As these requirements are not necessarily state or agency driven, funding for long-term maintenance should be a portion of every project to enable upper management and planners to integrate the maintenance activities and assets into the system

Every agency needs to ensure that training occurs at tiered levels, from executive level/upper management to supervisors and from designers and inspectors to ground-level crews. Ground-level crews often have not been given adequate and proper training for GI infrastructure maintenance.

In New York City, the Staten Island Bluebelt is an award-winning, ecologically sound and cost-effective stormwater management for approximately one third of Staten Island's land area.¹⁹ The city's simplified, easy-to-access and easy-to-read-in-the-field BMP cards used by maintenance crews are quick and effective (see **Figure 2-1**).

NYC Environmental Protection
Springfield Lake BLUEBELT

GENERAL MAINTENANCE CARD
BMP Site: SL-1
Location: Springfield Park (Jamaica Bay Watershed)
Facility: Constructed Stormwater Wetland
Property Ownership: NYC Dept. of Parks & Recreation

Major Areas of BMP:
A) Forebay
B) Open Water Channel
C) Wetland Shelf and Slope
D) Micropool
E) Outlet Structure

SHORT-TERM MEASURES (FREQUENCY: AT LEAST ONCE A MONTH)

Drainage Issues:

- Inspect Open Water Channel surface area. (Location B on Figure 1)
 - Remove accumulated debris/floatables by hand or skimmer, use waders if required.
 - Note the existence of excessive algae if present.
- Visually inspect the 54" arch culvert inlet and headwall. (Location A on Figure 1)
 - Remove accumulated debris/floatables by hand or skimmer, use waders if required.
 - Repair cracks/damaged stone on headwall, if present.
 - Repair cracks in pipe using a sealant, if required.
- Inspect Maintenance Access Weir at Forebay (Location A on Figure 1) and Micropool (Location D on Figure 1).
 - Manually remove debris lodged; dispose of properly off site.
- Inspect Outlet Culvert and Headwall (Location E on Figure 1)
 - Complete Outlet Structure Inspection Checklist (attached).
 - Repair cracks/damaged stone on headwall, if present.
 - Repair cracks in pipe using a sealant, if required.
 - Correct any issues related to flow short-circuiting, if present.
 - Manually remove debris lodged in outlet culvert; dispose of properly off site.
- Inspect adjacent catch basin grates and manhole covers.
 - Remove accumulated debris; dispose of properly off site.
 - Secure manhole covers using a hook.

Landscaping Issues:

- Inspect overall condition of installed vegetation.
 - Remove invasive plants manually if possible, ensuring root removal; dispose of properly off-site. Only use herbicides if exotics can be specifically targeted. Contact Field Manager for advice if required.
 - Remove muskrats and/or provide exclusion devices; consult Field Manager if required.
 - Trim shrubs along street frontages, as required.

Perimeter Treatments:

- Inspect overall condition of the perimeter treatment items.
 - Check integrity of stone faced headwalls.
 - Remove accumulated litter/debris by hand; dispose of properly off site.
 - Promptly notify DEC police regarding illegal dumping issue.
 - Lubricate locks and hinges on gates, as required.
 - Ensure security of gates and locks.
 - Inspect and repair damaged fencing, bollards, guiderails, BMP signs, and boulders, as required.
 - Refurbish boulder access path as required.

MODERATE-TERM MEASURES (FREQUENCY: ONCE EVERY SIX MONTHS)

Drainage Issues:

- Measure the sediment depth in Forebay (Location A on Figure 1) and Micropool (Location D on Figure 1). Use disk that indicates when forebay is half full, if visible.
- Inspect for unstable embankments.
 - Repair/reinforce unstable embankments using field stone, plantings, etc.

Landscaping Issues:

- Inspect septic inflow and nuisance odors.
 - If septic inflow exists, introduce plantings that promote nutrient uptake, as required.

Springfield Park Figure 1

LONG-TERM MEASURES (FREQUENCY: ANNUAL)

Drainage Issues:

- Factor Activity.
 - Factor sediment from Forebay.
 - Factor sediment from Micropool.
 - Factor sediment from adjacent catch basins.

LONG-TERM MEASURES (FREQUENCY: ONCE EVERY TEN YEARS)

Drainage Issues:

- Factor accumulated sediment from entire extended detention wetland. Use removable mattress shown on Figure 1 as a platform for dredging operations.
- Replant native wetland plants.

Note: Fill out the attached General Short-term and Long-term Inspection Checklist during inspection of the site.

Required Maintenance Permit Checklist:

Issuing Agency	Regulated Parameters
U.S. Army Corps of Engineers	Sediment Removal and placement of fill within wetlands
NYSDEC	Temporary dewatering of wetland, revegetation, herbicide applications
NYC Parks Department	Tree Removal

Figure 2-1 New York City Bluebelt BMP General Maintenance Card

Another Bluebelt tool is an inspection checklist, which provides triggers for maintenance and the tasks involved. If tied into an asset management system, this would help provide further feedback for planning and budgeting future maintenance needs.

19 The Bluebelt Program: A Natural Solution to Stormwater Management, NYC Environmental Protection, The City of New York, http://www.nyc.gov/html/dep/html/dep_projects/bluebelt.shtml

BMP Name: <u>BMP</u>		DATE: _____		
BMP Location: <u>Green Pond</u>		INSPECTED BY: _____		
BMP TYPE: <u>Storm Pond Retain</u>				
TASK NO.	TASK DESCRIPTION	YES	NO	REMARKS
1	MODERATE-TERM SITE INSPECTION (ONCE EVERY SIX MONTHS) <u>Drainage Issues:</u> Measurement of sediment depth in micropool			
	a. What is the maximum sediment depth at the center of the micropool?	N/A	N/A	Sediment depth =
	b. Is the sediment distributed uniformly throughout the micropool? If no, note spatial distribution.			
2	c. Note the physical texture of the sediment.	N/A	N/A	
	Inspect for unstable embankments			
	a. Do you notice any local excessive erosion or undercutting of the banks? If yes, note location and extent.			
3	b. Do you see any local sloughing/sliding of embankments? If yes, note location and extent.			
	<u>Landscaping Issues:</u> Inspect for septic inflow and nuisance odors			
	a. Can you smell any foul odor at the BMP site? If yes, describe nature of odor.			
4	b. Do you see any dead animals at the BMP site? If so, note species.			
	Inspect for plant mortality			
	a. Do you notice excessive plant mortality? If yes, note species and location.			
5	Inspect for wildlife damage			
	a. Do you notice any wildlife damage to topography or plantings? If yes, note nature of damage and suspect critter.			
	b. Do you see animal burrows? If yes, note location and size.			
6	MODERATE-TERM SITE INSPECTION (ONCE EVERY TWO YEARS) <u>Drainage Issues:</u> <u>Vectoring activity</u>			
	a. Has it been two years since the micropool was vectored? If yes, refer to 'Vectoring' procedure in the maintenance card.			
	b. Has it been two years since the adjacent catch basins were vectored? If yes, refer to 'Vectoring' procedure in the maintenance card.			
7	LONG-TERM SITE INSPECTION (ONCE EVERY TEN YEARS) <u>Drainage Issues:</u> <u>Vectoring activity</u>			
	a. Do you see signs of sediment accumulation within the wetland? If yes, note location.			
	b. Has it been ten years since the extended detention wetland was vectored? If yes, refer to 'Vectoring' procedure in the maintenance card.			

Figure 2-2 New York City Bluebelt Inspection Checklist

The importance of short- and long-term maintenance of GI cannot be overstated. Maintenance is a huge component for success. GI maintenance is not typical gray infrastructure or roadside maintenance and when it is not done or if it is done at the wrong time, there is a high probability it will fail. This not only is a waste of agency funding, but also gives the impression that GI is not an economical or practical solution, when in fact it is typically far more beneficial in terms of economic, social, and environmental considerations. However, GI maintenance needs to be planned and provided for throughout the life of the project, just as any other hardscape element is. DOTs understand gray infrastructure is doomed to failure without proper maintenance. They need to incorporate the same understanding and practices for GI.

Training should occur after preliminary engineering, including observations/monitoring over time, with training tracked and monitored through a similar tool to the Learning Management System used by Washington State DOT (WSDOT) and MaineDOT. All MaineDOT maintenance facility staff receive on-site Green Book training quarterly²⁰. The MaineDOT Green Book is an environmental practices guidebook for Maintenance and Operations (M&O) staff that covers these topics: hazardous chemicals, universal waste, oil and equipment maintenance waste, hazardous waste, materials management, and spill prevention and response.

20 Maine Department of Transportation Municipal Separate Storm Sewer Systems General Permit Annual Report PY3, September 2016 (Revised December 28, 2016), <https://www.maine.gov/mdot/env/documents/REVISED2016PY3MS4report.pdf>

DOTs need to be given training courses with qualified experts to provide the proper training. This training should include the right knowledge and skill sets, including ecological principles/ knowledge, and staff with appropriate localized knowledge of vegetation and soils. For this to occur, agencies need to also hire qualified personnel or contract out for these specialized skill sets. Human resource divisions may need to change the minimum qualifications so the right people with the right expertise are hired. This could also entail cooperative agreements with other agencies.

The National Green Infrastructure Certification Program²¹ provides training and certification for GI maintenance. This is one resource for agencies to train maintenance personnel.

Another critical component for each agency is to use asset tracking and workflow for stormwater-specific assets, maintenance needs and costs, activities, accomplishments, and inspections through reporting and work orders. Agencies should examine how to either modify existing technology within their current system or obtain the correct system for this type of asset tracking and workflow. Both workflow tracking and including stormwater assets in an asset management system are necessary. Workflow tracking is required for assessing resource and staffing needs, budgeting, and efficiency tracking and improvement. Asset management coordinates with the workflow tracking by ensuring that Maintenance staff knows what needs to be maintained. The system should also contain the necessary information for how and when stormwater features need to be maintained.

Further, a geographic information system (GIS) to visually show where *all* GI system assets exist should be used and tablets, cell phones, or global positioning system units, and the training to use them, should be provided to maintenance staff on the ground for tracking and record keeping.

Watershed Approach Versus Project Site Approach

There could be multiple definitions of watershed approach. The EPA defines it as “a coordinating framework for environmental management that focuses public and private sector efforts to address the highest priority problems within hydrologically defined geographic areas, taking into consideration both ground and surface water flow”²².

Oregon DOT (ODOT) defines watershed approach as selecting and placing stormwater mitigation BMPs so they provide a high level of benefit and address watershed-specific issues and priorities. This includes collaboration with other stakeholders and enhancing natural elements of the watershed that provide the water quality and hydrological services needed to provide the mitigation. ODOT does not take on the task of deciding watershed priorities or managing or regulating use of the watershed by other parties.

A watershed-level approach provides multiple benefits on a large scale. It also facilitates collaborative decision making between transportation agencies and local communities to work toward local and state water resource goals. On the other hand, often agencies are limited to relatively smaller scale, linear ROW acquisition, which limits activities to within that narrow

²¹ National Green Infrastructure Certification Program, <http://ngicp.org/program/>

²² Watershed Approach Framework, Office of Water (4501F) EPA 840-S-96-001, June 1996, <https://www.epa.gov/sites/production/files/2015-06/documents/watershed-approach-framework.pdf>

ROW. These limitations may be due to policy, funding, or other limitations, which can make GI approaches more difficult for transportation agencies. This could also make collaborative efforts difficult, as there are typically constraints on when and how much ROW can be purchased, which also limits the use of space-intensive stormwater management facilities.

Allowing DOTs to work at the watershed scale frees them of the constraints inherent in the ROW approach while promoting stormwater measures that are more valuable to the larger watershed.

MDOT SHA established a Water Quality Bank in 1994 as a means of overcoming these difficulties. The Water Quality Bank allows banking within eight different six-digit watershed basins in which the project occurs, thereby allowing MDOT SHA to consider the entire watershed(s) in allocating and receiving credit for water quality improvements. Acres of impervious surface that are managed or treated are credited against stormwater impacts. Whenever possible, Maryland undertakes to build more treatment than is needed for the project, so that it maintains a positive balance in the Water Quality Bank. **Figure 2-3** is a table of watersheds and the ledger for approved projects for water quality banking.

If a project is unable to meet the regulatory requirements for GI, the area receives a deficit in credit (indicated by the negative number). In the areas with a positive number, MDOT SHA has taken advantage of the ability to receive additional GI to obtain more credits and offset those areas where a deficit has occurred. This also allows it to bank credits for future use on projects. The bank acreage is subdivided by 18 distinct 6-digit watersheds as follows:

Watershed Number	Watershed Name	Approved Projects Balance + Reconciled
02-12-02	Lower Susquehanna River Area	-0.22
02-13-01	Coastal Area	13.27
02-13-02	Pocomoke River Area	3.32
02-13-03	Nanticoke River Area	3.65
02-13-04	Choptank River Area	-1.56
02-13-05	Chester River Area	2.73
02-13-06	Elk River Area	7.96
02-13-07	Bush River Area	8.15
02-13-08	Gunpowder River Area	5.32
02-13-09	Patapsco River Area	8.20
02-13-10	West Chesapeake Area	16.58
02-13-11	Patuxent River Area	18.08
02-14-01	Lower Potomac River Area	26.49
02-14-02	Washington Metropolitan Area	8.60
02-14-03	Middle Potomac River Area	19.14
02-14-05	Upper Potomac River Area	6.43
02-14-10	North Branch Potomac River Area	1.54
05-02-02	Youghiogheny River Area	-1.80

Figure 2-3 Maryland State Highway Administration Water Quality Bank treated acres

Having the ability to look at the overall watershed enables both large-scale planning of projects to maximize cost savings and more-effective water quality improvements.

ODOT has a similar system under the Federal Aid Highway Program (FAHP) Programmatic Biological Opinion. Excess treatment of highway runoff can be banked and used for another project in the same level (region, subregion, accounting unit, cataloging unit) or the same eight-digit hydrologic unit code, which is a number assigned by the U.S. Geological Survey to watersheds for identification purposes²³. Credit allocation is based on the amount of impervious surface area that must be treated to address the same pollutant load as is untreated at the project site, based on median suspended sediment concentrations in four average daily traffic classes.

Treatment of stormwater in excess of that required by the FAHP provides the opportunity to create credits for compensatory treatment of stormwater in advance of specific project needs. Doing so is beneficial for both the affected watershed and for the transportation agency developing and using the credits. The watershed receives cleaner water in advance of any project that needs compensatory treatment, providing a temporary gain. Transportation projects benefit through time savings resulting from not having to hunt for suitable stormwater management sites and negotiations with National Marine Fisheries Service (NMFS)²⁴ on the site's acceptability.

Treatment of highway runoff is considered excess and therefore eligible to be considered credit that can be retained and used for future projects when it meets all of these criteria:

- The project completely meets the FAHP Programmatic Biological Opinion stormwater management requirements.
- The excess runoff is from impervious surface outside of the project's contributing impervious area.
- The stormwater that will receive excess treatment is not already being treated by either an engineered or a nonengineered BMP.
- The contributing impervious area of the excess treatment is not expected to be included in a project triggering the requirement for stormwater treatment for 10 years (referred to as the provisional period).

The contributing impervious area of the excess treatment BMP is referred to as the credit site.

Projects can use stormwater management credits where on-site stormwater treatment is not practical. Practicality is affected by constraints that make it difficult or impossible for a project to fully meet FAHP stormwater management criteria. Constraints include:

- Safety considerations, including driving hazards, unsafe maintenance conditions, vector control, and creation of an attractive nuisance
- Adverse topography limiting facility placement, size, or maintenance access
- Adverse site conditions, including geotechnical instability and hazardous materials
- Conflicting protected resources, such as wetlands; Endangered Species Act-listed species habitat; and recreational, historic, or archaeological sites

²³ Hydrologic Unit Maps, Water Resources of the United States, U.S. Geological Survey, U.S. Department of the Interior, <https://water.usgs.gov/GIS/huc.html>

²⁴ National Marine Fisheries Service (NMFS), <https://www.fisheries.noaa.gov/>

- Socioeconomic impacts, such as loss of low-income housing and loss of jobs
- Excessive life-cycle costs compared to the project's scope and scale or compared to the environmental benefit of on-site treatment; costs include ROW purchase, construction, and maintenance

The threshold for determining that on-site treatment is not practical will vary with the magnitude of the impact of discharge of untreated stormwater and is a qualitative assessment. It will be high for discharges that are relatively large compared to the receiving water, where the traffic volumes are very high, and where sensitive habitat is close to the discharge point. NMFS must approve the conclusion that on-site treatment for a project is not practical and that off-site treatment is appropriate and acceptable.

With large-scale planning of watershed-approach projects, such as the above examples, agencies can maximize cost savings and outcomes for the largest benefit to the environment. For instance, the South East Michigan Council of Governments (SEMCOG) is a local government association working as a Municipal Planning Organization (MPO) that provides technical assistance to over 170 units of local government on transportation, environment (air, water, and solid waste), infrastructure, economic development, bicycle and pedestrian, and parks and recreation.

The Michigan jurisdictions for stormwater management include 83 counties, 276 cities, 257 villages, and 1,240 townships. Michigan has no dedicated funding source for stormwater management activities despite the municipal separate storm sewer system (MS4) permit program. Transportation agencies are challenged to address multiple outcomes, including implementing GI when most roadways already have sufficient stormwater conveyance systems. It is very challenging to consider using road funding towards stormwater management projects when 40% of the region's roads are in poor condition²⁵. Despite limited funding and multiple priorities, GI is a priority in all regional planning activities, including economic development, transportation, and environment. These collaborative efforts have resulted in regional plans that contain GI elements, including:

- LID manual for the State of Michigan
- GI vision for Southeast Michigan²⁶ water resources plan for Southeast Michigan
- Economic development strategy for Southeast Michigan
- Bicycle and pedestrian plan for Southeast Michigan
- Transportation alternatives program

Priorities include investing in critical infrastructure and aligning infrastructure improvements for cost efficiencies in addition to environmental and public health benefits. These plans highlight multiple avenues to address local water quality and infrastructure challenges, including implementing GI:

²⁵ Pavement, Southeast Michigan Council of Governments, <https://www.semco.org/pavement>

²⁶ Green Infrastructure, Southeast Michigan Council of Governments, <https://semco.org/green-infrastructure>

- To meet traditional infrastructure needs
- As a mechanism to reuse underused, vacant parcels
- To address runoff from highly impervious areas
- To strengthen collaborative approaches

SEMCOG engaged local agencies in Southeast Michigan to develop a region-wide process for implementing GI practices. As a result, by developing regional solutions they have established regional GI priorities.

SEMCOG's GI vision (**Figure 2-4**) entailed highlighting goals and establishing regional policies for expanding and influencing GI regionally. Its approaches included increased public accessibility and GI network connectivity.

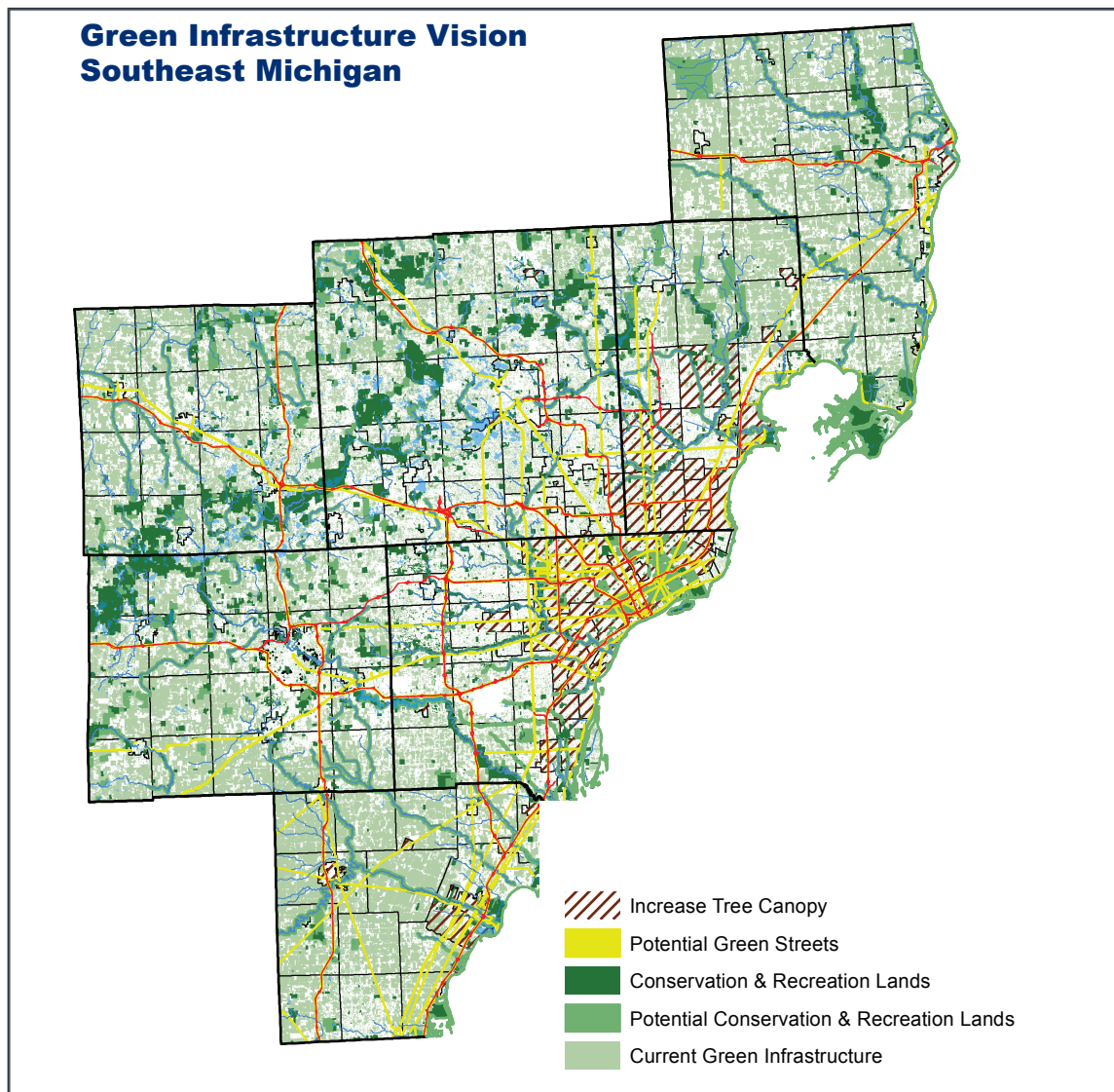


Figure 2-4 Green Infrastructure vision for Southeast Michigan

Because GI is used to reduce stormwater runoff volume and improve stormwater quality, the vision prioritized local implementation priority areas by watershed. The vision highlights priority impervious cover areas along with green space that can be enhanced with additional GI. By combining forces, SEMCOG was able to accomplish far more than any one agency alone could have done.

Figure 2-5 provides the results of a land cover and land use analysis that can be used as a basis for local, regional, and transportation planning. These results help to align watershed and GI planning. This process, if combined with a banking program similar to Maryland’s, can lead to significant transportation and environmental benefits.

Subwatershed	Institutional Land Use (Publicly-Owned)			Major Roadways (Publicly-Owned)		Privately-Owned Parking Lots	Riparian Corridor	
	Impervious Surfaces: Buildings	Impervious Surfaces: Parking Lots	Open Space	Impervious Surfaces: Pavement	Open Space		Tree Canopy Existing	Open Space
Lower 1	41	228	783	899	608	1,313	386	168
Lower 2	145	227	625	973	313	1,228	257	31
Main 1-2	333	725	1,342	2,564	850	2,760	883	146
Main 3-4	541	623	1,155	4,417	1,107	4,163	370	105
Middle 1	165	450	1,770	1,788	855	2,619	390	149
Middle 3	104	194	386	1,067	340	1,995	353	45
Upper	237	520	1,213	1,830	622	2,478	667	190
Total Area	1,568	2,967	7,274	13,537	4,694	16,556	3,307	835

Areas of opportunity in acres.

Figure 2-5 Example of Michigan Watershed Areas of Opportunity

In addition, SEMCOG partnered with the Michigan DOT and created a policy to support coordinated efforts to align water, natural resources, and transportation priorities. The actions they agreed upon to support those policies were to:

- Enhance environmental considerations within the regional transportation planning process
- Use the environmental sensitivity analysis to inform transportation agencies of potential impacts
- Support and facilitate collaboration between transportation agencies and local jurisdictions regarding stormwater management opportunities that work toward meeting water quality standards

An additional policy was formed that would integrate multiple outcomes, including mobility, recreation, and habitat into road stream crossing and culvert designs.

The agreement included these actions to support the policy:

- Inventory and conduct condition assessments of road stream crossings
- Categorize road stream crossings and prioritize improvements for multiple transportation modes, water trails, streamflow condition, and fish migration
- Evaluate adaptive capacity of high-priority road stream crossings

This included a Water Resources Plan for Southeast Michigan²⁷ and the AASHTO President's Award-winning I-75 Corridor Conservation Action Plan²⁸.

By educating the various agencies and the public, Southeast Michigan has made great strides in planning toward a watershed approach and identifying available areas to implement GI. By building off these partnerships, SEMCOG and Michigan DOT have combined resources to facilitate GI implementation on roads, which will continue leading them to a watershed area approach and achieve their multiple goals by following the above action plans.

SEMCOG received a grant from the EPA Great Lakes Restoration Initiative to demonstrate selected roadway GI techniques. One project included construction of native plant grow zones in the cloverleaf of a state primary road. These areas commonly collect runoff and are also difficult to maintain as mowed turf grass. Converting to native plant grow zones not only reduced maintenance costs, but also created a significantly improved visual context along this busy corridor. See **Figure 2-6** and **Figure 2-7**.



Figure 2-6 Before pictures of Southeast Michigan Council of Governments Green Streets projects (courtesy of SEMCOG)

27 Water Resources Plan for Southeast Michigan, Southeast Michigan Council of Governments, March 2018, <https://semcog.org/Reports/WaterResourcesPlan/index.html>

28 I-75 Corridor Conservation Action Plan in Monroe County: Stormwater Considerations, Southeast Michigan Council of Governments, <http://miwetlands.org/wp-content/uploads/2017/10/I-75-Corridor-Conservation-Plan-Wilson.pdf>



Figure 2-7 After pictures of the same SEMCOG Green Streets projects (courtesy of SEMCOG)

A watershed approach also helps surmount the ROW constraints that can limit the potential for GI in transportation projects. DOTs typically obtain ROW in linear segments in alignment with the roadway. This can limit the opportunity for some GI practices, such as bioretention areas, because there is not enough space within a linear ROW for effective treatments to be built. By taking a watershed approach and partnering with other agencies, the area for building GI or banking credits in other available areas is greatly increased.

For example, in Maine, the Long Creek restoration project began in 2007 as a collaborative, community-based initiative convened by the City of South Portland and led by a steering committee made up of representatives from the four Long Creek watershed municipalities (South Portland, Portland, Westbrook, and Scarborough), area businesses, nonprofit organizations, and state agencies. The City of South Portland obtained a grant from U.S. EPA and Maine Department of Environmental Protection to partner with the other watershed municipalities and individual stakeholders in this effort.²⁹

Both the New York City Bluebelt and Maine Long Creek Watershed partnered with private landowners (over 1 acre), helping the landowners comply with regulatory requirements for an annual fee; providing expertise for design, management, and construction; and removing the

²⁹ Long Creek Watershed Management District, <http://www.restorelongcreek.org/>

headache of management for the private landowners. This provided both agencies with the ability to successfully implement GI practices over a larger footprint by combining properties into one or more units for stormwater treatment.

Unfortunately, there are many obstacles to the large-scale planning of watershed approaches. Some of these obstacles come from the regulatory agencies themselves. Their goal is to promote clean water; however, sometimes these regulatory agencies don't have a clear understanding of how a policy might make implementation of a GI practice more difficult.

A major obstacle is that the MS4 permit program is on a jurisdictional basis and is not easily adapted to a watershed approach. While science says we should be addressing water resource challenges, the EPA and state regulatory programs make that difficult. For instance, MDOT SHA has an excellent relationship with the state regulatory agency. Nevertheless, conflicts can arise, with the best of intentions falling short. Maryland has an ongoing issue related to maintenance on BMP facilities. As stated in the Maryland Department of Transportation State Highway Administration's response to the amplifying questions, "To remain in compliance with the NPDES permit, maintenance must be regularly performed on stormwater measure BMP facilities. If this maintenance lapses, the facility may require more major remediation within the same footprint. A general permit was previously granted for this type of work to simplify the permitting process for this type of work."

That general permit expired and was replaced by an updated one. Maryland Department of Transportation State Highway Administration's response adds that the new permitting process added "a level of complexity with additional environmental feature designations and examinations for projects that will remain in the original footprint except for access and construction needs. Projects are funded in stages so that these types of conflicts can be addressed as design progresses.

It is not unusual for projects to be dropped midway through design because strict permitting requirements for construction of stormwater management (SWM) facilities then also prevent their retrofitting."

This is an example of a situation where the regulatory agency and the DOT are unintentionally at counter-purposes. If the regulatory and transportation agencies could develop an understanding of impacts contrary to the overall environmental intent, many issues could be resolved. Then, a watershed level approach could be attained more easily.

The team identified the following key features of and conclusions about a watershed-level approach:

- It provides multiple benefits for environmental and water quality improvements.
- The large-scale planning of these projects maximizes cost savings and outcomes for the largest benefit to the environment.
- Limited DOT ROW can make it difficult to address requirements on a project-specific basis; switching to this approach can overcome these difficulties.
- Both regulatory agencies and DOTs need to be educated on the effectiveness of this approach

Recommendations

If each agency developed a dedicated stormwater program or funding, this would provide for flexibility and prioritization. As described in the preceding examples, where those agencies were able to either provide a dedicated program or funding flexibility, GI became prioritized, even if a separate budget was not available. Furthermore, funding stretched further when done in partnership with other agencies, such as those used by SEMCOG, NYC Bluebelt, and the Maine Long Creek Watershed.

Again, DOTs need to modify procedures to incorporate a watershed approach (e.g., planning, environmental, and stormwater). Many agencies have not changed their policies and procedures to incorporate GI techniques, even though with planning, partnerships, and other available tools, this is readily achievable.

An integrated approach with other property owners, agency owners and partnerships, such as those described previously, would again make implementation of GI in SWM a far more accessible and attainable goal. It is also important when planning a watershed approach that the different partners have responsibilities limited to the elements that are appropriate to them. DOTs should not be responsible for assessing watershed conditions and priorities; they should be responsible for determining the type and level of highway-related impacts on the watershed.

Another important recommendation is for regulatory agencies and DOTs/implementing agencies to discuss a watershed-level approach. This would include practices in states currently using a watershed approach, wetland banking programs, removing obstacles to allowing a watershed-scale approach, and research comparing the costs and benefits of a watershed approach versus a site-specific approach.

Additionally, FHWA and EPA should work together to improve policies and the alignment of a watershed approach so that transportation agencies can more effectively integrate GI. The use of FHWA funds for maintenance should be considered. This would expand options, such as the ability to use FHWA funds on property that the state DOT might not own. With a watershed approach and a banking approach like MDOT SHA, GI techniques might be located on other public or even private property.

It is also important for the DOT and regulating agencies to develop common goals and outcomes for a watershed approach, so all parties are working toward the same beneficial objectives. Potentially, this could occur at a stormwater conference, or one created specifically for mitigation banking.

Following these recommendations would enable the desired outcomes of large-scale planning of watershed-approach projects. This would maximize cost savings and outcomes for the largest benefit to the environment, which is the stated goal of all environmental and regulatory agencies.

Information Development and Sharing

The scan team arrived at four conclusions regarding information development and sharing. The first conclusion confirms that there is a lack of generally available education, training, and

research for interested agencies. The scan team came to this conclusion not only from research during the desk scan, but also from shared experiences and discussions during the peer-to-peer exchange meeting. While there is a considerable amount of information about SWM and GI, there is no central repository or clearinghouse for such information as research results and information on SWM programs. This makes it difficult for individual agencies to gather the information they need to develop their own programs or evaluate various options.

For instance, states (and universities) have multiple approaches to GI and SWM; however, currently there is no avenue to disseminate that information. As described in previous examples, several agencies have well developed GI practices for SWM. However, these practices must be individually researched and often require a known contact at the agency for the information to be available. This is a hindrance to both agency cooperation and overall learning when a great deal of information and knowledge can be gained through information sharing.

One existing avenue for finding research information on stormwater technologies and long-term maintenance costs is through the Stormwater Technology Testing Center (STTC), introduced to the team by William Fletcher from the Oregon DOT (ODOT). The Center was developed because there was no test facility for determining maintenance requirements for stormwater BMPs, particularly proprietary devices. Currently, the STTC is still in the final stages of development. The STTC will provide a venue for manufacturers of proprietary stormwater treatment systems to not only test the effectiveness of their devices, but also their maintenance requirements. The manufacturers will pay for the testing and the data generated will belong to them. Once they submit it to a certifying agency, like the Washington State Department of Ecology's Technology Assessment Protocol-Ecology program, the results should become public.

The STTC assists end users of stormwater treatment technologies with NPDES compliance, life-cycle information (20 years of maintenance and maintenance cost estimating tools), and independent evaluation of technologies. It is hoped that the manufacturers' fees for testing their devices will support the STTC's operation.

University research has proven informative for DOT GI practices and the guided adoption of BMPs. For instance, the Pennsylvania DOT (PennDOT) has current research on several topics related to GI and stormwater (see **Figure 2-8**), and GI specifically (I-95 rain gardens). This information could be quite helpful, especially to states in the same geographic/climatic locations; however, it is not widely known.

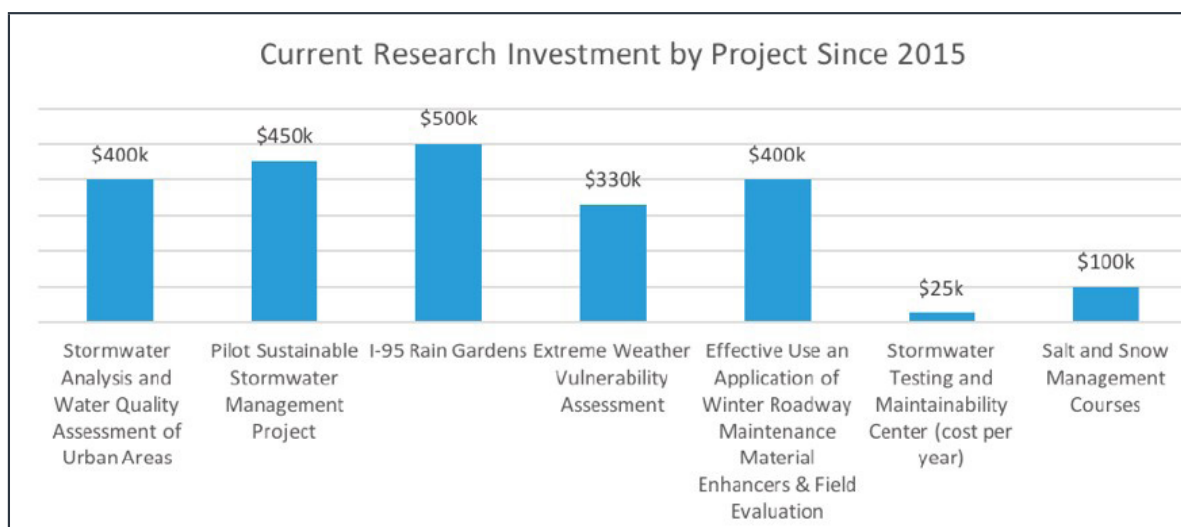


Figure 2-8 PennDOT's current research investment by project

The I-95 rain garden project is a partnership between Villanova University (VU), Temple University (TU), and PennDOT. The project involves multiple phases of work along a 51-mile stretch of the freeway system, a substantial effort producing valuable information. The universities implemented an applied research program to assist and inform PennDOT on stormwater design and maintenance practices. The two universities had both separate and dual roles in the research. Villanova took the lead on hydrologic soil processes while Temple's role was environmentally based. The research program included:

- Baseline monitoring (TU)
- Stormwater management program (SMP) monitoring and assessment (VU and TU)
- Plant monitoring (TU)
- Evaluate SMP functionality (VU and TU)
- Computer simulation (VU and TU)
- Maintenance (VU and TU)
- Recommend changes to future SMP designs (VU and TU)
- Adaptive research (VU and TU)

Monitoring over a two-year period included SMP performance, soils and vegetation, maintenance, model validation, and water quality. This was done to determine impacts to or on the highway environment, larger flow rates, replicates (duplicated samples), elevated highways, shading variations, effect of sediment on soil over time, maintenance (or lack thereof), and temperature.

For instance, one of the outcomes was information regarding plant health and mortality (see **Figure 2-9**). With copious quantities (54 species, 264 clusters, and 8124 plants) planted in over 70 bioswales, this was a substantial effort in determining plant health and mortality along a freeway.

Inventory Results - Health -

- Noticeable declines in health for a number of species

- Class 3: 92% → 82%
- Class 2: 6% → 12%
- Class 1: 2% → 5%

- Observation: health & survival varied with elevation



Figure 2-9 PennDOT/Temple University plant health inventoryt

This information is valuable data that would be of use to any DOT, even if it were not in the same geographic area. Nevertheless, it is not widely known of outside of Pennsylvania.

In addition to shared university and DOT research, a common resource for education and information sharing is at national conferences. Although national stormwater conferences are available, none is specific to GI, forcing a practitioner to identify conferences and sessions that might be applicable to GI practices. Currently, Maine holds a stormwater conference every two years aimed at engineers and suppliers. Additionally, there is a regional Pacific Northwest (PNW) Sustainable Stormwater Symposium³⁰ put on by ASCE-EWRG in Portland, Oregon. This symposium occurs biannually and draws a mixture of academics, practitioners, consultants, and presenters from outside the PNW. The focus is on GI/sustainable SWM. There is also usually a stormwater component in the biannual National Hydraulic Engineering Conference.

No peer exchanges specific to GI are available at either a regional or a national level. AASHTO used to conduct a stormwater practitioners meeting but that is longer available. Having websites, webinars, conferences, and an information clearinghouse would vastly elevate the level of information sharing and thus more useful, practical, and efficient implementation of GI.

30 Sustainable Stormwater Symposium, Oregon EWRG (a subgroup of ASCE Oregon Section), <http://www.stormwatersymposium.org/>

A good example of a successful information-sharing website is the Great Lakes Phragmites Collaborative³¹. This is a partnership at a regional level that helps to improve communication and collaboration that leads to more coordinated, efficient, and strategic approaches to nonnative Phragmites vegetation management, restoration, and research across the Great Lakes Basin. “This organization facilitates communication on a regional level, using an interactive approach to facilitate access to rigorous science and promote network building among managers, governmental agencies, private landowners and scientists.” A similar collaborative effort for GI on a national level would be extremely helpful for agencies wanting or needing to implement better and more-effective GI strategies, designs and approaches.

An additional website with a wealth of information is the Michigan Green Infrastructure Conference, which has compiled a comprehensive list of resources from controls to planning and codes to cost benefits and funding³².

Improved information dissemination can also help inform upper management. Upper management and executive-level decision-makers are not necessarily familiar with GI and the numerous economic, environmental, and social benefits GI can impart to their agency and surrounding communities/state. For instance, in the City of Philadelphia, the Philadelphia Water Department’s Office of Watersheds³³ is leading the next generation of innovation in water infrastructure with its plans to roll out an ambitious \$1.6 billion GI plan. This plan relies on rain gardens, green roofs, pervious pavements, and trees to recycle and reuse rainwater. According to one study, “one inch of rainwater hitting one acre of asphalt means 27,000 gallons of water” is going into the sewer. For a city like Philadelphia, that means billions of gallons are flooding its now aged water management system.”³⁴ The typical gray infrastructure alternative to the Philadelphia GI plan is an unthinkable expensive and disruptive hard infrastructure approach. This is a prime example of how GI solutions are often far more effective and economical solutions.

Philadelphia’s extensive GI plan is creating a new “green economy,” with job creation dedicated solely to the construction and maintenance of this large GI infrastructure. Green City, Clean Waters is fueling a green jobs economy in Philadelphia, creating high-value new jobs for residents and attracting smart workers and firms to the city. “An ambitious and forward-thinking green infrastructure plan needs an ambitious and forward-thinking workforce to succeed, and we’re making that happen right here, right now.”³⁵ One could say this statement reads like an advertisement, but it is also clear that the city is excited and proud of the accomplishments with its green economy. It is hoped that other municipalities and governmental agencies will see the

31 Great Lakes Phragmites Collaborative, Great Lakes Commission, <https://www.greatlakesphragmites.net/>

32 Online Resource for Conference Attendees, Michigan Green Infrastructure Conference, https://www.michigan.gov/documents/deq/Online_Resources_for_GI_Conference_455011_7.pdf

33 Office of Watersheds, Philadelphia Water Department, Philadelphia, Pennsylvania, <http://www.phillywatersheds.org/category/blog-tags/office-watersheds>

34 Philadelphia’s Cutting-edge Green Infrastructure Plan, The Dirt: Uniting the Built & Natural Environments, The American Society of Landscape Architects, May 10, 2010, <https://dirt.asla.org/2010/05/10/philadelphias-cutting-edge-green-infrastructure-plan/>

35 Jobs, Green City, Clean Waters, Philadelphia Water Department, Philadelphia, Pennsylvania, http://phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan

multiple positive benefits and pursue GI projects with the same zeal.

Clearly, there are knowledge, policies, and experiences to be accessed and disseminated throughout the nation that would not only help state, regional, and local agencies, but also aid in changing long-held misconceptions regarding the additional expense and problems associated with GI. The challenges of GI are not to be diminished; however, solutions and alternatives are available. If there were a repository for these approaches and solutions, GI would gain in acceptability and practice.

In summary, the final conclusions for Information Development and Sharing are:

- National stormwater conferences devoted specifically to GI are not currently available, though GI is often treated as a component of various stormwater and engineering conferences.
- There are no regular and recurring GI-specific peer exchanges at regional or national levels.
- A well-presented business case aimed toward upper management/decision-makers regarding the environmental, social, and economic benefits of GI to these decision-makers is lacking.
- A repository is needed to provide different approaches and solutions, because one size does not fit all. Approaches change, based on context and depending on location.

Recommendations

A free website clearinghouse needs to be developed and maintained. This would include a good search engine and moderated forum for GI information and research sharing. This could be like information available through resources such as the American Society of Civil Engineers (ASCE) or a site such as the International BMP Database. “The International Stormwater Best Management Practices (BMP) Database project website features a database of over 600 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance, and other study-related publications.”³⁶

As previously illustrated, much information and research can be obtained through partnering with local and state universities, especially those with landscape architecture and engineering programs. Student research assistance benefits both the university and the agency.

GI needs a reliable and self-sustaining national conference, specifically for DOTs and other stormwater practitioners. A national GI conference needs to be held regularly to keep agencies up to date and educated on state-of-the-art practices, solutions, and approaches. This would be a beneficial information-sharing event.

In addition to a dedicated national conference, GI sessions should be promoted at existing hydraulic and stormwater conferences. It is important to capture the experience of practitioners, planners, landscape architects, stormwater personnel, and maintenance personnel, in addition to the engineering perspective often seen at these conferences. Multiple regionally based GI programs

³⁶ International Stormwater BMP Database, <http://bmpdatabase.org/>

(e.g., SEMCOG, NYC/Bluebelt, and MaineDOT/Long Creek Watershed) can be used as examples of how to partner for successful outcomes. These experiences and knowledge bases can be expanded and scaled up to encompass state and national programs.

Agencies should use regionally based GI programs, such as the Green Infrastructure Champions Program of the Great Lakes Commission³⁷, to expand into state and national programs.

Developing a business case for management level executives would be advantageous to obtain buy-in and long-term support. This would include demonstrating that cost benefits, social value, and economic and environmental benefits are a part of GI's "triple bottom line."

For instance, a work plan could be sent to the AASHTO Center for Environmental Excellence to query how it can participate in disseminating information and implementing GI. Reinstating the former AASHTO Stormwater Webinar Series³⁸ would be a good starting point. This would be an excellent forum, particularly since it would provide a good platform for addressing the interface between traditional and GI SWM. There is apparently some resistance from non-stormwater practitioners, who seem to think that stormwater is "solved". Support or pressure from state DOTs could be helpful in getting this conference reinstated.

Additional resources, such as FHWA's "International Stormwater BMP Database: User's Reference Sheet for Transportation Professionals," are available for transportation professionals to access BMP information.³⁹

Public Outreach

Public support is critical not only to sustain GI infrastructure, but also to expand into local municipalities and encourage acceptance of previously unknown practices. Public unfamiliarity with GI practices can cause misunderstanding, criticism, and loss of public support. Native vegetation establishment can take one to five years and longer in environments that are more arid. During this interim period, local weeds can first inhabit a site to be replaced by natural succession with the longer lasting and more-suitable native species. However, public criticism can derail agency intent on establishing these natives.

For instance, one state DOT reported that it had a newly constructed facility with native revegetation as a part of the project and a GI practice. However, neither the public nor the maintenance crew had been sufficiently educated as to the intent of the project. During the first year, when common and temporary weeds were more visible, the public complained, and the district maintenance manager responded by sending out state prison crews to manually remove the offending weeds. Unfortunately, this practice guaranteed further proliferation and continuance of weeds and a longer period for establishment of native vegetation. This unfortunate and costly circumstance could have been avoided had a) the maintenance manager been willing to accept the

³⁷ Great Lakes Green Infrastructure Champions Program, Great Lakes Commission, <https://www.glc.org/work/champions/network>

³⁸ Stormwater Webinar Series, Center for Environmental Excellence by AASHTO, https://environment.transportation.org/center/products_programs/webinars/stormwater.aspx

³⁹ SIWM13T16/International Stormwater BMP Database Fact Sheets, The Water Research Foundation, http://www.werf.org/c/KnowledgeAreas/SIWM/Products/SIWM13T16_Fact_Sheets.aspx

paradigm shift the DOT was implementing and a willingness to adjust the staff approaches and b) a method to educate the public on this same paradigm shift and the promising eventual outcomes.

Brochures, educational public meetings, websites, and other methods all have an influence on the public and on political supporters. For example, the NYC Bluebelt brochure⁴⁰ encourages involvement by the public and is extremely informational about the intent and goals of the Bluebelt system in general. **Figure 2-10** shows examples of the NYC Bluebelt signage.



Figure 2-10 NYC Bluebelt perimeter signage

Brochures and other educational devices such as YouTube videos similar to those used by the Long Creek Watershed Management District⁴¹ also help educate and inform the public for long-term acceptance and involvement⁴². NDOT has used YouTube videos to help inform the public about current construction projects and SWM⁴³.

The NYC Bluebelt, SEMCOG, the City of Philadelphia, the Long Creek Watershed Management District, and PennDOT have all posted educational signs along the perimeter of GI-treated areas with the positive result of public acceptance and cooperation with these practices. Along the perimeter of treated areas, posted signs notify the user to be cognizant of the GI approaches used, which also helps the public be more diligent and cooperative.

Education and outreach also explain the need for cooperation by the public in maintaining the restoration of environmental areas of concern. For instance, King County, Washington, has developed signs to help educate the public on why it is using LID techniques and the benefits to the environment those techniques provide. The Department of Ecology approved the signs'

40 Staten Island Bluebelt, NYC Environmental Protection, Bureau of Water and Sewer Operations, Department of Environmental Protection, New York City, New York, http://www.nyc.gov/html/dep/pdf/brochures/si_bluebelt_brochure.pdf

41 Long Creek Watershed Management District, <http://www.restorelongcreek.org/>

42 Five "Good Housekeeping" Practices, Landowner Fact Sheet, Long Creek Watershed Management District, <http://www.restorelongcreek.org/CMSContent/documents/fact-sheets/20160817%20GHPP%20Fact%20Sheet.pdf>

43 Visit our NevadaDOT YouTube Channel!, Media and News, Nevada Department of Transportation, <https://www.nevadadot.com/doing-business/about-ndot/ndot-divisions/stormwater/media-and-news>

designs in 2014 and the signs were installed at the project site in 2015. The signs provide information about the locations, functions, and watershed benefits of the project’s various LID features. The effective sign graphics shown in **Figure 2-11** illustrate the goals that the agency is working toward. This works in everyone’s best interest while showing a clear representation of how this road/GI improvement is a benefit to the environment and can engender overall public understanding and support.

Clearly, a first line of defense is a robust education and outreach program. These education programs also encourage behavior change by creating an understanding of the overall goals and thus cooperation and participation by the public. King County has additional public education programs and approaches available. The region has developed several LID outreach tools for developers and the general public^{44, 45, 46}.



Figure 2-11 King County, Washington, low-impact development roadway improvements signage

In addition to public support, political support is also key. This is the foundation for funding and long-term sustenance of GI initiatives. The same resources dedicated to public education are also very beneficial for building and maintaining political support. Education related to regulatory factors, as well, is important in terms of political support. Having a champion in an agency or in a political position is beneficial to the implementation of an overall GI practice within an agency. Having political support and understanding of GI’s role and importance can be initiated either through or by a political or agency champion.

In addition, the public and agencies need to understand the importance of GI to clean water. When an agency does not educate the public or keep it informed, that agency is missing an opportunity to connect with its community and the social, environmental, and economic benefits provided by a strong GI program. Involving the public and having them as participating partners serves to strengthen the overall GI program and goals.

44 Low Impact Development Resources, Washington Stormwater Center, Washington State, <http://www.wastormwatercenter.org/lid-resources>

45 Low Impact Development: Technical Guidance Manual for Puget Sound, Washington State University Extension and Puget Sound Partnership, December 2012, http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf

46 Low Impact Development Program, Washington Stormwater Center, <http://www.wastormwatercenter.org/low-impact/>

Even when public education for a project is followed, the public can tend to forget these messages when the first bloom of weeds occurs, as will occur with seeding projects. Politicians and local leaders need to be educated and buy in on the process so that they can effectively respond to their constituents' complaints.

In summary:

- Public support is critical to sustaining GI infrastructure in DOTs.
- Political support is critical to obtaining funding for GI.
- The public needs to understand the importance of GI to clean water and clean air. This would include a focus on the triple benefits: environmental, social, and economic.
- Both public and political education needs to be combined and ongoing.

Recommendations

Each DOT should have its public information officer or communications expert develop a GI factsheet, relevant signage, and other materials to provide the public with a good understanding of the locations and importance of GI. For example, with some of the current construction projects, WSDOT has developed good public outreach campaigns to keep the public informed, such as the SR 520 floating bridge replacement project⁴⁷ and SR 99 Alaska Hwy viaduct⁴⁸. NDOT also uses its website and YouTube for informing and highlighting current projects under construction⁴⁹.

Social media (e.g., Facebook, Twitter, Instagram, YouTube, and LinkedIn) is a great resource for posting information.

Messages should be consistent with the recommendations and conclusions in this report, so the public receives that same consistent and overriding importance and understanding of GI.

DOTs should also develop advocacy outreach to local, regional, and national legislators to ensure needed funding and support.

Asset Management

Currently, DOTs track highway assets such as bridges, barrier rail, and pavement miles. However, stormwater and GI are not necessarily included in geospatial tracking systems as assets. This is a huge and crucial lack of important documentation. Not only are DOTs missing out on potential regulatory credits by not knowing exactly what assets they own and where they are, but agencies could also be more accurate in tracking their GI inventory and the maintenance condition of those assets. There would also be documentation on those facilities that are maintained, tracking associated costs, while also providing Maintenance staff with up-to-date locations of the BMPs. Additionally, DOTs would have the ability to more accurately assess the impact of the highway system on water quality, as many analyses probably do not consider the effectiveness

47 SR 520 Bridge Replacement and HOV Program, Washington State Department of Transportation, <http://www.wsdot.wa.gov/Projects/SR520Bridge/default.htm>

48 Alaskan Way Viaduct removal scheduled to begin in February, Alaskan Way Viaduct Replacement Program, Washington State Department of Transportation, December 4, 2018, <http://www.wsdot.wa.gov/projects/viaduct>

49 NDOT News: A Look at I-11, July/August 2017, YouTube, Nevada Department of Transportation, <https://www.youtube.com/watch?v=U2EquEkCvIQ>

of implemented BMPs. The FHWA also encourages use of GIS and geospatial tracking systems to help with transportation performance measures⁵⁰, which can be tied to eligibility for federal funding.

Tracking is critical for many reasons. It is used to document and satisfy regulatory requirements and manage assets. For instance, MDOT SHA has an exemplary asset management system, with all stormwater and GI assets documented within the system. This is especially helpful in terms of maintaining and managing each asset.

According to the MDOT SHA, “much of the maintenance planning by the Drainage and SWM Asset Management team is focused on overall triannual inspections and remediation efforts of the SWM facilities that require work beyond the capacity of the MDOT SHA forces. A master list of the facilities statewide is kept for just facilities that have been marked and assessed as marginally functioning. The list is kept to track permitting, design, and construction activities on any given BMP. In addition, the list of minor maintenance needs is cross-referenced with location information so it can be shared with Office of Maintenance managers, who can support maintenance shops in getting the minor repairs performed.”⁵¹

A strong asset management system is beneficial for tracking of maintenance and budgeting. Having that information is also valuable in predicting future funding needs. Furthermore, asset tracking is essential to working at the larger watershed scale. Finally, it is impossible for an agency to develop, refine, and manage a clear vision of future needs and goals without an effective asset management system that includes GI assets.

When there is a legal challenge to ownership of ROW or assets, having an asset management system in place can provide the legal division with accurate and clear evidence of ownership. This can help the agency avoid costly and unnecessary time and money expenditures.

Finally, with an asset management system and accurate tracking in place it is far easier to develop and share maintenance agreements and participate with other agencies. Without that information, cooperation is difficult and agencies can find themselves at cross-purposes, resulting in unnecessary and expensive duplication of efforts. An asset management system allows cooperative agreements and shared maintenance efforts to be far more achievable and realistic.

The following conclusions were reached regarding asset management:

- DOTs currently track assets such as bridges. Stormwater and GI are not necessarily a part of the geospatial tracking systems as an asset.
- Asset databases need to be used to track GI inventory and their maintenance condition.

50 Uses of Geospatial Applications for Transportation Performance Management, Case Studies of Select Transportation Agencies, Federal Highway Administration, U.S. Department of Transportation, September 2016, https://www.gis.fhwa.dot.gov/documents/Uses_of_Geospatial_Applications_for_Transportation_Performance_Management_Case_Studies.htm

51 Partial Response to amplifying question, “Are maintenance personnel trained on GI maintenance requirements?”, **Maryland Department of Transportation State Highway Administration**

- Tracking is important to:
 - Satisfy and document regulatory compliance
 - Manage assets
 - Prioritize projects
 - Track costs and predict future funding needs
 - Track life-cycle costs
 - Support watershed modeling and decision making from a watershed approach
 - Provide the DOT's legal division with correct information to defend against complaints (e.g., ownership of ROW and assets)
 - Manage shared maintenance obligations/cooperative agreements

Recommendations

It is critical that state DOTs and other agencies set up a standardized geospatial tracking system for *all* GI components across all districts. These various components then need to be integrated into the overall asset management system. Without a clear knowledge of the various assets, and their location and maintenance requirements, it is far more difficult to maintain these assets properly. Furthermore, if there were a maintenance tracking system, it would be more efficient and effective to tie that system in to the overall asset management system.

Including GI in the general agency-wide asset management system allows an agency to report to regulatory agencies the types and quantities of GI components that are in place for stormwater controls. It also allows an agency to plan and budget for necessary maintenance staff, inspections, materials, supplies, and scheduling. Should a staff member, upper management, or regulatory agencies have questions, there is also a quickly and easily identifiable method to access data on that asset.

A higher-level organization, such as AASHTO or FHWA, should provide information or references from other DOTs that have successfully developed asset management systems that integrate all maintenance requirements, including GI. This would allow DOTs to learn from each other's successes and challenges. As an example, the National Highway Institute has a webinar on "Developing a Transportation Asset Management Plan."⁵²

It would also be important to include various asset management system examples in the above-mentioned information sharing forum or clearinghouse.

⁵² Developing a Transportation Asset Management Plan, National Highway Institute, https://www.nhi.fhwa.dot.gov/course-search?tab=0&key=136106B&course_no=136106B&sf=0

Design

Currently, DOT GI practices are still strongly regulation driven; they have not yet been absorbed into routine SWM design. Given this stage of development within DOTs and the fact that regulatory agencies are often looking at impacts at the project scale, DOTs typically are required to demonstrate the benefit of proposed GI designs for specific applications. Several examples illustrate how DOTs and regional bodies are addressing these demands when it comes to project design. They point the way toward more-standardized design approaches within the typical DOT project development environment. Design standardization must be accompanied by DOT confidence of acceptance by the regulatory agency.

Additionally, the interdisciplinary nature of GI is an important aspect to be considered in the actual design of GI elements. Design is typically done by staff who may not be engineers and are working from a design manual. Utilizing a design team that includes landscape architects who are trained in site design, grading and drainage, soil types, correct regional plant selection, and other aspects of GI will provide for more-holistic and successful design practices and standards. This should include the development of effective design manuals and maintenance schedules that will ensure the long-term success of GI elements.

In Washington State, requirements go even further. In 2008-2009, the Pollution Control Hearings Board directed the Department of Ecology not only to encourage but also to require LID in municipal stormwater permits for western Washington. They developed LID requirements for municipal stormwater permits and an accompanying guidebook to help permittees comply with requirements and change their local codes and standards⁵³. Further, a LID technical guidance Manual for Puget Sound⁵⁴ was developed to provide “stormwater managers and designers with a common understanding of LID goals, objectives, specifications for individual practices and flow reduction and water quality treatment credits that are applicable to the Puget Sound region.” This manual is intended for engineers, planners, landscape architects, technical staff, policy makers, and developers. Clearly, it was important to the Puget Sound area to ensure there was comprehensive guidance and consistent approaches to the design and planning of stormwater.

Typically, DOTs have inefficiencies in the design of their various GI and BMP components due to a lack of standardized design for those components. It is also often difficult to receive regulatory agency acceptance of standardized designs and applications. This can be avoided by providing such manuals and guidance as has been made available in the Puget Sound area. WSDOT has an updated (2016) Highway Runoff Manual⁵⁵ that addresses stormwater controls that are required and implemented statewide, including in the Puget Sound area. The manual also references the

53 Integrating LID into Local Codes: A Guidebook for Local Governments, Puget Sound Partnership, Washington State, July 2012, http://www.psp.wa.gov/downloads/LID_Guidebook/20120731_LIDguidebook.pdf

54 Low Impact Development: Technical Guidance Manual for Puget Sound, Washington State University Extension and Puget Sound Partnership, Washington State, http://www.psp.wa.gov/downloads/LID/20121221_LIDmanual_FINAL_secure.pdf


55 Highway Runoff Manual (M 31-16.04, Supplement February 2016), Washington State Department of Transportation, <https://www.wsdot.wa.gov/publications/manuals/fulltext/M31-16/highwayrunoff.pdf>

equally effective Hydraulics Manual⁵⁶ as another component of stormwater and LID controls. This manual also contains specifications for required controls for typical situations.

In WSDOT's 2009 NPDES permit, LID was introduced as a WSDOT requirement. "WSDOT's SWM plan shall require nonstructural preventive actions and source reduction approaches, including LID techniques, to minimize the creation of impervious surfaces, and measures to minimize the disturbance of soils and vegetation where feasible ... WSDOT shall identify barriers to implementation of LID and, in each annual report, identify actions taken to remove barriers identified."⁵⁷ As a result of these requirements, the various manuals and guidance were developed to help the various impacted agencies respond to the regulations in a cohesive and effective manner.

Over time, analyzing the effectiveness of various BMPs in different situations, WSDOT was able to provide further direction regarding BMPs. For instance, a runoff-treatment BMP selection flowchart is provided with the accompanying appropriate treatment selection. This quickly narrows down the appropriate selection for designers and provides required details, simplifying the design time for projects.

LID BMP: Natural Dispersion



Natural Dispersion Area Along SR 516 in King County

Description: Existing soils, vegetation, and topography are used to provide flow control and runoff treatment. Runoff enters the dispersion area as sheet flow and disperses into the surrounding landscape. It requires little or no construction activity.

BMP Function

- LID
- Flow Control
- Runoff Treatment
- Oil Control
- Phosphorus
- TSS - Basic
- Dissolved Metals - Enhanced

Effective Life (Years)

↻ 50-100

Capital Cost

↻ Low

O & M Cost

↻ Low

Critical Design Issues:

- Ownership
- Length in Type C and D soils (100 feet minimum)
- BMP held in perpetuity

Additional Constraints/Requirements

<ul style="list-style-type: none"> <input checked="" type="checkbox"/> 4-5 Infiltration Design Criteria <input checked="" type="checkbox"/> Setback <input type="checkbox"/> Landscaping/Planting <input type="checkbox"/> Wetland Planting and Plant Establishment <input type="checkbox"/> Inlet and Outlet Spacing <input type="checkbox"/> Overflow <input type="checkbox"/> Multidisciplinary Team <input type="checkbox"/> WSDOT Pavement Engineer Approval 	<ul style="list-style-type: none"> <input type="checkbox"/> Soil Amendments/Compost <input checked="" type="checkbox"/> Energy Dissipater/Level Spreader <input type="checkbox"/> 5-4.3.3 Facility Liners <input checked="" type="checkbox"/> 5-4.3.7 Signing <input type="checkbox"/> Fencing <input type="checkbox"/> Presetting/Pretreatment <input type="checkbox"/> Underdrain <input type="checkbox"/> Soil Preparation
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TMDL/303(d) – Considerations¹

Avoid	Preferred	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Fecal Coliform
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Phosphorus
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Nitrogen
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Temperature
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Dissolved Metals
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Total Suspended Solids/Turbidity
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Dissolved Oxygen
<input type="checkbox"/>	<input checked="" type="checkbox"/>	pH
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Oil/Grease
<input type="checkbox"/>	<input checked="" type="checkbox"/>	PAHs
<input type="checkbox"/>	<input checked="" type="checkbox"/>	Pesticides

1. See Table 3-1 and Section 2-6.4 for additional guidance.

Maintenance Requirements

- Access Roads or Pullouts
- Vector Truck Access
- Mowing
- Valve Access
- Specialized Equipment
- Specialized Training

Further Requirements: See Sections 5-3.6.1 and 5.5. See Table 5.5.12.

Figure 2-12 Washington State DOT low-impact development best management practice, natural dispersion

⁵⁶ Hydraulics Manual (M 23-03.05, March 2017), Washington State Department of Transportation, <https://www.wsdot.wa.gov/publications/manuals/fulltext/M23-03/HydraulicsManual.pdf>

⁵⁷ From WSDOT peer scan presentation

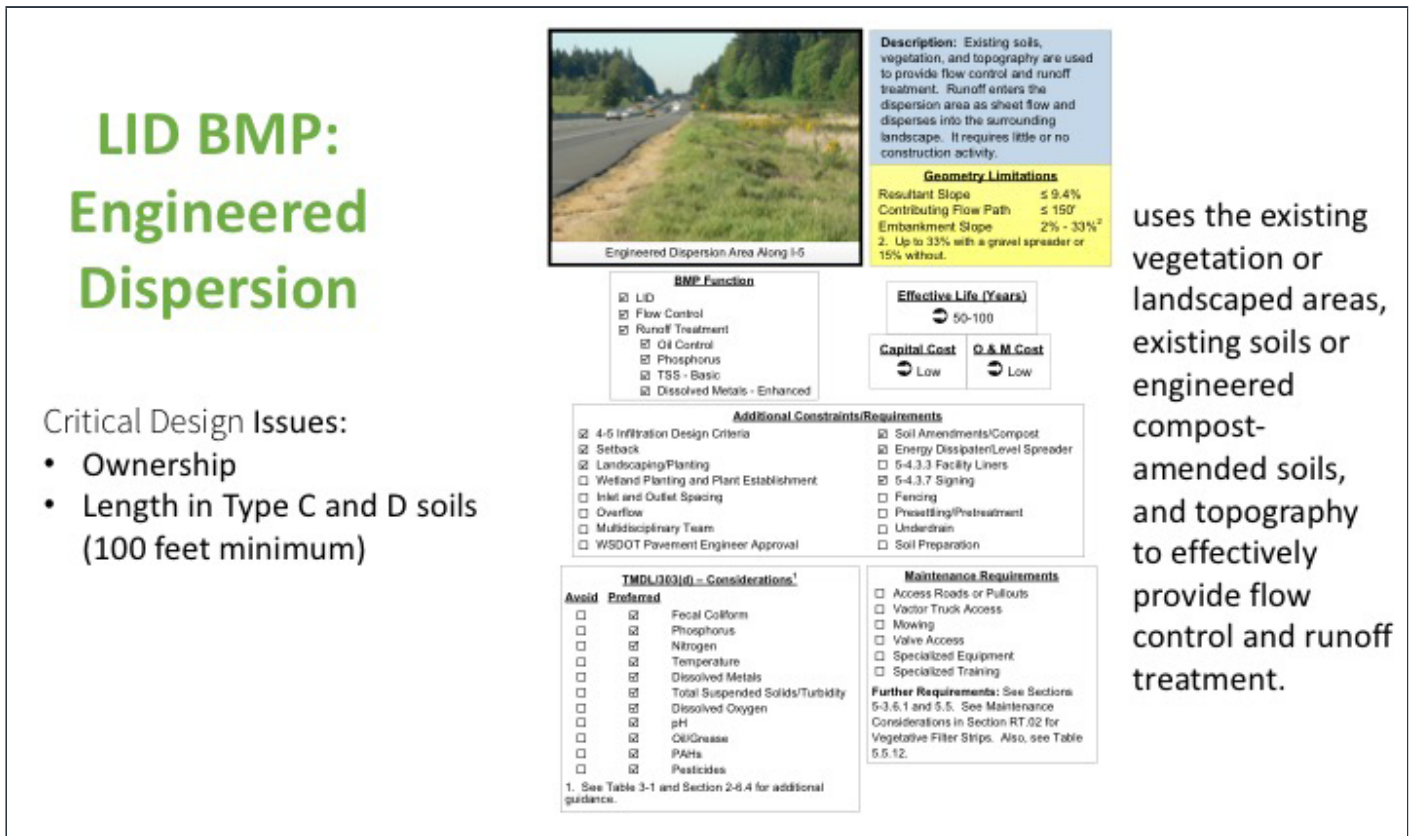


Figure 2-13 Washington State DOT low-impact development best management practice, engineered dispersion

As previously mentioned, DOTs typically have inefficiencies in the design of various GI and BMPs. Having manuals, guidance, typical details, and specifications such as those above would improve those inefficiencies and provide cost and maintenance efficiencies.

Further, not all states are required to use GI versus gray infrastructure. Typically, in those areas of the country where the stormwater is discharging to critical waterways, such as the Chesapeake Bay and Puget Sound, regulatory agencies have become more restrictive; GI is a requirement, as opposed to gray infrastructure. Regulations are coming from not only statewide departments, such as the Washington Department of Ecology, but also from local and regional bodies, and with additional requirements. However, the Puget Sound Partnership, the Washington agency leading the region’s collective effort to restore and protect Puget Sound, works to align regional efforts⁵⁸.

King County, Washington, is a part of the Puget Sound watershed, the second largest receiving body in the U.S. (second only to the Chesapeake Bay). The county, which includes Seattle, has its own set of regulations. Prior to 1990, there were few if any regulations. In unincorporated King County, conveyance of stormwater is 70% through roadside ditches and 30% through pipes. The incorporated areas of the county have a much higher percentage of enclosed systems. This contributed to the pollution of waterways with flow and contaminants, such as roadway

⁵⁸ Strategies and Actions – C: Pollution, The 2014/2015 Action Agenda for Puget Sound, http://www.psp.wa.gov/downloads/2014_action_agenda/Final%202014%20action%20agenda%20update/Section3C_Pollution.pdf

and property runoff, so that the system itself was a contributing pollutant. Eroding conveyance systems and streams in ditches (i.e., direct discharge to surface waters [streams, lakes, rivers, and the Sound]) also negatively impacted discharges on the ground and discharges to groundwater.

Since 1995, however, King County has been under a Phase I Municipal Stormwater Permit. As a result, the county now must manage the construction of regional water quality facilities in addition to flow control facilities and sometimes facilities that are serving a dual function. There are requirements for developers to build new facilities when developing and redeveloping their properties and for local jurisdictions to start retrofit programs. King County regional operations and guidance include a SWM program that details those requirements⁵⁹.

In addition to more disciplines being included in SWM – asset management, retrofitting, capital planning, source control, education and outreach, land use planning, scientific studies, information management, and code enforcement – more regulatory compliance is being required. It was determined that placed in county road ROW, BMPs could have a significant impact in helping to control pollutants.

Several research projects were started to determine some effective strategies for reducing the pollutants. One of these was a ditch BMP study. After several years of experimentation and various iterations of a ditch profile, the result was a detail for an effective strategy for assisting in pollution control (**Figure 2-14, Figure 2-15**). This has resulted in an effective BMP strategy for King County’s extensive ditch area and is an example of a jurisdiction finding solutions to a regional issue with a standardized design element that has received general regulatory agency acceptance.

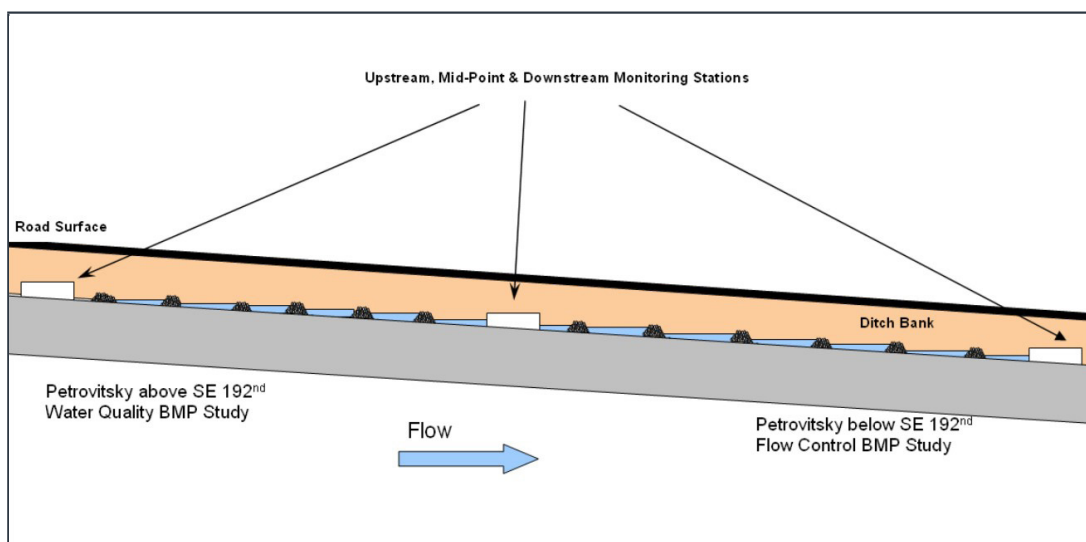


Figure 2-14 King County best management practice detail for ditch construction

59 Stormwater Management Program Plan, King County, Seattle, Washington, March 2017.

https://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/stormwater-management-program/King%20County_SWMP_2017.pdf



Figure 2-15 King County constructed ditch

In parts of the country that are more arid, such as Arizona and Nevada, regulations are still necessary, but the focus may be different. Rain events typically come in the form of monsoons that drop significant amounts of water (for the desert) in short periods of time; the desert soils are unable to absorb those amounts of rainfall. It is important to slow the water down so that this needed water could infiltrate the soil and recharge groundwater and to prevent the erosion of the delicate desert soils (**Figure 2-16**).



Figure 2-16 Arizona DOT depiction of rain event impacts

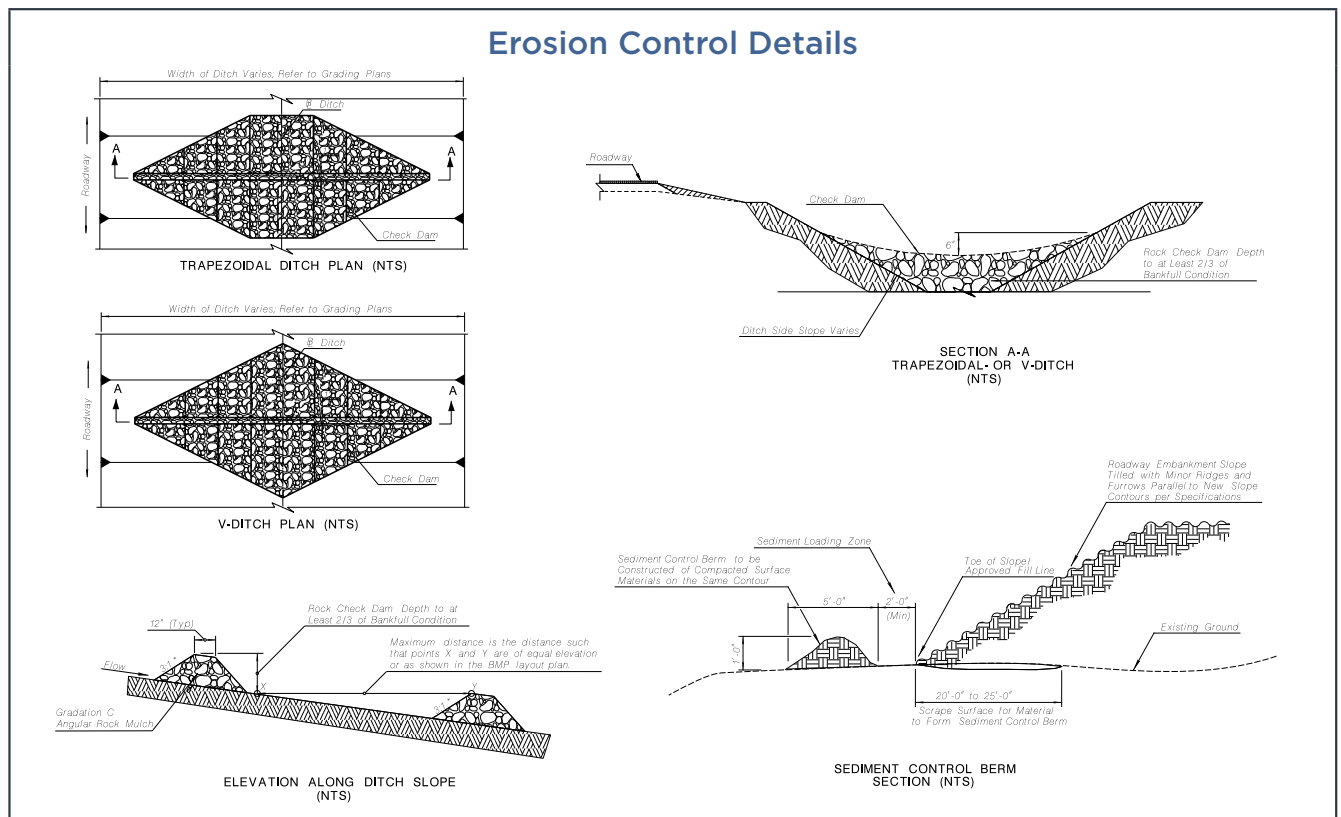


Figure 2-19 Arizona DOT Erosion Control details

Not all states are required to use GI versus gray infrastructure, but especially in those areas with substantial stormwater and pollution control needs, it has been shown that GI has the potential to become the preferred method of treatment, as illustrated by WSDOT.

It is also clear that not all states have standardized criteria or design guidance for GI. Although design guidance would vary somewhat according to regional and local geography and climatic conditions, if each state had standard criteria and design guidelines, it would be far more effective and helpful rather than state and regional agencies having to reinvent the wheel on a project-by-project basis, using guidance from outside the agency.

As shown in the preceding examples, context-sensitive BMP selection is critical to long-term success. This would include regulatory, topographic, geographic, and climatic considerations.

The following are the conclusions for the sixth category, design:

- SWM is regulation driven, so often agencies are required to prove the benefit of proposed BMPs at a specific location, are limited to preferred BMPs, or are required to submit lengthy documentation for proprietary BMPs.
- DOTs have inefficiencies in the design of various GI and BMPs due to the lack of standardization and acceptance by regulatory agencies.
- Not all states have requirements to use GI versus gray infrastructure.
- Not all states have standardized criteria or design guidance for GI.
- Context-sensitive BMP selection is critical to long-term success and includes regulatory, geographic, and climatic considerations.

Recommendations

Higher level organizations, such as FHWA, AASHTO, and state agencies, need to support research that demonstrates the effectiveness of proposed GI measures. These measures may include simple approaches such as using existing roadside vegetation and simple ditch modifications.

For instance, King County, Washington, has documented the effectiveness of its in-line ditch stormwater treatment BMP program⁶¹. This approach can be scaled to the appropriate regional need, if it were more widely available as an accepted BMP option.

Also, DOTs need to use the appropriate BMP with specific guidance on site attributes that support the various GI and LID techniques and the constraints that may limit their use. This would maximize the efficient use of ROW. Ditches, median shoulders, replacing turf with native vegetation, or other related items would provide additional pollution-load reductions or credits.

Cooperative research, such as the above-cited King County report⁶⁰, should be provided to regulatory agencies to demonstrate GI as an effective treatment for pollutant reduction. This would also include university research, such as that done by Temple and Villanova Universities in cooperation with PennDOT (see page 2-20).

AASHTO needs to develop criteria that define GI, including common BMPs with corresponding maintenance techniques for each treatment. Correspondingly, state DOTs need to develop such elements as a GI toolbox for specific state needs, such as the Erosion Control Toolbox⁶² developed by Caltrans.

The team recommends that AASHTO consider adding GI design guidance into “A Policy On Geometric Design of Highways and Streets” to provide general guidance for any future GI design. FHWA may consider providing incentives for GI wherever practicable prior to the use of gray infrastructure. It is past time for a paradigm shift to occur and rather than the old “tried and true” engineered gray solutions, DOTs need to approach the use of GI as a regular and necessary component. Besides critical environmental solutions, GI also has social and economic benefits, such as those discussed earlier in the City of Philadelphia (new businesses geared to maintenance and installation of GI; see page 2-22).

Another example is SEMCOG, whose regional “blue economy” is highly impacted by stormwater runoff (Figure 2-20). Managing runoff volume and quality at the source with GI is a priority in the region to strengthen the blue economy. As part of the Great Lakes State, the Huron-Erie Corridor is an international water resource that serves both as the region’s eastern boundary and as a 400-mile shoreline providing recreational access, drinking water, and economic commerce opportunities for the region’s 4.7 million residents. Southeast Michigan’s water-related industries are directly connected to more than 350,000 jobs, generating \$21 billion in annual earnings. These water resources also support valuable fish, waterfowl, and wildlife populations that are essential to sustaining Southeast Michigan’s nationally recognized fisheries and globally significant natural

61 In-Line Ditch Stormwater Treatment BMP Program Final Report, King County Department of Transportation, Seattle, Washington, December 2011,

<https://www.kingcounty.gov/~media/depts/transportation/roads/projects-plans-reports/StormwaterBMPFinalReport.ashx?la=en>

62 Erosion Control Toolbox, Caltrans, <http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/toolbox.html>

landscapes. Their roads account for more than 35% of all impervious cover in the region and generate more stormwater runoff than any other type of land use⁶³. This is primarily because the transportation network is also a conveyor of runoff from adjacent properties.



Figure 2-20 Southeast Michigan's Blue Economy

Thus, it is critical that management of transportation stormwater use every available tool. SEMCOG recognizes that GI is a vital component of economic prosperity⁶⁴. Evaluating SWM opportunities early in the transportation planning process is a key to addressing these challenges. The goal is to connect natural resources, such as wetlands, woodlands, and riparian corridors, to create a regional system consistent with SEMCOG's GI vision. These natural features play a contributing role in reducing stormwater runoff impacts.

SEMCOG's regional policies include promoting the use of complete and green streets when planning and designing transportation improvements near natural and water resources to achieve multiple desired outcomes, including enhanced mobility, recreational opportunities, and water quality.

Its vision also includes the promotion and recognition of sustainable development practices, such as leadership in energy and environmental design, LID, and GI techniques. This same vision should be emulated by other states and regions to obtain the multiple benefits GI affords a community and state.

⁶³ Excerpt from SEMCOG presentation at peer-to-peer scan

⁶⁴ Partnering for Prosperity: Economic Development Strategy for Southeast Michigan, Southeast Michigan Council of Governments and Metropolitan Affairs Coalition, January 2016, <http://smcg.informz.net/SMCG/data/images/publicnotices/EconomicDevelopmentStrategy.1-16.PublicComment.pdf>

Construction Inspection of Permanent BMPs

Typically, the DOT construction process is not necessarily effective for building BMPs and establishing vegetation. As was discussed earlier, maintenance, the lack of training for maintenance and the need to hire knowledgeable, experienced professionals during construction is also important. This includes having on the project site professionals with experience in plant ecology and native revegetation because there are many variables and factors in evaluating successful vegetation, including recognizing what are annual weeds that can be ignored versus invasive species that need to be dealt with immediately. Skilled, knowledgeable staff has a large impact on the success of the vegetation and reducing erosion into stormwater and other bodies of water.

Vegetation establishment is an ongoing and consistent problem among DOTs. For instance, the Colorado DOT contracted an excellent study for the “Assessment of CDOT Revegetation Practices for Highway Construction Sites,”⁶⁵ which described ongoing issues the DOT experienced. In their findings, it was determined “the revegetation of previously disturbed areas from highway construction and maintenance activities is a critical component to overall site SWM strategy. Poor revegetation actions during and after construction can lead to difficulty in deactivating stormwater construction permits. Excessive duration of open permits due to poor revegetation success can result in higher non-project costs for erosion control, revegetation rework and maintenance, and regulatory compliance monitoring and documentation.”

There are ongoing issues with plant establishment periods. Many DOTs have a conflict between the length of time required to establish vegetation and the length of time given to close out a construction project. Revegetation usually requires several years to become established. This is especially true when the agency is attempting to establish native vegetation, which regulatory agencies often require. There are ongoing problems with how and by whom inspections are done during a project’s plant establishment period. When the construction project is considered “closed,” no construction budget is available for these inspections or for correcting deficiencies, such as not attaining required vegetative cover.

The revegetation challenges facing most DOTs involve many areas, such as process quality control, contractor compliance with specifications, and contractor and DOT field personnel understanding of the overall revegetation process and specifications. Additionally, a post-construction process in which consistent methods and protocols are used to obtain contractor compliance with revegetation expectations typically does not exist.

One of the main challenges facing DOTs to reduce revegetation costs is based on the current system of post-construction responsibilities and process. There is a condition of competing interests associated with revegetation. Project engineers and contractors are in a hurry to close out the project, be compensated for all completed work, and move on. Unfortunately, successful

65 Assessment of CDOT Revegetation Practices for Highway Construction Sites (Report No. CDOT-2015-02), Colorado Department of Transportation, February 2015, <https://www.codot.gov/programs/research/pdfs/2015-research-reports/assessment-of-cdot-revegetation-practices-for-highway-construction-sites>


revegetation does not necessarily follow the typical construction closeout time frame. Frequently, revegetation is one of the last considerations of many projects, and the vegetative success factors can easily be overlooked or ignored. This condition has the high potential of impacting DOT maintenance resources toward the end of the construction project and into the post-construction phase. DOT maintenance managers are then faced with a potentially high environmental and regulatory compliance risk due to potential soil erosion discharges from poor contractor revegetation performance.

Additionally, there are no current standardized requirements for infiltration methods. Therefore, there are widely varying test results that aren't consistent between methods. This makes it difficult during construction to enforce specified items/methods. Soil infiltration testing is typically conducted in the early stages of the planning and design process. This is done to determine if an infiltration-based design is suitable for a specific site and at what locations within the site. Testing enables a successful and effective SWM design that incorporates a suitable infiltration rate for design calculations. Soil testing also helps investigate the subsurface conditions below existing surfaces/pavement and identifies existing soil horizons (layers) and any limiting features, historic conditions, and other factors. These are critical factors to be considered for the GI to be successful. However, inconsistency in test results due to different testing methods makes accurate design difficult.


In areas such as Lake Tahoe, Nevada, where the strict regulatory requirements for fine sediment particles is less than 16 μm , having the ability to enforce a standardized infiltration test would be influential not only to the success of the GI measures, but also to the successful reversal of Lake Tahoe's diminishing clarity (**Figure 2-21**). As NDOT has committed to ensuring a clarity improvement over a relatively short period of time, this would be a critical tool for its toolbox.

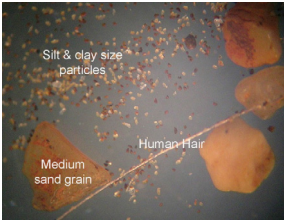
What Is Causing It?

- **Nutrients (Nitrogen & Phosphorous)**
 - fuel algal growth
- **Fine Sediment Particles (< 16 μm) scatter & absorb light**



16 μm is about the size of a blood cell!





1

Figure 2-21 *Nutrient pollution from Nevada DOT scan presentation slide*

The final conclusions for construction inspection of permanent BMPs are:

- The typical DOT construction process is not necessarily effective for building BMPs and establishing vegetation.
- Plant establishment periods are typically inadequate to establish necessary vegetative cover compared to the overall construction project closeout periods.
- Standardized requirements for infiltration test methods do not currently exist. As a result, there are widely varying test results that are not consistent between methods.

Recommendations

For every construction project, the contractor must submit site management plans to include stormwater, construction activities, and post-project vegetation and erosion control. These plans are then reviewed and approved by the appropriate and knowledgeable staff who have been involved in the planning/design of the project. This shall occur prior to any work being performed in critical areas, such as near building infiltration, infiltration basins, or bodies of water.

The environmental requirements and accompanying GI and stormwater components, including temporary and permanent BMPs, should be discussed during the preconstruction meeting. This is to ensure that the contractor and inspectors understand the design elements and requirements for GI and SWM in general.

If the general contractor does not have the appropriate knowledgeable, qualified, experienced personnel needed to install GI features, hiring qualified, specialized subcontractors should be required for the installation of those features. Strong, clear specifications and details requiring those qualifications need to be a part of the contract to be enforceable and an incentive for the contractor to hire the necessary qualified personnel. During construction, oversight is critically important in ensuring that the contractors are executing the revegetation actions according to the DOT specifications.

A high-level DOT management discussion about changing the mindset of closing out construction projects as soon as possible and better defining long-term revegetation responsibilities must be considered. The overall cost of performing revegetation correctly the first time during construction as opposed to leaving DOT maintenance to perform revegetation rework needs to be considered under a life-cycle cost perspective. Contractors need to be made more responsible for successful revegetation. DOTs should consider other post-construction contract mechanisms with qualified landscape contractors to manage revegetation, meet regulatory requirement responsibilities, and ensure long-term site stabilization.

Additionally, rather than the general contractor, agencies should pursue specialized subcontractors having plant installation, plant establishment, and vegetation management skills and appropriate experience. This may require revising SOPs for contractor review, including rating of contractors' personnel qualifications. Agencies could provide incentives to offset the cost of hiring qualified personnel or contractors. The cost would probably be negligible because it would likely result in two or three specialized persons being hired. Often there is no clear directive for

contractor oversight of the revegetation process, resulting in poor revegetation outcomes. Hiring qualified oversight personnel would save agencies money in the long run. It has been demonstrated in the literature that it is cost-effective to perform site revegetation correctly the first time as opposed to revegetating after failure⁶⁶.

DOTs need to be required to salvage topsoil and reuse for vegetation establishment under conditions shown to sustain seed bank viability. Remediation activities (e.g., additional planting, removal of nonnative invasive species, or erosion control) need to occur to ensure the success of the restoration/revegetation efforts.

Additionally, a process for documenting seed viability needs to be implemented. Native seeds are an expensive and limited resource, and the investments of time and resources required for revegetation and rehabilitation are substantial. Expensive rehabilitation efforts are wasted if the viability of seeds is substandard. Seed batches should be tested to ensure they meet the viability and germination rate standards that are required for revegetation projects.

A process for ensuring correct implementation of permanent and temporary stormwater and GI features needs to be developed. This should include sequencing/time frames (e.g., contract hold points) for critical work and vegetation establishment. For example, WSDOT provides just-in-time training for its Hydraulics Section for each project, so its personnel are familiar with the project requirements and can recognize how to successfully implement GI. It may be necessary for agencies to review and approve more-detailed vegetation management plans submitted by the contractor. If so, DOTs would also need to ensure qualified personnel are available to review those detailed plans.

Additionally, specialized GI construction inspectors with proper training need to be on site. These would include staff knowledgeable in the areas of vegetation, revegetation, hydrology, soils, geotech/infiltration, and landscape architecture, as examples. These inspectors should have the authority to either stop or require corrective work be made on site prior to any further construction being completed. The MaineDOT construction environmental compliance inspectors are granted the authority to do this and it ensures that the work is done properly the first time.

For a successful program of stormwater infiltration measures, standardized, recognized infiltration tests, such as ASTM standards, would be necessary. State DOTs could then adopt those standards and require the applicable tests on their project sites.

Final Conclusion

The scan team's conclusion was that successful management of stormwater and GI is best accomplished by using a holistic approach. Planning, asset management, maintenance, and watershed approach are interrelated and impact each other. Long-term success in both regulatory compliance and environmental stewardship is greatly improved when GI is approached as an entire system rather than segmented on a project-by-project basis.

⁶⁶ Chenoweth D, D Holland, G Jacob, L Kruckenberg, J Rizza, and B Whiteley, The Economic Benefits of Completing Reclamation Successfully the First Time for Oil & Gas Sites,

<http://www.quattroenvironmental.com/wp-content/uploads/2013/06/Economic-Benefits-of-CompletingReclamation-Successfully-the-First-Time-for-Oil-Gas-Sites.pdf>

Recommendations

The scan team’s primary recommendations for the eight categories are:

Definition of Green Infrastructure

- Develop a national-level standard definition. This definition should also explain the relationship between LID and GI.

Recruit champions in AASHTO to define and incorporate GI into the “A Policy on the Geometric Design of Highways and Streets” (aka the Green Book) to achieve consistent recognition and compliance at state DOTs.

Maintenance

- Establish a working relationship between the state DOTs, local agencies, funding sponsors, and possibly FHWA at the beginning of the project to develop a funding mechanism to support future maintenance activities.
- Ensure that appropriate training needs occurs at tiered levels.
- Institute asset tracking and workflow for stormwater-specific assets.
- Use GIS systems to visually show where *all* GI system assets exist.

Watershed Approach Versus Project Site Approach

- Establish a dedicated stormwater program or funding for flexibility and prioritization.
- Modify DOT procedures to incorporate a watershed-level approach (e.g., planning, environmental, stormwater) because it is extremely important to consider SWM early in the transportation planning process rather than waiting until the design phase.
- Develop an integrated approach with other property/agency owners/partnerships for more flexibility and potential for successful outcomes.
- Begin a dialogue between regulatory agencies and DOTs and coordinate toward using a watershed-level approach.
- Create an understanding that the large-scale planning of watershed-approach projects maximizes cost savings and outcomes for the largest benefit to the environment.

Information Development and Sharing

- Develop and maintain a free website/clearinghouse of information with a good search engine and moderated forum for GI information and research sharing.

- Create DOT/university partnerships on GI
- Initiate a National Green Infrastructure conference. GI should have a reliable, self-sustaining national conference specific to DOTs.
- Expand the scope of hydraulics/stormwater conferences to include GI sessions and GI practitioners, planners, landscape architects, stormwater personnel, and maintenance staff.
- Use regionally based GI programs to then expand into state and national programs.
- Develop a business case for management level executives to obtain buy-in and long-term support; include cost benefits, social value, and economic, environmental and other benefits.

Public Outreach

- Have DOT public information officers or communications experts develop a GI factsheet, relevant signage, and other materials to provide the public with a good understanding of GI locations and the importance of GI.
- Use social media (e.g., Facebook, Twitter, Instagram, YouTube, LinkedIn) as an excellent resource to post information and keep the public informed and educated.
- Develop advocacy outreach from state DOTs to local, regional, and national legislators

Asset Management

- Set up standardized state DOT geospatial tracking systems for all GI components across state districts and then integrate these components into the existing asset management systems.
- Provide information or reference other DOTs that have developed an asset management system that integrates all maintenance requirements.
- Include asset management system examples in the information sharing forum/clearinghouse.

Design

- Support research that evaluates the effectiveness (or lack of effectiveness) of existing roadside vegetation and simple ditch modifications.
- Use the appropriate BMP at specific locations, maximizing the efficient use of ROW.
- Provide cooperative research to regulatory agencies to demonstrate GI as an effective treatment for pollutant reduction; this would also include university research.
- Encourage AASHTO to develop criteria that defines GI, including common BMPs, with corresponding maintenance techniques for each treatment.
- Develop a GI toolbox for specific state needs.
- Include context considerations for BMP selections in design guidance, including signage.
- Encourage FHWA to consider providing incentives for GI wherever practicable prior to the use of gray infrastructure.

Construction Inspection of Permanent BMPs

- Require contractors to submit site management plans that are reviewed and approved by appropriate, knowledgeable staff prior to any work in critical areas, such as near bodies of water, building infiltration, and filtration basins.
- Require DOT construction experts in the following disciplines to be on site during construction:
 - Vegetation
 - Revegetation
 - Hydrology
 - Soils
 - Geotech/infiltration
 - Landscape architecture
- Address environmental requirements and temporary and permanent BMPs in the preconstruction meeting.
- Require specialized contractors or subcontractors to install GI features.
- Develop a process for ensuring the correct implementation of permanent and temporary stormwater and GI features, including sequencing/time frames (e.g., contract hold points) for critical work and vegetation establishment.
- Create a paradigm shift in the upper management of state DOTs regarding closing out construction projects as soon as possible; instead, the proper revegetation needs to occur prior to closeout. Define and assign long-term revegetation responsibilities.
- Use specialized GI construction inspectors with proper training; they also need to have the authority to stop work or require corrective work.
- Develop standardized infiltration testing methodologies for GI (ASTM or other recognized authority). State DOTs should adopt and require applicable testing on project sites.

Implementation Strategy

The scan team identified several strategies and avenues for dissemination and implementation of this report, which included opportunities such as national meetings, committees, national and regional conferences, internal presentations, training, outreach, research, and publications.

Other organizations could also disseminate the results of the report such as AASHTO, TRB, FHWA, U.S. DOT, and state DOTs. Similar strategies can also include presenting the results of the scan at the TRB annual meeting to committees such as the Hydraulics, Stormwater, and Environmental Design Committees. Another audience for the report results would be the AASHTO Standing Committee on the Environment and the AASHTO Subcommittee on Hydraulics. Scan team members identified other related organizations that would benefit from a presentation of the scan results, such as the Minnesota Statewide Hydraulics Committee and other similar state committees.

Conferences where the information from the report could be presented are the Washington Municipal Stormwater Conference, StormCon, the FHWA National Hydraulic Engineering Conference, the Maine Water Conference, the National Stormwater and Watershed Conference, the International Erosion Control Conference, and the American Society of Landscape Architects Conference on Landscape Architecture.

Under training and outreach, expanding the scope of the National Hydraulics Engineering Conference could be a possibility. This would also include GI sessions for practitioners, planners, landscape architects, stormwater personnel, and maintenance staff. A team member is also investigating sessions on GI at the Hydraulics Engineering Conference.

Over the long term, other steps would be to initiate a national GI conference specific to DOTs, with the same funding source as National Hydraulics Engineering Conference; AASHTO and FHWA could provide guidance on setting this up. The first steps would involve getting the topic of GI on the agenda of existing conferences.

Another avenue of dissemination would be webinars and videos related to maintenance, design, and construction. A video presentation could be developed for state DOTs.

Additional dissemination activities could include regional peer exchanges. The scan team would help investigate potential opportunities, which would include developing a proposal based on NCHRP 20-44 (Moving Research into Practice) possibilities.

An AASHTO champion would considerably help the implementation and acceptance of GI in state DOTs. Some of the team members are investigating potential champions, possibly an existing AASHTO committee member.

Research would also be a resource to be used for further dissemination of GI information. This would include vegetation BMP guides and GI decision support tools and toolboxes for state DOTs. State of the practice for what other DOTs are doing regarding green stormwater infrastructure practices could be investigated and a synthesis of existing guides compiled. This could be done via a survey to the DOTs, with potentially a separate preliminary investigation to determine if it would yield relevant results. The same could be done for design and maintenance guidance by researching if there are existing databases and information on decision-support tools.

Other possibilities for research would be outreach to colleges and universities for help with the research. Once research projects have been established, have students assist with them. Research should be developed to show the effectiveness of alternative BMPs and existing roadside vegetation, as was done by the PennDOT, discussed earlier in the report.

An additional NCHRP research proposal could also be introduced for a GI repository, clearinghouse, forum or website. The NCHRP 25-25 project (Research for the AASHTO Committee on Environment and Sustainability) could be used to establish a highway GI portal in the International BMP Database with support from the EPA and FHWA.

Another avenue for dissemination of the report results would be publications or viewing resources, such as Stormwater magazine, *Public Roads*, *Landscape Architect and Specifier News*, *ASLA Landscape Architecture Magazine*, and AASHTO Transportation TV.

The status of the implementation plan will be followed up via conference call with scan team members.

Appendix A: Scan Team Contact Information

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Appendix B: Scan Team Biographical Sketches

JENNIFER TAIRA (AASHTO CHAIR) is senior landscape architect with the California Department of Transportation (Caltrans) and has been with Caltrans for 19 years. As coordinator of Roadside Research and Innovation, she is a leader in innovation for the department through management of state and national roadside and landscape architectural research. Taira currently works in the Office of Landscape Architecture Standards and Procedures in providing Caltrans standards, procedures, and guidance on landscape architectural practices that contribute to enhanced and innovative design solutions in addition to her research responsibilities.

KEN GRAEVE supervises the Erosion and Stormwater Management Unit at the Minnesota Department of Transportation (MnDOT) in Saint Paul, MN. He and his team provide statewide program direction and technical support regarding erosion prevention, sediment control, construction stormwater management and roadside vegetation establishment. He has been at MnDOT for 11 years, which includes previous work in roadside vegetation management, roadside prescribed fire, invasive species control, and threatened/endangered plant protection. Ken has a Bachelor's degree in Biology, with an educational and work background in Ecological Restoration and Botany. .

CHARLES HEBSON is manager of the Surface Water Resources Division in the Maine Department of Transportation Environmental Office. He holds a master's degree in hydrology/water resources (civil engineering) from Princeton University and a bachelor's degree in civil engineering from Brown University. His responsibilities include hydrology and hydraulics for transportation design, special projects with significant water-related environmental issues, and special emphasis on field evaluations and design for fish passage. Hebson provides technical support to ongoing policy developments related to fish passage, stormwater, and climate, as well as development of technical guidance materials for hydrology, hydraulics, and fish passage design. The Surface Water Resources Division consists of the Hydrology Section and the Surface Water Quality (Stormwater) Section. Hydrology, Hydraulics, drainage, and fish passage are generally assigned to the Hydrology Unit; stormwater design and stormwater regulatory compliance and program management take place in the Surface Water Quality Section. The division includes two engineers, two hydrologists, one environmental specialist, and two field technicians. Prior to joining MaineDOT in 2001, Hebson worked in consulting and for the U.S. Department of Agriculture – Agricultural Research Service and the U.S. Geological Survey and taught high school science for four years immediately before joining MaineDOT.

GARRET W. JACKSON is the Hydrology Program manager at the Washington State Department of Transportation Headquarters in Olympia, Washington. He oversees a statewide program that provides design and oversight of stream-bank stabilization projects and emergency roadway repair projects involving rivers, fish-passage projects, and drainage-related problems. He is a licensed geologist and has worked as a geomorphologist and hydrologist for 30 years, including 11 years with Washington State DOT. Jackson has been involved in numerous stormwater and water quality studies and projects during the course of his career. He also provides technical oversight on Washington State DOT research programs related to hydrology and hydraulics and serves as a technical expert on coastal erosion and sedimentation hazards for Washington State DOT.

LAURA RIGGS is the program manager of the Local Road Safety Program and Safe Routes to Public Places for the Louisiana Department of Transportation in Baton Rouge. She is a member of the Council on Active Transportation. Before joining the Office of Planning, Safety Section, Laura was the program manager of the Urban System Program (STP>200k), the Transportation Alternatives Program, the Recreational Trails Program, and Scenic Byways Program. Riggs is a graduate of Louisiana State University and holds a bachelor's degree in civil engineering. She is a licensed professional engineer in Louisiana.

BRIAN SMITH is an ecologist with the Resource Center of the Federal Highway Administration. He provides technical assistance and deploys innovations in areas related to stormwater management, soil erosion and sediment control, roadside vegetation management, wetlands, ecosystem, effects analysis, and environmental stewardship. He worked with the U.S. Army Corps of Engineers (1992-2001), the U.S. Forest Service (1989-1991), and served as co-chair for the NCHRP scan and report Best Practices in Addressing NPDES and Other Water Quality Issues in Highway System Management (2009). He is a certified professional in erosion and sediment control, certified professional in stormwater quality, and a graduate of Illinois State University (bachelor's degree) and Northern Illinois University (master's degree).

LUCY JOYCE (SUBJECT MATTER EXPERT) retired from Nevada Department of Transportation as landscape architect supervisor in 2016. She oversaw the creation and implementation of Nevada DOT's award-winning Landscape and Aesthetic Program. In her tenure at Nevada DOT, Joyce made significant contributions by promoting landscape architecture as a profession and recognizing the importance of aesthetics as well as sustainable design. Her insistence on landscape architecture being an integral part of the design process changed how the agency does business, from using sustainable practices such as LID to applying sound and enduring design principles. Her efforts resulted in the program achieving regional and national recognition and awards for Nevada DOT's landscape architecture, planning, and context-sensitive solutions.

Appendix C: Amplifying Questions

Agency Information

As defined for this domestic scan, green infrastructure (GI) includes roadside stormwater management; low-impact development; hydromodification, or watershed actions that conserve water, buffer climate-change impacts, improve water quality, water supply, and public health; and restore and protect rivers, creeks, and streams as a component of transportation development projects and operations.

1. Please identify types of GI required to be implemented under regulatory programs (i.e., NPDES, etc.) versus voluntary GI initiatives (i.e., community rain gardens).
2. Does your agency have rule-/ordinance-making authority? Do your GI efforts distinguish from a stormwater (SW) program? Are there distinct duties, responsibilities, and designated staff between GI and SW? Are they distinguished as different sections or are they so integrated that they are the same section? Describe any recent organizational changes made to implement the program.
3. What types of GI have been installed by your agency? How does your agency track GI type and location? How do you track function and performance to understand if constructed GI is working as designed? Describe any recent changes made or recommended.
4. Does your agency have policies, guidance, or tools for designers to use when designing GI projects? If so, can you provide a link?
5. Who in your agency identifies and selects potential GI projects? Did you encounter resistance from certain groups? If so, how did you overcome this resistance?
6. What criteria does your agency use for programming, prioritizing, and funding GI projects? Is GI considered for all projects? Is GI required for specific watersheds in your state? How does the regulatory authority convey GI requirements to the transportation agency?
7. What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least- and most-restrictive funding sources you use?
8. Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?
9. Does the design consist of a multidisciplinary team (i.e., hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?
10. How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them? Does your training extend to external customers, such as local agencies, MPOs, consultants, and contractors?
11. Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (e.g., concrete lined ditches,

pipng, etc.)?

12. What considerations does your agency take into account when considering gray versus green infrastructure? Do both approaches work equally well? Is one less expensive? Can they be combined? Are residents willing to put up with construction in their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?
13. What current trends do you see? Increases in GI implementation? An increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

1. Why does your agency implement GI (i.e., vision, mission, resource agency demand, regulatory, total maximum daily load [TMDL], or public demand, etc.)?
2. What criteria do you use to evaluate GI proposals?
3. What criteria do you use to select alternatives and practices? Is your agency willing to purchase right of way or condemn property solely for use as GI?
4. Describe what is driving your decision to use GI.
5. For what type of environments (i.e., urban, rural, desert, mountain, flatland, or coastal) does your agency design GI?
6. At what phase of project development do you begin identifying specific GI practices?
7. Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?
8. Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?
9. Does your agency leadership support the use of GI on transportation projects? Does your agency engage stakeholders to evaluate the use of GI for roadside water management? If so, how do they engage the stakeholders? Do your regulators promote and support the use of GI? If yes, how do they work with your agency to select, develop, and fund GI?
10. What tools or techniques does your agency use for sharing information with internal and external stakeholders (public outreach)?
11. Is there a database to keep track of GI projects? What do you track (acres treated, types of benefits to the environment after completion, economic benefits after completion, social benefits after completion, or other items)? Is the database proprietary or open to DOTs?
12. In your experience, what is the most crucial factor to consider in GI?

13. Do you document and monitor pilot projects? Does this encourage better and increased implementation?
14. Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in project design or funding?
15. Has your agency considered other design considerations that were not supported? Why not?
16. What lessons have been learned from the GI installed? Have different BMPs performed better than others? Have any GI types been eliminated from use? If yes, why?
17. Based on lessons learned, what project types are most feasible for future projects?
18. What were the unique challenges during construction? What was the overall timing of the construction/ installation?
19. Have there been issues with successful vegetation establishment related to specific BMPs? What were the specific challenges associated with vegetation on the urban roadside?
20. When designing the GI, what metrics were used and were extreme weather events part of the calculation?
21. Does your design accommodate increased long-term flows? On what is that based?
22. Describe the coordination, training, and outreach with the public, including adjacent property owners.

Performance Measures

1. What requirements do the regulatory agencies impose? Describe any programmatic agreements achieved through your GI project design approach (e.g., mitigation credits).
2. Have you developed a general rule of thumb for funding spent on GI?
3. Have you seen a difference in cost between GI and gray infrastructure?
4. Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction?
5. Have you documented a cost savings for these processes?
6. Do you conduct a cost/benefit analysis of the GI proposed for a specific project to determine the efficacy of the BMP? Is the funding amount tied to GI performance measures?
7. Do you require contractors to have a plant establishment period? If so, for how long?
8. Are there any challenges associated with setting a plant establishment period? Describe how the plant establishment period is handled (e.g., Is it in the contract? Is it covered by a bond? Do state forces assist?).
9. Do you have any issues with establishing prescribed permanent vegetation after construction of GI? Have invasive species presented any challenges with a GI type? Location? How has this been resolved?

10. Has there been pushback on the appearance of GI in urban areas?
11. How many acre-feet of water per year are captured by GI techniques?
12. Do you use a scoring tool to prioritize projects, funding, and programming?
13. Can you provide data demonstrating how GI implementation has helped to mitigate impacts or improve environmental outcomes? For example:
 - Was there habitat enhancement after project completion? How long did it take for the enhancement to occur?
 - Did your GI project support efforts to address pollutants of concern for 303d-listed water bodies? Was funding made available to prioritize the use of GI when it was done in association with the transportation project? Was the quantity of pollutants removed measured and identified? Over time, did the pollutants decrease?
14. Was land acquired outside of the right of way to meet the GI objective?
15. Were regional hydrology needs identified when selecting the project site and did that help meet local/regional plan goals and/or water quality concerns?

Maintenance

1. How does your maintenance personnel take care of GI (no maintenance or equipment [mechanical, handheld, or other])? Please describe. Does your GI take more maintenance than gray infrastructure or less? Are there seasonal requirements?
2. How is maintenance funded?
3. Has funding increased or decreased as a result of GI? Is there a dedicated funding source for maintenance of GI?
4. Are maintenance personnel trained on GI maintenance requirements?
5. Is there a dedicated crew for GI or is it considered part of general maintenance? Does your agency maintain GI as part of larger roadside maintenance contracts or agreements?
6. How do you inspect GI to ensure function is maintained? Does each GI type have a scheduled maintenance plan in place? How is this delivered? Do you coordinate between other/multiple agencies for maintenance?
7. Do you have a method to identify maintenance triggers?
8. Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.
9. Is special equipment required for maintenance of GI elements? If so, how is this funded?
10. Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area (e.g., replacing or repairing infrastructure under streets)?

Miscellaneous Questions

1. Does your agency only focus on small-scale design specific to an area or take a regional approach? Describe key alliances, partnerships, and tools used to integrate planning and landscape scale planning and coordination.
2. What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water or traffic patterns)?
3. What did we miss? Is there some better technique or approach to GI planning, design, funding, construction, maintenance, or inventory of GI locations that we did not address? How do innovative contracting methods affect GI implementation strategies?
4. Do you test soils prior to design to identify the best solution?
5. Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?
6. Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?
7. Is there a framework or forum for continued community engagement/awareness and/or economic consideration?
8. What obstacles still exist (e.g., organizational culture; lack of buy-in from managers, designers, stakeholders, or the public; long-term stable funding; coordination; or lack of vision)?

For Cities/MPOs

1. Has your city/agency made zoning requirements to enforce GI?
2. Are incentives offered for implementing GI?
3. Do you:
 - Start by including small-scale GI practices in individual municipal projects that are currently in the planning stage?
 - Consider requiring that all local road projects allocate a minimum amount of the total project cost to GI elements?
 - Have stormwater fees based on impervious surfaces?
 - Have pilot projects?
4. How did you achieve leadership/championship of the cause?
5. Do you have buy-in from all municipal infrastructure departments?
6. Are your projects documented? Is there documentation on both a design and construction

level and on a citywide tracking level?

7. What resources do you have for financing GI?
8. Is the visibility of a project a consideration for GI?
9. Are cost comparisons made to doing the same with gray infrastructure?
10. Do you consider the cost/benefit ratio in these comparisons? Do you consider environmental, health or social benefits in these comparisons?
11. Over what timeframe do you consider these comparisons/benefits?

Additional Information

1. **Does your agency Have pilot projects?** Pilot projects are critical. The most successful municipal green street programs to date all began with well documented and well monitored pilot projects. These projects have often been at least partially grant funded and receive the participation of locally active watershed groups working with the city infrastructure programs. The pilot projects are necessary to demonstrate that green streets can work in the local environment, can be relied upon, and fit with existing infrastructure. Pilot projects will help to dispel myths and resolve concerns.
2. **Is there leadership in sustainability from the top?** The cities with the strongest green streets programs are those with mayors and city councils that have fully bought into sustainable infrastructure. Council-passed green policies and mayoral sustainability mandates or mission statements are needed to institutionalize green street approaches and bring it beyond the token green project.
3. **Are the efforts coordinated?** By their nature, green streets cross many municipal programs. Green street practices impact stormwater management, street design, underground utilities, public lighting, green space planning, public work maintenance, and budgeting. When developing green streets, all the relevant agencies must be represented. Also, coordination between the agencies on project planning is important for keeping GI construction costs low. Superior green street design at less cost occurs when sewer and water line replacement projects can be done in tandem with street redevelopment. These types of coordination efforts must happen at the long-term planning stage.
4. **Are your projects documented?** Green street projects need to be documented on two levels, the design and construction level and on a citywide tracking level. Due to the different street types and siting conditions, green street designs will take on many variations. By documenting the costs, construction, and design, the costs of similar future projects can be minimized and construction or design problems can be avoided or addressed. Tracking green street practices across the city is crucial for managing maintenance and quantifying aggregate benefits.

5. **Is there public outreach?** Traditional pollution prevention outreach goes hand in hand with green street programs. Properly disposing of litter, yard waste, and hazardous chemicals and appropriately applying yard chemicals will help prolong the life of green street practices. An information campaign should also give the public an understanding of how green infrastructure works and the benefits and tradeoffs. In many cases, remedial maintenance of green street practices will be performed by neighboring property owners; they need to know how to maintain the practices to keep them performing optimally.

Appendix D: Responses to Amplifying Questions

The responses to the scan team’s amplifying questions have been collated and are provided in alphabetical order, appearing as they were provided by the agencies. Questions that were not answered have been omitted.

- *Arizona Department of Transportation*
- *King County, Washington State*
- *Long Creek Watershed Management District*
- *Maine Department of Transportation*
- *Maryland Department of Transportation State Highway Administration*
- *Nevada Department of Transportation*
- *Oregon Department of Transportation*
- *Pennsylvania Department of Transportation*
- *Philadelphia Water Department*
- *Southeast Michigan Council of Governments*

Arizona Department of Transportation

Agency Information

ADOT 10-25-17 – John Hucko, Kirk Kiser, Mark Schalliol

Please identify types of GI required to be implemented under regulatory programs (i.e., NPDES, etc.) versus voluntary GI initiatives (i.e., community rain gardens).

Follow NPDES and Arizona PDES requirements guidelines and requirements. Introduced some minor rainwater harvesting basins in remote rest area locations.

Does your agency have rule-/ordinance-making authority?

Established guidelines

Do your GI efforts distinguish from a stormwater (SW) program?

No

Are there distinct duties, responsibilities, and designated staff between GI and SW? Are they distinguished as different sections or are they so integrated that they are the same section?

ADOT Roadside Development – Follow proven landscape architectural practices

Describe any recent organizational changes made to implement the program.

None

What types of GI have been installed by your agency?

Required agricultural soil testing, topsoil salvage and plating, deep tillage to promote rainwater infiltration on site.

How does your agency track GI type and location? How do you track function and performance to understand if constructed GI is working as designed?

Look at lessons learned reviews.

Does your agency have policies, guidance, or tools for designers to use when designing GI projects? If so, can you provide a link?

ADOT Roadside Development⁶⁷ has several links on our website.

Are you considering revising/changing current guidance, tools? If yes, describe the change, process, and why.

We update special provisions on a regular basis.

GI best management practices have been in use for many years as part of comprehensive stormwater management strategies. When did your agency begin implementation of a GI program?

BMPs and CMs have been incorporated in ADOT projects since the early 2000s.

Does your agency have a leader/champion for GI design practices and planning?

LeRoy Brady, chief landscape architect

What is the leadership/champions role in promoting GI?

LeRoy has over 45 years of experience At ADOT. He has the wisdom, knowledge, experience, and political capital to promote GI with upper management and design engineers alike.

What obstacles, concerns or barriers to GI exist in the agency?

Civil Engineers, economics

Who in your agency identifies and selects potential GI projects? Did you encounter resistance from certain groups? If so, how did you overcome this resistance?

⁶⁷ Roadside Development, Roadway Engineering, Arizona Department of Transportation,
<https://www.azdot.gov/business/engineering-and-construction/roadway-engineering/roadside-development>

Roadside Development, Environmental planning group.

What criteria does your agency use for programming, prioritizing, and funding GI projects? Is GI considered for all projects? Is GI required for specific watersheds in your state? How does the regulatory authority convey GI requirements to the transportation agency?

Project-specific environmental mitigation requirements; stakeholder requirements (i.e., Forest Service, BLM, cities. component of construction cost)

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

Combinations

Is GI a priority for executive management? Any there any specific problems with innovative practices and getting management approval?

Not necessarily a priority but not an obstacle either.

Does the design consist of a multidisciplinary team (i.e., hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

Usually a multidisciplinary team as listed above. Roadside Development takes the lead.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them? Does your training extend to external customers, such as local agencies, MPOs, consultants, and contractors?

Webinars, workshops, and training courses. Consultant presentations of their work on the subject.

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

ADOT is not subject to permits. Preferred method of choice.

What considerations does your agency take into account when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined? Are residents willing to put up with construction in their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?

Gray – build it and move on – less \$ for long-term maintenance but little or no

consideration for aesthetics, visual quality, and environmental benefits. ADOT does not have enough ROW to capture all water on the surface.

What current trends do you see – increases in implementation of GI? Increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

Less funding for maintenance. Less money for landscape construction.

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

What criteria do you use to evaluate GI proposals?

No specific requirements – proposal is typically prepared by an engineering consultant listing a landscape architect as a sub-consultant to provide any required GI requirements. Typically, the sub-consultant has previous ADOT experience.

What criteria do you use to select alternatives and practices? Is your agency willing to purchase right of way or condemn property solely for use as GI?

No, other than possible retention basins.

Describe what is driving your decision to use GI.

Water conservation requirements, heat island effects, habitat restoration and or connectivity

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

Everything but coastal

At what phase of project development do you begin identifying specific GI practices?

Initial project development and the environmental mitigation requirements

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

No.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

No.

Does your agency leadership support the use of GI on transportation projects? Does your agency engage stakeholders to evaluate the use of GI for roadside water management? If so, how do they engage the stakeholders? Do your regulators promote and support the use of GI? If yes, how do they work with your agency to select, develop and fund GI?

N/A

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

N/A

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

No.

In your experience, what is the most crucial factor to consider in GI?

Education and training, understanding and promoting benefits and getting buy-in

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

No.

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

No.

Are there other design considerations your agency had considered that were not supported? Why not?

No.

What lessons have been learned from the GI installed? Have different BMPs performed better than others? Have any GI types been eliminated from use? If yes, why?

Yes, better performance, ease of installation, and cost considerations

Based on lessons learned, what project types are most feasible going forward for future projects?

Rest area rehabilitation projects – project limits are smaller and defined – Maintenance

personnel on site usually – controlled environment – easier access. Smaller projects.
Opportunity to educate traveling public.

What were the unique challenges during construction? Overall timing of the construction/
installation?

Typically, seasonal weather – summer monsoons in the desert areas.

Have there been issues with successful vegetation establishment related to specific BMPs?
What were the specific challenges associated with vegetation on the urban roadside?

Always temperatures, precipitation, soils, topography, etc.

When designing the GI, what metrics were used and were extreme weather events part of
the calculation?

No

Does your design accommodate increased long-term flows? On what is that based?

No.

Describe coordination, training and outreach with the public, including adjacent property
owners.

None.

Performance Measures

(Note: Questions with two responses were answered by two people.)

What requirements do the regulatory agencies impose? Describe any programmatic
agreements achieved through GI project design approach (e.g., mitigation credits).

None to date.

We had a couple freeway landscape projects in which we had to meet Army Corp of
Engineers (ACOE) requirements: SR 202L RMF, Power to University, low flow channel
(riparian like basins), which had salvage and transplanting requirements, also the SR
101/SR51 TI which had large drainage basins as part of Reach 11 that ACOE required
us to replant a natural Mesquite Bosque.

Have you developed a general rule of thumb for funding spent on GI?

No.

Have you seen a difference in cost between GI and gray infrastructure?

No.

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction?

Yes.

Have you documented a cost savings for these processes?

No.

Do you conduct a cost/benefit analysis of the GI proposed for a specific project to determine the efficacy of the BMP? Is the funding amount tied to GI performance measures?

No.

Do you require contractors to have a plant establishment period? If so, for how long?

365 to 720 days

Yes, one to two years, typically depending on scope of project, type of planting

Are there any challenges associated with setting a plant establishment period? How is the plant establishment period handled? (e.g., Is it in the contract? Is it covered by a bond? Do state forces assist?

Follow up and inspection on remote projects across the state

Urban highway projects require monthly inspections by contractor with department inspectors and are tied to contract payments.

Do you have any issues with establishing prescribed permanent vegetation after construction of GI? Have invasive species presented any challenges with a GI type? Location? How has this been resolved?

NSCP required before and after construction; part of establishment process.

Yes, success is based on climatic conditions, which are very hot and dry right now for seeding areas. We have better results when the landscape project includes an urban landscape with plants irrigated from a drip irrigation system.

Has there been pushback on the appearance of GI in urban areas?

No.

How many acre-feet of water per year are captured by GI techniques?

Don't know.

Do you use a scoring tool to prioritize projects, funding, and programming?

No.

We currently use the value analysis process and are looking into the risk management process.

Can you provide data demonstrating how GI implementation has helped to mitigate impacts or improve environmental outcomes? For example, was there habitat enhancement after project completion? How long did it take for the enhancement to occur?

We believe there was habitat enhancement but do not have specific data for the SR 202L RMF Power-University, low-flow channel (basin) restoration. ACOE may have results provided by consultant firm LSD on that project.

Did your GI project support efforts to address 303d listed water bodies pollutants of concern?

Not sure.

Was funding made available to prioritize the use of GI when in association with the transportation project?

Not sure.

Was the quantity of pollutants removed measured and identified?

No.

Over time, did the pollutants decrease?

No data.

Was land acquired outside of the right of way to meet the GI objective?

N/A

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals and/or water quality concerns?

No.

Maintenance

How does your maintenance personnel take care of GI (no maintenance or equipment [mechanical, handheld, or other])? Please describe. Does your GI take more maintenance

than gray infrastructure or less? Are there seasonal requirements?

Have to preface that first off, not sure we have any GI in our system. Our engineered freeway slopes leave little opportunity to incorporate GI. The freeways and slopes are constructed to minimize R/W width so often they are constructed to 3:1 slopes, some even 2:1, which would be fine for turf, but since we do not plant turf, the granite mulches are applied to abate erosion. If there were opportunities for harvesting water presumably it would require creating low basin areas to capture and retain the water to percolate into the surrounding soils, and thus be a benefit to the plants in our landscapes. – Maintenance response

How is maintenance funded?

Maintenance is funded by dollars appropriated through the legislature for highway maintenance, and in Maricopa County also through the Regional Transportation Programs' 1/2 cent money, approved for infrastructure design, construction, and maintenance. – Maintenance response

Has funding increased or decreased as a result of GI? Is there a dedicated funding source for maintenance of GI?

No information.

Are maintenance personnel trained on GI maintenance requirements?

No training specifically for GI

Is there a dedicated crew for GI or is it considered part of general maintenance? Does your agency maintain GI as part of larger roadside maintenance contracts or agreements?

No.

How do you inspect GI to ensure function is maintained? Does each GI type have a scheduled maintenance plan in place? How is this delivered? Do you coordinate between other/multiple agencies for maintenance?

ADOT maintenance uses the PECOS system program to track scheduled maintenance.

No special inspection. The cities may have programs for their projects if they are considered GI. This would be handled through intergovernmental agreements for areas within the ADOT R/W. I've not seen any language addressing GI, so it would be described as normal landscape care at this point. – Maintenance response

Do you have a method to identify maintenance triggers?

We do perform a level of service inspection annually. This is for all features, none specific to GI. We have targets for service levels and attempt to attain those by allocating dollars to those specific work items that would improve the rating. For example, if litter pick up had a low rating (below target) we would ask for more funding for the next fiscal year to improve the service and the rating should go up. . – Maintenance response

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

We have vector issues, but not related to GI. Occurs in retention and detention basins, catch basins, etc., in any standing water. . – Maintenance response

Is special equipment required for maintenance of GI elements? If so, how is this funded?

No.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

No.

Miscellaneous Questions

Does your agency only focus on small-scale design specific to an area or take a regional approach?

Project specific

Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

USFS, BLM, state parks, local government, and MAG. Mostly regional approach through MAG. Might be worth visiting their website to see if they have a GI page. We are one of a few DOTs that welcome the input of the area planning agencies.

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

Project specific

What did we miss? Is there some better technique or approach to GI planning, design, funding, construction, maintenance, or inventory of GI locations that we did not address? How do innovative contracting methods affect GI implementation strategies?

In this time of restricted funding for infrastructure improvements and expansion, we have sought creative funding (public private partnership [P3], for example) to construct

the South Mountain Freeway⁶⁸. I'd bet there is no language in the package for GI; it's looked upon as an extra cost item. No one to my knowledge has been able to "sell" the concept to our highway designers as a cost savings and benefit. . – Maintenance comment

Do you test soils prior to design to identify the best solution?

Yes, specifically in areas of known poor soils or potential issues. Yes, soil tests are done for growability.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

No, not at ADOT

Were other public or private groups involved from the beginning for input or support/outreach for the project?

No.

If not, why, and were there consequences for not including them?

N/A.

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

Not really. There is a local firm/city promoting GI. If so, they are low key. Certification in leadership in energy and environmental design is out there for buildings, but for freeway landscapes, no.

What obstacles still exist (e.g., organizational culture, lack of buy-in from managers, designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

All of the above. All listed are good examples of our obstacles.

King County, Washington State

Agency Information

Definitions

⁶⁸ South Mountain Documents, P3 Initiatives, Programs and Partnerships, Arizona Department of Transportation, [https://www.azdot.gov/business/programs-and-partnerships/Public-PrivatePartnerships\(P3\)/p3-projects/south-mountain-documents](https://www.azdot.gov/business/programs-and-partnerships/Public-PrivatePartnerships(P3)/p3-projects/south-mountain-documents)

Roadside Water Management Low Impact Design (LID)/GI

Do your GI efforts distinguish from a stormwater program?

No, and none.

Are there distinct duties, responsibilities, designated staff between GI and SW? Do they think of themselves as a different section or are they so integrated it is unrecognizable as two different sections? Describe any recent organizational changes made to implement the program.

Our LID/GI efforts are part of our overall stormwater program. The Washington Phase I Municipal NPDES permit has required LID/GI to be part of our overall stormwater program. Multiple updates to the King County Surface Water Design Manual were required to comply with permit requirements. These included removing barriers to LID/GI and ultimately requiring LID/GI for all new development and redevelopment.

What types of GI have been installed by your agency, and how many of each type?

King County is made up of multiple agencies. These agencies perform this work individually and there is not a central repository for this information. Primary GI Bioretention (LID, hydromodification). There are over 3,000 BMPs in total. Not all of these are roadside LID; most are associated with private development. See the King County Surface Water Design Manual ⁶⁹.

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

Yes, the KC Surface Water Design Manual⁷⁰.

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

LID requirements were included in the modified 2007 permit. These early requirements included minimizing impervious surfaces and disturbing soils/vegetation.

Performance measures around LID/GI have been required by the Phase I Municipal NPDES Permit beginning with the 2012 permit. LID BMPs such as bioretention, vegetated roofs, and permeable pavement were included in the definition of stormwater treatment and flow control BMPs/facilities and were installed to help meet flow control and/or treatment requirements for new development and redevelopment.

⁶⁹ Chapter 5: Flow Control Design and Chapter 6: Water Quality Design, Surface Water Design Manual, King County, Washington, <https://www.kingcounty.gov/services/environment/water-and-land/stormwater/documents/surface-water-design-manual.aspx>

Permittees were required to review, revise, and make effective their local development-related codes, rules, standards, or other enforceable documents to incorporate and require LID principles and BMPs. The intent of the revisions was to make LID the preferred and commonly used approach to site development. The revisions were required to be designed to minimize impervious surfaces, native vegetation loss, and stormwater runoff in all types of development situations.

Guidance was provided in *Integrating LID into Local Codes: A Guidebook for Local Governments*⁷⁰.

When did your agency begin implementation of GI?

As early as 2000, King County began implementing LID into its stormwater manual in the form of grass-lined ditches.

Is the existing, constructed GI working as designed?

Some of these continue to perform.

Describe any recent changes made or recommended

King County is working to create a better ditch maintenance BMP to improve long-term function and reduce turbidity during and immediately after maintenance.

Does your agency have a leader/champion for GI design practices and planning? What is the leadership/champions role in promoting GI?

Yes, individuals in the county championed LID practices early on. The entire organization began implementing LID in the *Surface Water Design Manual*⁷¹.

What obstacles, concerns or barriers to GI exist in the agency?

2009 SWDM - Engineered facilities cannot mitigate all of the hydrologic impacts of development. Detention facilities do not mitigate seasonal volume shifts, wetland water level fluctuations, groundwater recharge reductions, or base flow changes. Such impacts can be further reduced through the use of LID techniques, beginning with careful site planning. LID stormwater management approaches, such as permeable pavements, bioretention, green roofs, and rainwater harvesting can be effective in reducing increases in surface water volumes.

Who identifies and selects potential projects?

70 *Integrating LID into Local Codes: A Guidebook for Local Governments*, Puget Sound Partnership, Final July 2012, http://www.psp.wa.gov/downloads/LID_Guidebook/20120731_LIDguidebook.pdf

71 *Surface Water Design Manual*, Department of Natural Resources and Parks, King County Washington, January 9, 2009, <https://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/surface-water-design-manual/SWDM-2009.pdf>

King County's current stormwater manual requires LID for new development and redevelopment projects. Since LID is part of the project, the project funds LID implementation.

What criteria does your agency use for programming, prioritizing, and funding GI projects?

Retrofits are selected from small basin planning efforts that are part of King County's capital improvement program.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

See previous response. King County uses local, state, and federal funds. Typically the local funds are the least restrictive. State and federal funds often won't allow for innovation or experimental BMP implementation.

Is GI a priority for executive management?

Yes.

Are there any specific problems with innovative practices and getting management approval?

Some. New development and redevelopment LID is required in the King County Surface Water Design Manual. Manual requirements are considered innovative. No specific requirements are in place for stormwater retrofits that do not trigger new development or redevelopment. These projects can be creative; however, since LID is not required some designs lack innovation.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)?

Multidisciplinary teams are standard business practice in order to comply with LID requirements.

If not, who is responsible for the GI design and why?

The design or required LID is the responsibility of the developer.

At what point do the different disciplines come into the planning and design process?

This is normal and required; it's part of the process for all new/redevelopment.

Which discipline typically takes the design lead? Do you find this to be an effective strategy?

Same.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them?

Washington has ample opportunities for LID design, construction, and inspection training. The state allocated \$ 1M/year for three years for training with mixed results. Washington is currently considering a standardized LID design and maintenance review program. Right now educational resources are decentralized and inspections are required

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

LID is mandatory and preferred per permit requirements.

What considerations does your agency take into account when considering gray versus green infrastructure:

Is GI feasible? If not, then gray infrastructure

Do both approaches work equally as well?

The literature seems to indicate that this is true although King County has not been able to prove this in the field. Still to be determined.

Is one less expensive?

King County believes that the two types of infrastructure have comparable design costs and these should decrease with GI as engineers become more familiar with LID. However, there are still long-term unknown costs associated with the maintenance of GI that need to be determined.

Can they be combined?

Yes.

Are residents willing to put up with years of tunneling under their neighborhoods?

Probably not, but don't know.

Conversely, does the agency have enough unbuilt land to capture water on the surface?

Yes.

What current trends do you see – increases in implementation of GI? Increase or decrease of funding?

There will be an increase in funding at the local level and perhaps at the federal level.

Dedicated maintenance forces to maintain GI?

Yes, an increase in dedicated maintenance and inspection teams.

Any changes to legislation or permitting agencies increased requirements?

Yes, potentially. Requirements have been done, so probably not. LID has been in the process of implementation since 2007. This includes removing barriers during the 2007 municipal NPDES permit, then requiring GI/LID in the 2013 Phase I municipal permit. It is possible that GI/LID planning efforts may be integrated with watershed basin planning efforts; feasibility mapping exists countywide.

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

What criteria do you use to evaluate GI proposals? What criteria do you use to select alternatives and practices?

Evaluation of projects that trigger LID requirements (new development and redevelopment over a certain size) are governed by King County code and the County's Phase I municipal NPDES stormwater permit, which contains specific requirements for drainage review and inspection of development projects.

The Water and Land Resources Division of the King County Department of Natural Resources is responsible for developing the requirements and standards, which includes publishing, updating, and providing the technical support for the Surface Water Design Manual. The division also reviews requests for experimental design adjustments and blanket adjustments.

The first criteria evaluated after project size is the feasibility of LID. Once all LID BMPs are evaluated, more typical engineered facilities (ponds, vaults, etc.) can be evaluated for each project.

The ultimate design for a project can range from full LID to a mix of LID and typical engineered facilities. If completely infeasible, engineered, non-GI solutions are installed.

Describe what is driving your decision to use GI.

LID in King County has been championed and required since 2007. King County's surface water features – the rivers, lakes, wetlands, streams, and Puget Sound – are a significant part of our natural beauty and rich heritage. Spawning salmon, meandering rivers, and clean water are important natural resources that must be managed wisely to protect their value.

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

All types except desert

At what phase of project development do you begin identifying specific GI practices?

At site review and design

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

No. This is not needed because LID is required if feasible.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design?

Not yet, not location specific

Is GIS used on a larger regional scale to help determine GI planning?

Yes, Juanita Creek is an example. Also King County Small Stream Basin Retrofit Siting Program⁷² and King County Small Stream Basins Targeted for Retrofit⁷³.

How does your agency convince management or stakeholders that GI is critical to roadside water management (or vice versa)?

It's a King County design manual requirement.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

Public meeting, signs, websites, manual, etc.

Is there a database to keep track of GI projects?

Yes.

What do you track? Acres treated?

Acres treated are not tracked.

⁷² King County Small Stream Basin Retrofit Siting Program, King County, Washington, <https://www.kingcounty.gov/depts/dnrp/wlr/sections-programs/stormwater-services-section/capital-services-unit/small-stream-basin-retrofit.aspx>

⁷³ King County Small Stream Basins Targeted for Retrofit, <https://your.kingcounty.gov/dnrp/library/water-and-land/stormwater/capital-projects/small-stream-retrofit-map.pdf>

Types of benefits to the environment after completion?

Benefits to the environment are not tracked.

Economic benefits after completion?

Economic benefits after completion are not tracked.

Social benefits after completion?

Social benefits after completion are tracked.

Other items?

Location and type are tracked. In addition, ongoing maintenance and inspection schedules are also tracked.

Is the database proprietary or open to DOTs?

The database of location and type is available to the public.

In your experience, what is the most crucial factor to consider in GI?

Long-term function, maintenance, and impacts to groundwater are concerns. Knowing where the water goes when it infiltrates is critical. For example, some residents have experienced basement flooding after the installation of LID.

Do you document and monitor pilot projects?

Yes.

Does this encourage better and increased implementation?

No, but it helps inform which BMPs/LID facilities work and which do not.

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

No inconsistencies, we only have one set of requirements.

Are there other design considerations your agency had considered that were not accepted by management?

N/A

Why not?

At this time, modeling tells us LID reduces flows and pollutants. Data to support this is still in progress. Regionally we are still learning about how well LID BMPs work. For example, the bioretention mix used in the construction of some LID BMPs has been shown to export nitrates, copper, and phosphorous. Estimating feasibilities is critical to the success of LID BMPs. We have some unfortunate examples regionally of what happens if feasibility is not evaluated correctly.

What lessons have been learned from the GI installed?

See previous answers.

Based on lessons learned, what project types are most feasible going forward for future projects?

Linear bioretention, grass-lined ditches

What were the unique challenges during construction? Overall timing of the construction/installation?

LID has to be protected during construction. Large equipment compacting soils in LID facilities will shorten or eliminate the facility's function. LID facilities need to be protected from compaction and sedimentation. They must be restored and sometimes re-installed to remove sediment and any sediment-laden bioretention/rain garden soils. If replacement is required, the new soils must meet the design specification.

When designing the GI, what metrics were used and were extreme weather events part of the calculation?

Feasibility is the determining factor. Feasibility studies include understanding soil types, infiltrating capabilities, location of the ground water table, contaminated soils, critical areas, steep slopes, underground utility layout, etc. King County also feels that feasibility needs to account for and anticipate climate change.

Does your design accommodate increased long-term flows? What is that based on?

Currently modeling is used to anticipate long-term flow and survivability. Climate change impacts are being factored into these models.

Describe coordination, training and outreach with the public including adjacent property owners.

State Environmental Policy Act, public meetings, website—it depends on the scope of projects.

Performance Measures

Do you require contractors to have a plant establishment period? If so, how long?

For county facilities there is a two-year bond to maintain 80% coverage. If that criterion is met, the bond is released to the contractor. For private facilities, a 60% stormwater fee discount is provided to the owner. If plantings are not maintained, the fee discount is discontinued.

What requirements do the regulatory agencies impose?

The Phase I Municipal NPDES permit mandated code and manual changes.

Describe any programmatic agreements achieved through GI project design approach (e.g., mitigation credits).

See Surface Water Management Fee Discounts and Cost-Sharing Program⁷⁴. Covenants are required to achieve project design approval. Any areas assumed not to be cleared when computing the developed conditions runoff volume must be set aside in an open space tract or covenant for the proposed project to be approved. In residential subdivisions, this overflow must be contained within an onsite drainage easement, tract, covenant, or public ROW.

Flow control and water quality facilities and flow control BMP devices to be maintained and operated by King County must be located in a tract or ROW dedicated to King County. Required vegetated flow paths for full dispersion and basic dispersion BMPs require a recorded declaration of covenant that stipulates restrictions on use and shall be located in an easement that includes provisions for access and maintenance.

Have you developed a general rule of thumb for amount of \$ spent on GI?

Not yet.

Have you seen a difference in cost between GI and gray infrastructure?

Yes, but we don't have internal information to support that conclusion.

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction?

N/A – LID is required.

Have you documented a cost savings for these processes?

⁷⁴ Surface Water Management Fee Discounts and Cost-Sharing Program, King County, Washington, <https://www.kingcounty.gov/depts/dnrp/wlr/surface-water-mgt-fee/discount.aspx>

N/A

Does the cost/benefit of the project determine the funding amount?

N/A

Do you have any issues with establishing permanent vegetation after construction of GI?

Results are mixed even when installed properly.

How many acre-feet of water per year are captured by GI techniques?

This information is not collected.

Do you use a scoring tool to prioritize projects, funding, and programming?

Yes. One example is King County Small Stream Basins Targeted for Retrofit⁷².

What environmental problems have been solved and what supporting data can you provide?
For example

Flow control and water quality are problems that LID is attempting to mitigate. Designs are required to meet specific-sized storms with the goal of reducing flow to streams, for example.

Was there habitat enhancement after project completion? How long did it take the enhancement to occur?

It depends. There have been projects that included enhancement and other GI installations did not.

Did any endangered species benefit or thrive or were they reintroduced to the site after project completion?

Yes.

Did 303d listed water bodies for pollutants of concern prioritize selecting the project site?

Yes.

Was the quantity of pollutants removed measured and identified? Over time, did the pollutants decrease?

See Stormwater Action Monitoring, whose goal is to improve stormwater management to reduce pollution, improve water quality, and reduce flooding.

These projects are underway:

- ◆ Bioretention hydrologic performance study⁷⁵ (LID BMPs)
- ◆ Rain garden and bioretention assessment protocol⁷⁶ (LID BMPs)
- ◆ Bioretention toxicity reduction to salmon study (LID and receiving waters)
- ◆ Bioretention reduction of PCBs study⁷⁷ (LID and receiving waters)
- ◆ Bioretention amendment with fungi study⁷⁸ (LID receiving waters)

Reduction in basement flooding and fewer days of missed school (or other quality of life/public safety and convenience responses)?

See previous responses.

Was land acquired outside of the right of way to meet the GI objective?

Unknown.

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals, water quality concerns?

No.

Maintenance

How does your maintenance personnel take care of GI – no maintenance, equipment (mechanical, handheld, other – please describe)? Does your GI take more maintenance than normal, or less? Seasonal requirements?

The King County SWDM and related codes include maintenance standards for LID BMPs, effective as of April 24, 2016. As development and redevelopment projects add increasing numbers of LID BMPs to the county’s stormwater infrastructure inventory, King County will be responsible for inspecting and/or maintaining more and more nontraditional stormwater controls. LID is relatively new and knowledge of effective

75 Bioretention hydrologic performance studies, Department of Ecology, State of Washington, <https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-effectiveness-studies/Bioretention-hydrologic-performance-study>

76 Rain garden and bioretention assessment protocol, Department of Ecology, State of Washington, <https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-effectiveness-studies/Raingarden-and-bioretention>

77 Bioretention reduction of PCBs study, Department of Ecology, State of Washington, <https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-effectiveness-studies/Bioretention-reduction-of-PCBs-study>

78 Bioretention amendment with fungi study, Department of Ecology, State of Washington, <https://ecology.wa.gov/Regulations-Permits/Reporting-requirements/Stormwater-monitoring/Stormwater-Action-Monitoring/SAM-effectiveness-studies/Bioretention-amendment-with-fungi-study>

maintenance practices is limited, which means that the County will have to adaptively manage its approach to inspection and maintenance of LID BMPs. This will likely require development of new maintenance techniques, potentially with new types of equipment, and training of County personnel involved in completing this body of work.

How is maintenance funded?

Through dedicated maintenance budget funding.

Has funding increased because of GI? Is there a dedicated funding source for maintenance of GI?

There is no dedicated funding source. The funding for maintenance does not distinguish between the maintenance of traditional infrastructure versus GI. It's too soon to tell if LID will decrease or increase maintenance funding requirements.

What is the skill set of maintenance personnel?

See previous answers.

Is it a dedicated crew for GI or part of general maintenance?

No, because it's part of regular/routine maintenance.

How do you plan for maintenance?

It's regularly scheduled or, in the event of a malfunction, maintenance is reactionary.

Do you coordinate between other/multiple agencies for maintenance?

As needed between jurisdictions.

Do you have a method to identify maintenance triggers?

These are included in the maintenance standards for LID BMPs.

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

No. Although Washington State does have a West Nile Virus program that requires the ongoing sampling for mosquitoes in the standing water of stormwater facilities.

Is special equipment required for maintenance of GI elements? If so, how is this funded?

Not typically. If so, funding would come from the agency maintenance budget.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

There are requirements to screen 12% of our stormwater conveyance system annually. Inspections of GI along the roadside are used to also screen for illicit connections and discharges as a measure of efficiency.

Miscellaneous Questions

Does your agency only focus on small-scale design specific to an area or take a regional approach? Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

No, we do what's required, which includes all sizes.

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

As required. Retrofit will attempt to focus on highest need with largest potential for improvement.

What did we miss? Is there some better technique or approach to GI planning, design, construction, maintenance, or inventory of GI locations that we did not address?

No.

Do you test soils prior to design to identify the best solution?

This part of feasibility site assessment for designing LID.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

Yes. See previous answers.

Minimum performance measures included in the Phase I Municipal NPDES permit include:

- ◆ No later than June 30, 2015 ... permittees shall review, revise, and make effective their local development-related codes, rules, standards, or other enforceable documents to incorporate and require LID principles and LID MBPs. The intent of the revisions shall be to make LID the preferred and commonly used approach to site development.
- ◆ Each permittee shall submit a summary of the results of the review and revision process.

- ◆ Funding is included in routine budget process and partially paid for by stormwater management fees.

Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?

Ecology formed two advisory committees comprising representatives from local government permittees, state government, ports, environmental groups, scientists, consultants, and the development industry. The advisory groups met 11 times between October 2009 and August 2010. The committees provided input to Ecology on the definition of LID, a performance standard, feasibility criteria, and a number of implementation issues.

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

Ongoing discussions are held through a variety of groups, specifically, the Stormwater Work Group⁷⁹, various Phase I and II permit coordinators groups, such as RoadMap, the American Public Works Association, the Municipal Stormwater Permit Ad Hoc Committee⁸⁰, Green Infrastructure Partnership⁸¹, and others.

What obstacles still exist (e.g., organizational culture, lack of buy-in from designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

Information on performance; what's working, what's not; and the lifespan of BMPs

Long Creek Watershed Management District

These responses are provided by the Long Creek Watershed Management District (LCWMD), a quasi-municipal, special-district, Maine nonprofit corporation formed by the state municipalities of Portland, Scarborough, South Portland, and Westbrook. LCWMD implements the Long Creek Watershed Management Plan on behalf of the MaineDOT and over 100 other public, quasi-public, and private entities in the Long Creek Watershed. Implementation of the Long Creek Watershed Management Plan is required of permittees under the General Permit – Post Construction Discharge of Stormwater in the Long Creek Watershed (Long Creek General Permit) issued by the Maine Department of Environmental Protection pursuant to its authorization by the U.S. EPA to implement the requirements of the Clean Water Act in Maine. NPDES (or, in this case, MEPDES) permits are required of operators of parcels containing one

79 Stormwater Work Group, Department of Ecology, State of Washington, <https://ecology.wa.gov/About-us/Our-role-in-the-community/Partnerships-committees/Stormwater-Work-Group>

80 Working on the 2018 Municipal NPDES Stormwater Permit, Washington Stormwater Center, <http://www.wastormwatercenter.org/2018-municipal-npdes-stormwater-permit/>

81 Green Infrastructure Partnership (GrIP), <http://www.700milliongallons.org/about/green-infrastructure-partnership-grip/>

or more acres of impervious area in the Long Creek Watershed pursuant to an exercise of Residual Designation Authority by the U.S. EPA on October 28, 2009. LCWMD is providing responses to the following questions to the extent that they are relevant to LCWMD's role in implementing the Long Creek Watershed Management Plan on behalf of the MaineDOT.

Agency Information:

Please identify types of GI required to be implemented under regulatory programs (i.e., NPDES, etc.) versus voluntary GI initiatives i.e., community rain gardens.

The Long Creek Watershed Management Plan requires the construction and/or implementation of structural BMPs, in-stream and riparian restoration projects, and nonstructural BMPs such as pavement sweeping and catch basin cleaning.

Does your agency have rule/ordinance making authority? Do your GI efforts distinguish from a stormwater (SW) program? Are there distinct duties, responsibilities, and designated staff between GI and SW? Are they distinguished as different sections or are they so integrated they are considered to be the same section? Describe any recent organizational changes made to implement the program.

LCWMD does not have independent rule-making or ordinance-making authority; however, the four municipalities that formed LCWMD do have ordinance-making authority. The Long Creek Watershed Management Plan does contain recommendations to the municipalities for new or amended ordinances. These recommendations include:

- ◆ Post-construction stormwater management requirements for parcels for sites with less than one-acre of impervious cover
- ◆ Requiring redevelopment projects to meet current stormwater management standards
- ◆ Modifying local code, design standards, and guidelines to incorporate LID techniques
- ◆ Implementation of transportation demand strategies to decrease the use of single occupant vehicles
- ◆ Implementation of parking demand strategies to reduce the need for paved parking facilities
- ◆ Market incentives for enhanced stormwater management
- ◆ Enhanced shoreland zoning regulations
- ◆ Promoting separated management and treatment of rooftop runoff

What types of GI have been installed by your agency? How does your agency track GI type and location? How do you track function and performance to understand if constructed GI is

working as designed? Describe any recent changes made or recommended.

LCWMD has constructed 92 structural BMPs and completed two in-stream restoration projects. A third in-stream restoration, the largest to be undertaken by LCWMD to date, is presently in the design stage with construction expected to commence in early-to-mid 2018. BMPs constructed to date include:

- ◆ CONTECH Filtterra® Bioretention Systems
- ◆ Vegetated swales
- ◆ Underdrained soil filters
- ◆ Gravel wetlands
- ◆ Bioretention cells/rain gardens
- ◆ ADS Storm-Pure™ Catch Basin Inserts
- ◆ CONTECH Jellyfish® Filters
- ◆ Hydro First Defense® Catch Basin Inserts
- ◆ ADS StormTech® Infiltration and Treatment BMPs
- ◆ StormTreat Bioretention and Treatment BMPs
- ◆ Brentwood StormTank® Subsurface Retention BMPs

GI location and type is maintained in ArcGIS. LCWMD budgets approximately \$100,000 annually for continuous and grab sample water quality monitoring throughout the watershed to determine the effectiveness of BMPs.

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

LCWMD's guidance on implementation of stormwater BMPs and in-stream restoration projects is found in the Long Creek Watershed Management Plan⁸².

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

The Long Creek Watershed Management Plan operates under an adaptive management approach that entails regular adjustments to the plan based upon information about the watershed that is collected on an ongoing basis.

⁸² Long Creek Watershed Management Plan: A Community-Based, Collaborative Approach to the Restoration of Long Creek, FB Environmental Associates, Inc. in cooperation with Woodard & Curran and the Maine Department of Environmental Protection, July 2009, <http://www.restorelongcreek.org/CMSContent/documents/watershed-management-plan/Managment%20Plan.pdf>

Green Infrastructure best management practices have been in use for many years as part of comprehensive stormwater management strategies. When did your agency begin implementation of a GI Program?

LCWMD began implementation of the Long Creek Watershed Management Plan as the result of NPDES permitting requirements that became effective in 2010.

What criteria does your agency use for programming, prioritizing, and funding GI projects? Is GI considered for all projects? Is GI required for specific watersheds in your state? How does the regulatory authority convey GI requirements to the transportation agency?

LCWMD uses a three-tiered approach for prioritizing projects based on good, average, and below-average cost-to-benefit ratios. A NPDES permit is required for discharges of stormwater from parcels with one acre or more of impervious area pursuant to an exercise of Residual Designation Authority by the U.S. EPA.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

Funds for implementing the Long Creek Watershed Management Plan are paid by permittees under the Long Creek General Permit. Participating landowners pay \$3,000 per acre of impervious surface annually. Annual revenue is approximately \$1.5 million.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

Yes, the design teams are multidisciplinary. Typically involved are hydraulics modelers, design engineers, landscape architects, permitting consultants, plant specialists, fluvial geomorphologists, and surveyors. The design team is typically put together at the beginning of a project. The design engineer typically takes the design lead.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them? Does your training extend to external customers, such as local agencies, MPOs, consultants, and contractors?

LCWMD primarily uses private contractors who LCWMD selects for their expertise in designing stormwater management BMPs.

GI techniques, lessons learned, best management practices and emerging practices:

What criteria do you use to evaluate GI proposals?

The Long Creek Watershed Management Plan identified projects that exhibit the most potential for water quality enhancement with minimum capital investment and maximum partnership potential. This inventory also attempted to identify stormwater BMP retrofits that have value-added community benefits, such as landscape enhancement. The retrofit inventory generally followed the principles of LID where the use of multiple small structures is preferred over the use of single large structures. In order to identify targeted, practicable, structural stormwater management opportunities, individual retrofits were prioritized by catchment area and are referred to as priority catchments. The Maine Department of Environmental Protection delineated catchments represent the developed land area that contributes runoff to a distinct stormwater outfall. The catchment scale provides a discrete hydrologic unit that allows for targeted stormwater management and monitoring.

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

Long Creek is a low-gradient, sandy-silty bottomed, freshwater coastal stream that flows into the Fore River and eventually Casco Bay.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

Permittees under the Long Creek General Permit are required to enter into participating landowner agreements with LCWMD to effectuate implementation of the Long Creek Watershed Management Plan. The plan provides for a notification process of differing levels of formality based on the LCWMD activity being conducted. LCWMD maintains project updates on its website and social media feeds. Larger construction projects typically involve direct contact with landowners concerning specific impacts to their properties. LCWMD staff and contractors are known to many participating landowners who have been involved with the Long Creek restoration project since its inception.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

Yes. LCWMD maintains a database of completed projects. Projects are primarily tracked in acres treated. The Long Creek Watershed Management Plan has a goal of treating 150 acres of impervious area over 10 years. Presently, approximately 110 acres of impervious area are being treated by LCWMD-constructed BMPs.

In your experience, what is the most crucial factor to consider in GI?

Precise design and long-term inspection, maintenance, and repair costs

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

In several circumstances the Long Creek General Permit substitutes for other permitting requirements, which can alleviate issues concerning inconsistencies among various regulations (e.g., where a participating landowner redevelops existing impervious area, the Long Creek General Permit is a substitute to meeting the standards of the Maine Department of Environmental Protection's stormwater management rules).

What lessons have been learned from the GI installed? Have different BMPs performed better than others? Have any GI types been eliminated from use? If yes, why?

Beware of high-maintenance BMPs. Develop an inspection and maintenance plan up front and understand routine inspection and maintenance costs. Many LCWMD BMPs have an aesthetic component that is important to participating landowners who operate commercial, retail, and hospitality businesses. While perhaps not providing a water quality benefit, landscaping is important to maintaining the aesthetic element of projects and it is expensive. Be prepared to conduct nonroutine maintenance and make unanticipated repairs.

What were the unique challenges during construction? Overall timing of the construction/installation?

Maine's weather and regulatory permitting windows are challenges impacting construction. Site access can also be a challenge. While participating landowners are obligated to provide construction easements, many participating landowners operate commercial, retail, and hospitality businesses and are concerned with disruption to their business routine, parking, and appearance.

Have there been issues with successful vegetation establishment related to specific BMPs? What were the specific challenges associated with vegetation on the urban roadside?

Yes. LCWMD is presently looking into poor establishment of vegetation in a constructed gravel wetland. Factors being reviewed are planting stock, planting methodology, and water level.

Describe coordination, training and outreach with the public, including adjacent property owners.

LCWMD inspects participating landowners' parcels annually, during which time site-specific education and outreach is conducted with each landowner. LCWMD conducts monthly board meetings and an annual participating landowner meeting, all of which are open to the public. LCWMD maintains a website and social media feeds. At times, LCWMD needs to engage non-participating landowners related to construction or construction access. LCWMD has thus far successfully obtained necessary easements from nonparticipating landowners on a voluntary basis.

Performance Measures

Do you require contractors to have a plant establishment period? If so, for how long?

Typically one year from substantial completion or final acceptance

Are there any challenges associated with setting a plant establishment period? How is the plant establishment period handled? (e.g., Is it in the contract? Is it covered by a bond? Do state forces assist?)

The plant establishment period is typically determined by contract, which includes a warranty.

Do you have any issues with establishing prescribed permanent vegetation after construction of GI? Have invasive species presented any challenges with a particular GI type? Location? How has this been resolved?

The Long Creek Watershed contains several invasive plant species that impact riparian habitat and threaten the structural integrity of constructed BMPs. LCWMD develops BMP-specific management plans to control invasive plant species where they are an issue. LCWMD's maintenance or landscaping contractors typically implement the management plans. Eradication of invasive plant species is generally not an option due to their prevalence on the watershed; therefore, the focus is on management.

Has there been pushback on the appearance of GI in urban areas?

Aesthetic concerns relating to maintenance and landscaping are sometimes raised by participating landowners. Many LCWMD BMPs have an aesthetic component that is important to participating landowners who operate commercial, retail, and hospitality businesses. There is a fine line between lush and vibrant and overgrown.

Can you provide data demonstrating how GI implementation has helped to mitigate impacts or improve environmental outcomes?

LCWMD operates a long-term, comprehensive water-quality monitoring program throughout the Long Creek Watershed that includes continuous and grab-sample monitoring. Parameters monitored include dissolved oxygen, temperature, specific conductance, metals, chlorides, and nutrients. LCWMD also operates a long-term, comprehensive hydrologic monitoring program through the watershed that includes continuous water-level monitoring and periodic spring-melt, base, and storm-stage flow monitoring.

Was there habitat enhancement after project completion? How long did it take for the enhancement to occur?

Yes. Monitoring is ongoing. It is anticipated that it will take years for water quality improvements to manifest.

Did your GI project support efforts to address 303d listed water bodies pollutants of concern? Was funding made available to prioritize the use of GI when in association with

the transportation project? Was the quantity of pollutants removed measured and identified? Over time, did the pollutants decrease?

Long Creek is a 303(d)-listed water body. Long Creek's listing as a 303(d)-water body was the basis for the U.S. EPA's exercise of its Residual Designation Authority to require NPDES permits for the discharge of stormwater from impervious surfaces of one acre or more in the Long Creek Watershed. LCWMD budgets approximately \$100,000 annually for its water-quality monitoring program. LCWMD's data evaluation is ongoing.

Maintenance

How does your maintenance personnel take care of GI (no maintenance or equipment [mechanical, handheld, or other])? Please describe. Does your GI take more maintenance than gray infrastructure, or less? Are there seasonal requirements?

LCWMD utilizes private contractors to conduct BMP inspection and maintenance, pavement sweeping, catch basin cleaning, and landscaping activities. Pavement sweeping changes seasonally, with large-particle collection occurring in the spring and fine-particle collection taking place throughout the rest of the year. Landscaping is also seasonal, with spring cleanup, routine activities occurring in summer and fall, and cutting down and removing vegetation in late fall.

How is maintenance funded?

Maintenance is funded through annual participating landowner assessments.

Has funding increased or decreased as a result of GI? Is there a dedicated funding source for maintenance of GI?

Maintenance budgets continue to increase. The source of funding for maintenance is secure insofar as permit requirements are in place.

Are maintenance personnel trained on GI maintenance requirements?

LCWMD maintenance contractors tend to be experienced in inspecting and performing maintenance on stormwater-specific BMPs.

Is there a dedicated crew for GI or is it considered part of general maintenance? Does your agency maintain GI as part of larger roadside maintenance contracts or agreements?

Private contractors perform inspection and maintenance activities.

How do you inspect GI to ensure function is maintained? Does each GI type have a scheduled maintenance plan in place? How is this delivered? Do you coordinate between other/multiple

agencies for maintenance?

LCWMD has an inspection and maintenance plan in place. Each BMP has a BMP-specific inspection and maintenance standard operating procedure and reporting form.

Miscellaneous Questions

Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

LCWMD implements the Long Creek Watershed Management Plan on behalf of the MaineDOT in the Long Creek Watershed.

Do you test soils prior to design to identify the best solution?

Yes. LCWMD conducts project-specific soil borings and testing when necessary.

Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?

LCWMD was cooperatively formed by four municipalities under statutory interlocal agreement authority. Implementation of the Long Creek Watershed Management Plan is supported by over 100 public, quasi-public, and private entities in the Long Creek Watershed as a requirement of their permit coverage under the Long Creek General Permit.

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

The Long Creek General Permit provides the framework for implementation of the Long Creek Watershed Management Plan. LCWMD, as a quasi-municipal entity, provides the forum for ongoing community engagement and awareness.

What obstacles still exist (e.g., organizational culture, lack of buy-in from managers, designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

The greatest uncertainty at this point is what will happen upon expiration of the current Long Creek General Permit, which will occur in June 2020. The Long Creek restoration project was originally anticipated to be completed over the course of two permit cycles (i.e., 10 years). At this point, the larger visions extend out to the end of the present permit cycle. It is unclear what will happen with LCWMD as an entity and who will be responsible for maintenance and monitoring, at the end of the present permit cycle.

Maine Department of Transportation

Agency Information

Please identify types of GI required to be implemented under regulatory programs (i.e., NPDES, etc.) versus voluntary GI initiatives i.e., community rain gardens.

The main types of MaineDOT GI are compost-enhanced inslope buffers, followed by tree box filters, with occasional biofiltration. MaineDOT does not undertake voluntary GI, though we will occasionally contribute to 319 projects when we are working in that watershed.

Does your agency have rule/ordinance making authority? Do your GI efforts distinguish from a stormwater (SW) program? Are there distinct duties, responsibilities, and designated staff between GI and SW? Are they distinguished as different sections or are they so integrated they are considered to be the same section? Describe any recent organizational changes made to implement the program.

MaineDOT does not have rulemaking authority. We do not distinguish GI from stormwater in our program organization. GI is always done in the context of stormwater.

What types of GI have been installed by your agency? How does your agency track GI type and location? How do you track function and performance to understand if constructed GI is working as designed? Describe any recent changes made or recommended.

Commonly used types of MaineDOT GI are compost-enhanced inslope buffers, followed by tree box filters, with occasional biofiltration.

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

MaineDOT maintains the document *MaineDOT Best Management Practices for Erosion and Sedimentation Control*⁸³. This manual dates to 2008, when the department's primary concern was temporary construction BMPs for erosion and sedimentation control. It includes some traditional engineering approaches for permanent measures; however, this manual does not address modern GI techniques for stormwater management.

In the absence of MaineDOT GI guidance, practitioners in Maine might be expected to use the *Maine Stormwater Best Management Practices Manual*⁸⁴. This manual is current through 2016 and provides good technical guidance on a limited range of GI

83 Best Management Practices for Erosion and Sedimentation Control, Maine Department of Transportation, February 2008, <https://www.maine.gov/mdot/env/documents/bmp/BMP2008full.pdf>

84 Maine Stormwater Best Management Practices Manual, Maine Department of Environmental Protection, <https://www.maine.gov/dep/land/stormwater/stormwaterbmps/>

practices acceptable to the Maine Department of Environmental Protection. We have tailored these methods to linear projects, such as ditches with underdrained filters and compost inslope filters.

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

MaineDOT recognizes that the most recent 2008 manual is due for revision and updating. As of 2008, MaineDOT did relatively little in the way of permanent BMPs and GI, focusing almost exclusively on temporary-construction BMPs. We anticipate developing a separate guide for permanent post-construction BMPs suitable transportation projects that will utilize GI methods.

Green Infrastructure best management practices have been in use for many years as part of comprehensive stormwater management strategies. When did your agency begin implementation of a GI Program?

MaineDOT does not have a formal GI program within the Stormwater Program. GI methods are utilized on an as-needed, as-appropriate basis.

Does your agency have a leader/champion for GI design practices and planning?

The leader/champion for GI naturally resides in the MaineDOT Stormwater Engineer (formally the manager of the Surface Water Quality Unit within the Surface Water Resources Division of the MaineDOT Environmental Office). The stormwater engineer has ready access to support from landscape architects working in the Bureau of Project Development (Highway Program).

What is the leadership/champions role in promoting GI?

The champion's role is mainly one of identifying suitable transportation projects for GI applications. GI is not widely and generally applied across MaineDOT projects.

What obstacles, concerns or barriers to GI exist in the agency?

Major concerns relate to cost, effectiveness, maintenance, and need.

Who in your agency identifies and selects potential GI projects? Did you encounter resistance from certain groups? If so, how did you overcome this resistance?

Our stormwater engineer would generally identify and select projects suitable for GI.

What criteria does your agency use for programming, prioritizing, and funding GI projects? Is GI considered for all projects? Is GI required for specific watersheds in your state? How does the regulatory authority convey GI requirements to the transportation agency?

Application of GI is driven primarily by regulatory requirements; it is not considered for all projects. GI is not required for specific watersheds (with the possible exception of MaineDOT's participation in Long Creek Watershed). GI "requirements" are conveyed through the Maine Stormwater Law (Chapter 500), administered by Maine Department of Environmental Protection with delegated authority from EPA.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

GI is almost always done in the context of MaineDOT transportation capital projects and therefore are funded with something like an 80/20 federal/state match. GI is rarely funded as standalone projects, though we will occasionally contribute funding to associated 319 projects.

Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?

GI is not a priority for management. That said, we do not encounter problems getting support as long as a genuine need is identified. Choices of practices and methods are left to the stormwater engineer and are not a management concern. That said, we do not do GI for the sake of GI or as a general practice.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

In-house design is typically led by the stormwater engineer with assistance from a landscape architect. There is not a formal interdisciplinary GI team.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them? Does your training extend to external customers, such as local agencies, MPOs, consultants, and contractors?

Our stormwater engineer is well versed in GI design. He provides direction and oversight to highway designers when GI is used. Highway designers do not receive training in GI. MaineDOT does not provide training, either internally or to consultants; there seems to be enough expertise in the consultant community. Contractors have offered training, though primarily in temporary BMPs, through the Maine Department of Environmental Protection with assistance from MaineDOT.

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

MaineDOT has not widely and generally adopted modern GI practices. Yet given that Maine is predominantly rural and undeveloped, our standard stormwater management tends to be simple and on the greener side, though not heavily engineered or designed. Rock-lined ditches and downspouts are commonly employed on steeper gradients, grass-lined ditches and sheetflow on gentler slopes and inslopes.

What considerations does your agency take into account when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined? Are residents willing to put up with construction in their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?

Assuming no regulatory requirements, cost, effectiveness, and maintenance are the primary drivers in choosing an appropriate stormwater management technology. Traditionally rock has been viewed as being most cost-effective, but TRMs have come down in price and offer other benefits. It is reasonable to expect that GI may become the preferred option in some cases. GI will always be done in the context of a transportation project so it is unlikely that residents will separate out construction impacts of different parts of a project. MaineDOT does not excess unbuilt land to dedicate to GI. In fact, the general idea is to get rid of unneeded land.

What current trends do you see – increases in implementation of GI? Increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

MaineDOT has definitely felt the notion of “green is good” and this is reflected in the department’s overall practices over the past 20 years; GI is just one aspect. We do not anticipate any increase in GI-dedicated funding. Department maintenance is an even bigger challenge; recruitment and retention of M&O staff is a major problem. We not have any particular expectations of regulatory changes at the state and federal levels over coming years.

GI techniques, lessons learned, best management practices and emerging practices:

What criteria do you use to evaluate GI proposals?

Cost, treatment effectiveness, aesthetics

What criteria do you use to select alternatives and practices? Is your agency willing to purchase right of way or condemn property solely for use as GI?

We do not have a formal evaluation procedure. We will purchase ROW if needed; condemnation/taking by eminent domain is a last resort.

Describe what is driving your decision to use GI.

Prime driver is regulatory requirements under MS4 and state stormwater law, followed by cost and effectiveness.

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

All of the above (excepting deserts), as needed. That said, MaineDOT has few responsibilities in heavily urban areas. So most activities are areas ranging from semi-urban to rural. Geographically, they range from the Atlantic coast to the western mountains.

At what phase of project development do you begin identifying specific GI practices?

Candidate projects are screened for stormwater requirements once the work plan is approved. Actual evaluation of design alternatives and actual design occur much later, at the design phase.

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

No.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

No. We employ GI at the project scale. MaineDOT projects tend to be small in linear and areal extent. Within that scale, appropriate locations tend to be limited; therefore, GIS does not add value to evaluation process.

Does your agency leadership support the use of GI on transportation projects? Does your agency engage stakeholders to evaluate the use of GI for roadside water management? If so, how do they engage the stakeholders? Do your regulators promote and support the use of GI? If yes, how do they work with your agency to select, develop and fund GI?

The department does not promote GI in a general way. We employ it, and receive support, on an as-needed, project-by-project basis. GI is not a general practice. Since we work entirely within the context of a specific project, and most projects impact relatively small populations, we do not employ a stakeholder process for MaineDOT GI. State regulators generally promote and support GI. MaineDOT and the regulators do not work together to select, develop, and fund GI.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

Generally N/A. We do not engage in outreach specifically around GI.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

To date we have done relatively few GI designs. At this point our database consists of a simple list, nothing else.

In your experience, what is the most crucial factor to consider in GI?

Good design, documented effectiveness, regular inspection, maintenance, and repair costs

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

Yes and yes.

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

Generally no. MaineDOT has a productive relationship with Maine Department of Environmental Protection.

Are there other design considerations your agency had considered that were not supported? Why not?

No.

Based on lessons learned, what project types are most feasible going forward for future projects?

We currently limit our toolbox to compost inslopes, underdrained filter ditches, tree box filters, and bioretention.

What were the unique challenges during construction? Overall timing of the construction/installation?

Weather, establishment of plants, getting the grades right, getting the material right

Have there been issues with successful vegetation establishment related to specific BMPs? What were the specific challenges associated with vegetation on the urban roadside?

Road salt is especially challenging; also, major unpredictable rain events shortly after project completion

When designing the GI, what metrics were used and were extreme weather events part of the calculation?

Plant survivability is a primary and easily observed metric. Extreme events were not part of the design calculation, just the water quality volume.

Does your design accommodate increased long-term flows? On what is that based?

No. Climate change is not considered.

Describe coordination, training and outreach with the public, including adjacent property owners.

Generally not applicable for MaineDOT projects. For major projects, possibly done in context of public meetings.

Performance Measures

What requirements do the regulatory agencies impose? Describe any programmatic agreements achieved through GI project design approach (e.g., mitigation credits).

Nothing beyond initial design review

Have you developed a general rule of thumb for funding spent on GI?

No. As long as regulation is the primary driver, cost is something of a secondary consideration.

Have you seen a difference in cost between GI and gray infrastructure?

Not enough data to reach a conclusion

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction?

Not enough data to reach a conclusion

Have you documented a cost savings for these processes?

No.

Do you conduct a cost/benefit analysis of the GI proposed for a specific project to determine the efficacy of the BMP? Is the funding amount tied to GI performance measures?

No and no – as long as regulation is the primary driver and there is no alternative to GI

Do you require contractors to have a plant establishment period? If so, for how long?

Typically, one year from substantial completion or final acceptance

Are there any challenges associated with setting a plant establishment period? How is the plant establishment period handled? (e.g., Is it in the contract? Is it covered by a bond? Do state forces assist?

The plant establishment period is typically determined by contract, which includes a warranty.

Do you have any issues with establishing prescribed permanent vegetation after construction of GI? Have invasive species presented any challenges with a particular GI type? Location? How has this been resolved?

So far, no major problems. Weeds tend to come in; it's a fact of life we have to live with. So far invasives have not been a problem.

Has there been pushback on the appearance of GI in urban areas?

Not enough experience yet; however, MaineDOT projects are generally not in urban areas.

How many acre-feet of water per year are captured by GI techniques?

Don't know – not documented, tabulated. Probably < 100 ac-ft.

Do you use a scoring tool to prioritize projects, funding, and programming?

No. We only do GI in context of specific transportation projects so we are not prioritizing.

Can you provide data demonstrating how GI implementation has helped to mitigate impacts or improve environmental outcomes?

No.

Was land acquired outside of the right of way to meet the GI objective?

No.

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals and/or water quality concerns?

No.

Maintenance

How does your maintenance personnel take care of GI (no maintenance or equipment [mechanical, handheld, or other])? Please describe. Does your GI take more maintenance than gray infrastructure, or less? Are there seasonal requirements?

Handwork, plant replacement, cleaning

How is maintenance funded?

Same as all general MaineDOT maintenance – state general funds (and that is a problem).

Has funding increased or decreased as a result of GI? Is there a dedicated funding source for maintenance of GI?

GI has not affected maintenance funding. It is currently a very small aspect of MaineDOT maintenance. There is no dedicated GI maintenance funding.

Are maintenance personnel trained on GI maintenance requirements?

No.

Is there a dedicated crew for GI or is it considered part of general maintenance? Does your agency maintain GI as part of larger roadside maintenance contracts or agreements?

No dedicated GI maintenance crew; yes, GI maintenance is done as part of general roadside maintenance.

How do you inspect GI to ensure function is maintained? Does each GI type have a scheduled maintenance plan in place? How is this delivered? Do you coordinate between other/multiple agencies for maintenance?

We use consultants as well as in-house stormwater engineer review. There is a maintenance plan for most GI installations. We do not coordinate with other agencies.

Do you have a method to identify maintenance triggers?

No.

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

No.

Is special equipment required for maintenance of GI elements? If so, how is this funded?

No.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

No.

Miscellaneous Questions

Does your agency only focus on small-scale design specific to an area or take a regional approach?

Small-scale, highway project-specific

Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

No key alliances; a landscape architect is accessible within MaineDOT.

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

Primarily suitability with ROW

What did we miss? Is there some better technique or approach to GI planning, design, funding, construction, maintenance, or inventory of GI locations that we did not address? How do innovative contracting methods affect GI implementation strategies?

Given our limited use of GI, our simple approaches work well.

Do you test soils prior to design to identify the best solution?

Yes.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

No.

Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?

No – not how we do our projects.

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

No. Though Maine has a stormwater conference every two years aimed at engineers and suppliers.

What obstacles still exist (e.g., organizational culture, lack of buy-in from managers, designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

No obstacles – as long we continue with GI on an as-needed, project-by-project basis. This would change significantly if we were to try to employ GI more widely and generally.

Maryland Department of Transportation State Highway Administration (MDOT SHA)

EPD	Environmental Programs Division
ESC	Erosion and Sediment Control
HHD	Highway Hydraulics Division
LAD	Landscape Architecture Division
LOD	Landscape Operations Division
MDE	Maryland Department of the Environment
OED	Office of Environmental Design
OHD	Office of Highway Development
OOM	Office of Maintenance
WIP I	Maryland Phase I Watershed Implementation Plan
WLA	Wasteload Allocation
WPD	Water Programs Division

The Maryland Department of Transportation State Highway Administration (MDOT SHA) is pleased to submit these responses to the Domestic Scan 16-02 amplifying questions. For this domestic scan, two major aspects of GI planning at MDOT SHA have been involved in providing answers. The Drainage and Stormwater Management (SWM) Asset Management Program and the MS4/TMDL Program have collaborated to answer these questions. Both the Drainage and SWM Asset Management Team and the MS4/TMDL Restoration Team have answered the first question (agency information). All other questions have been answered by the Drainage and SWM Asset Management Team.

Agency Information

MDOT SHA practices that include GI include:

- ◆ Roadside stormwater management
- ◆ A practical design approach to all roadway projects has been implemented within the MDOT SHA Office of Highway Development. This approach is an organizational philosophy to maximize the value in design. Project needs are developed through the use of an objective statement, which is a collaborative design team effort to identify the goals/needs of a given project before design commences. Retroactively many projects have been put through this process; by focusing on the objective statement

it has been discovered that proposed pavement amounts are reduced. Reduction in pavement is used in SWM design, especially as a part of GI planning.

- ◆ Watershed actions covered under TMDL, such as inlet cleaning, street sweeping, off-site stream restoration, outfall stabilization, new SWM control structures, partnering with watershed groups for stream trash and debris collection and removal, pet waste disposal stations at rest areas, public education, tree planting, retrofitting of existing SWM facilities for higher pollutant removal, redevelopment credit, and nutrient and sediment credit trading (coming soon).
- ◆ Stream restoration projects within MDOT SHA R/W.
- ◆ The use of pervious pavement within certain areas, such as sidewalks or park-and-ride lots
- ◆ The use of BMPs at shop and snow removal facilities to help contain any possible spills, line chemical and salt storage facilities, and idling policy for state employees.

Do your GI efforts distinguish from a stormwater program? Are there distinct duties, responsibilities, designated staff between GI and SW? Do they think of themselves as a different section or are they so integrated it is unrecognizable as two different sections? Describe any recent organizational changes made to implement the program.

Environmental regulations and permits general govern GI efforts at MDOT SHA. These projects are either stormwater management associated with new and redevelopment roadway projects or restoration projects associated with NPDES MS4 permit 20% impervious restoration and TMDL wasteload allocation (WLA) requirements for the Chesapeake Bay and local waterways. Maryland law and regulations require that stormwater management be provided for new impervious surfaces. Depending upon the amount of existing impervious surfaces within the site limits, the laws and regulations also provide SWM to treat 50% (redevelopment condition if, for example, impervious surfaces are equal to or greater than 40% of the site area) or 100% (new development if impervious surfaces are less than 40% of site area) of the existing surfaces. MDOT SHA has an agreement with the Maryland Department of the Environment (MDE), the regulating authority for SWM/ESC, that allows MDOT SHA to review and approve SWM/ESC and perform compliance inspections. This delegated authority does not include small pond or dam safety permits.

The MS4 Phase I permit (individual permit issued by MDE), requires that the MDOT SHA identify and document in GIS all impervious surfaces owned by the jurisdiction. Impervious accounting that determines the amount of untreated impervious surfaces is required. Baseline impervious acreage is the amount of impervious surfaces the jurisdiction owns where the stormwater runoff and associated pollutants are not treated or offset. Baseline treatment (used to determine the impervious surfaces that are treated and removed from the total to determine the untreated surfaces) is achieved

through the installation of SWM control structures when impervious surfaces are originally installed or through restoration practices put in place during previous MS4 permit terms. Restoration practices are stormwater controls that provide treatment to runoff associated with 1 inch of rainfall (water quality volume) or approved alternative practices that offset the impacts of runoff rather than treating it directly. The restoration requirement is computed as 20% of the baseline untreated impervious. The MDOT SHA current baseline 20% restoration requirement is 4,709 acres. We have been given until October 8, 2020, to complete installation of BMPs or develop operations activities that provide restoration credit equal to our 20% requirement.

The MS4 permit also requires that MDOT SHA build practices or perform activities that reduce pollutants to meet TMDLs for the Chesapeake Bay and local waterways. The Bay pollutants are nitrogen, phosphorus, and sediment. Local TMDLs for MDOT SHA include bacteria, PCBs, trash, phosphorus, and sediment. Both the impervious surface treatment and TMDL projects are called restoration projects so as not to confuse these efforts with mitigation.

Mitigation projects are required to offset impacts to environmental resources, such as forests, roadside trees, Maryland critical areas, wetlands, and U.S. waters. For our purposes in reporting for this scan, mitigation projects are not considered GI because they are not managing or restoring decreased water quality/increased water quantity due to roadway projects; rather, they are replacing existing resources and the functions associated with them prior to being impacted.

Within MDOT SHA there are two main offices responsible for developing and implementing GI water quality projects: the Office of Highway Development (OHD) and Office of Environmental Design (OED). The OHD Highway Hydraulics Division (HHD) addresses stormwater and erosion and sediment control design and permitting associated with roadway projects. The OED Water Programs Division (WPD) addresses 20% impervious restoration and TMDL R/W requirements associated with the NPDES MS4 permit. The WPD was established in 2013 to focus on achieving compliance with the Chesapeake Bay TMDL and MS4 impervious restoration requirements. The MDOT SHA Office of Maintenance (OOM) also coordinates activities through district maintenance shops that support GI intent, although they are performed for other reasons and brought into the GI/MS4 tracking and reporting efforts by the OED WPD. These activities include trash pick-up and disposal, inlet cleaning, and street sweeping.

The OHD HHD is responsible for managing the SW control assets while the OED WPD is responsible for managing the other GI assets. HHD has several teams that work directly in the SW program: the Drainage and SWM Asset Management Team, the Construction Coordination and Dam Safety Team, and the Water Quality Banking Team. In cooperation with other teams within the division and in other offices, these three teams generally manage the SW asset inspections, coordinate routine maintenance with

the OOM, develop work orders for remediation, and develop retrofit contracts as needed.

The OED WPD implements new SW controls to treat existing impervious surfaces (rather than new or redevelopment roadway projects) and SW control retrofits for TMDL/impervious restoration purposes, and these become SW assets managed by OHD HHD. OED WPD also implements alternative practices for TMDL pollutant load reductions and MS4 impervious restoration and manages these alternative assets. These alternative practices include impervious disconnection (sheet flow and grassed swales), tree planting, outfall stabilization, stream restoration, and impervious surface removal (which has proven to be too costly and has been discontinued as a viable practice). The OED WPD also coordinates and tracks inlet cleaning, street sweeping, and trash removal operations practices with OOM.

Nutrient and sediment credit trading is another practice that will be implemented in Maryland soon. Draft regulations are under review and anticipated for adoption in January 2018. This will allow purchasing or selling of nutrient and sediment reduction credits between the agricultural, wastewater, stormwater, and on-site sewage-disposal sectors.

Offsetting new growth is another initiative specific to the Chesapeake Bay TMDL; the MDE is working to develop policy, legislation, and regulation. This centers on offsetting pollutant loads associated with new or redevelopment projects because no SW control structure is 100% effective at reducing pollutants in stormwater runoff. Offsetting would account for the new loads contributed to the watershed above the loads that are reduced by the SW control practices and erosion and sediment control measures required as part of acquiring a grading permit to construct roadway projects.

What types of GI have been installed by your agency, and how many of each type?

MDOT SHA currently owns nearly 5000 SWM BMPs, which includes a variety of types, such as:

- ◆ ~695 Bioretention, including bioswales, basins, micro-bioretention facilities, and rain gardens
- ◆ 860 Retention and detention ponds, including micro-pool extended detention, underground detention, pocket, and other ponds
- ◆ 2435 Swales – grass, dry, wet and other
- ◆ 120 Sand filters – above and below grade and other
- ◆ 1315 Infiltration facilities, including basins, trenches, landscape, shallow marsh, pond/wetland systems, and other
- ◆ 30 Submerged gravel wetlands

- ◆ 90 Other SWM BMPs, including oil grit separators, permeable pavement, and stream restoration
- ◆ Stream restoration projects between 1999-2009
 - 16 in OBD 17 for a total of 8435 LF in HHD for a total of 18,147 LF restored 2480 of which directly impact watershed restoration
 - 42 sites are in various advertisement and construction phases
 - 5-9 more under design within HHD
- ◆ 3 Pervious pavement installation (existing)
- ◆ 4 Pervious pavement installation (currently under design or construction)

Projects that have been sent through Practical Design 30-40

The OED WPD has documented completion of the following practices as progress toward meeting the 20% impervious restoration requirement of 4709 acres to be treated by October 2020:

- ◆ 389 new SWM BMPs (also accounted for in numbers above)
- ◆ 21 grass swale upgrades
- ◆ 25 SWM retrofits
- ◆ 1825 LF outfalls restored
- ◆ 64,828 LF streams restored
- ◆ 1808 acres of tree planting
- ◆ 3500 inlets cleaned (annually)
- ◆ 370 street miles swept (annually)
- ◆ 81 acres redevelopment credit

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

Various design guidelines exist as follows:

- ◆ Maryland Stormwater and Design Manual, Volumes I and II (October 2000, Revised May 2009)⁸⁵

⁸⁵ Maryland Stormwater and Design Manual, Volumes I and II (October 2000, Revised May 2009), Maryland Department of the Environment, http://www.mde.state.md.us/programs/Water/StormwaterManagementProgram/Pages/stormwater_design.aspx

- ◆ Additional internal design guidelines include documents on Design Approach to Implementing ESD to the MEP for Major Projects; SWM Details, Checklists and Tabulations; Critical Area Regulatory Guidance; MDE Guidelines for Federal and State Projects; and other resources
- ◆ MDE Erosion and Sediment Control in Maryland manual⁸⁶
- ◆ Practical design guidelines are stated more as MDOT-wide policy 701.01 and can be found at
- ◆ MDOT SHA Stormwater Site Development Criteria (June 2011) – Link not available but PDF version can be provided.
- ◆ MDOT SHA Landscape Design Guide (December 2016)⁸⁷
- ◆ MDE state and federal guidelines⁸⁸
- ◆ MS4- and TMDL-related guidelines:
- ◆ Maryland’s NPDES Municipal Separate Storm Sewer System (MS4) Permits⁸⁹
- ◆ Municipal Separate Storm Sewer System (MS4) Permit⁹⁰
- ◆ MDOT SHA Existing Water Quality Grassed Swale Identification Protocol⁹¹
- ◆ MDOT SHA site selection process and criteria (link not available)
- ◆ Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System Stormwater Permits⁹²
- ◆ TMDL Stormwater Implementation Resources⁹³

86 Erosion and Sediment Control in Maryland, Maryland Department of the Environment,

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/erosionsedimentcontrol.aspx>

87 Landscape Design Guide, Maryland State Highway Administration, Maryland Department of Transportation,

<https://www.roads.maryland.gov/OED/SHALandscapeDesignGuide.pdf>

88 Erosion and Sediment Control and Stormwater Management Plans for State and Federal Projects, Maryland Department of the Environment,

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/PlanReviewforStateandFederalProjects.aspx>

89 Maryland’s NPDES Municipal Separate Storm Sewer System (MS4) Permits, Maryland Department of the Environment,

https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Pages/storm_gen_permit.aspx

90 Municipal Separate Storm Sewer System (MS4) Permit, State Highway Administration, Maryland Department of Transportation,

<https://www.roads.maryland.gov/Index.aspx?pageid=336>

91 Existing Water Quality Grass Swale Identification Protocol, State Highway Administration, Maryland Department of Transportation, April 13, 2016,

<https://www.roads.maryland.gov/OED/SHA-Existing-Water-Quality-Grass-Swale-Identification-Protocol-and-Appendices.pdf>

92 Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated: Guidance for National Pollutant Discharge Elimination System Stormwater Permits, Maryland Department of the Environment, August 2014,

<https://mde.maryland.gov/programs/Water/StormwaterManagementProgram/Documents/NPDES%20MS4%20Guidance%20August%2018%202014.pdf>

93 TMDL Stormwater Implementation Resources, Maryland Department of the Environment,

<https://mde.maryland.gov/programs/Water/TMDL/DataCenter/Pages/TMDLStormwaterImplementation.aspx>

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- ◆ MDE MS4 Geodatabase Guidelines (rev. 2017) (link not available)
 - Chesapeake Bay Program BMP expert panel recommendations:
 - ◆ Urban Stormwater Workgroup⁹⁴
 - ◆ Forest Workgroup⁹⁵
 - ◆ Toxic Contaminants Workgroup⁹⁶

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

Recent discussions with the MDE have been about additional delegated authority to MDOT SHA for regulated design review and approval authority of SWM and sediment/erosion control measures. These discussions are currently centered on delegated authority of pond designs; the current delegated authority only covers smaller environmental site design facilities and SWM credit practices. This new policy will create a cascade of new policies, manuals, and design

criteria as it is fleshed out and put into practice. The law to allow this additional authority must first be changed then additional changes and practices will be put in place. It is anticipated that this transition will take the next two to three years to complete. In addition, currently stricter dam safety analysis related to freeboard at roadway embankments and downstream emergency action plans has been required and will be monitored in that time as well.

The MDOT SHA Landscape Design Guide was originally developed by OED and is currently being reviewed to determine needed updates to include guidance for planting design, construction specifications, and maintenance of SWM control facilities and alternative practices associated with the impervious restoration and TMDL compliance projects. Also, the Stormwater Management Site Development Criteria Manual that HHD originally developed needs to be updated to include criteria and guidance for new ESD facilities associated with Chapter 5 of the MD 2000 SW Design Manual (2009 revision). WPD has established a multidisciplinary work group has been established to collaborate on both these updates and the group is led by a consultant landscape architect/water resources engineer and includes members from the HHD, WPD, and other offices within OED, including the Landscape Operations Division (LOD), Landscape Architecture Division (LAD), and Environmental Programs Division (EPD).

94 Urban Stormwater Workgroup, Chesapeake Bay Program,
https://www.chesapeakebay.net/who/group/urban_stormwater_workgroup

95 Forestry Workgroup, Chesapeake Bay Program,
https://www.chesapeakebay.net/who/group/forestry_workgroup

96 Toxic Contaminants Workgroup, Chesapeake Bay Program,
https://www.chesapeakebay.net/who/group/toxic_contaminants_workgroup

The LOD is responsible for maintaining special landscape features within MDOT SHA ROW, including streetscapes and community partnership plantings; providing technical guidance and training on nutrient management, vegetation management, and pesticide application; and developing vegetation management contracts for invasive species removal and pollinator habitat enhancement. The LAD provides planting design for roadway projects, streetscape design for community development and context-sensitive solutions projects, hardscape design for bridges and noise barriers, and critical areas of mitigation. EPD provides permitting and mitigation support for roadway projects, including wetland and U.S. waters, Maryland critical areas and forest and roadside trees, and construction erosion and sediment control quality assurance inspections under MDE-delegated authority.

The MDE 2014 Accounting Guidance (“Accounting for Stormwater Wasteload...,” linked in the preceding bulleted list) allows for jurisdictions to develop alternative crediting methods and submit for approval. These can either apply to baseline treatment or restoration credit. These guidelines provide guidance for computing impervious restoration requirements and restoration credits and also provide efficiencies for computing reductions of nutrient and sediment loads provided by the same restoration BMPs. The baseline requirement can be reduced by methods to demonstrate disconnected impervious surfaces. Jurisdictions can develop these methods based on the MD 2000 SW Manual water quality criteria and submit for approval. MDOT SHA has developed and received approval for a method to identify and document existing grass swales (ditches) along roadsides and quantify the water quality treatment provided and impervious restoration credit. MDOT SHA has also developed and received approval for (pending submittal of a final revised version) an alternative crediting method for stabilization of storm drain outfalls that quantifies the mass of sediment and associated nutrients that is at risk of downstream transport but retained using stabilization techniques.

When did your agency begin implementation of GI? Is the existing, constructed GI working as designed? Describe any recent changes made or recommended?

GI began to formalize in 1999 with updated SWM regulations from MDE. These regulations began to consider water quality in addition to the previously required water quantity management. A formal drainage and SWM asset management program was also instituted as MDE began to require through state law triannual inspections and maintenance reporting of SWM BMPs. All SWM practices constructed depend heavily on maintenance activities to continue working as designed. Certain practices such as dry (detention) ponds or swales tend to work consistently with far less maintenance than infiltration-type practices such as infiltration basins and ponds. The SWM Asset Management Team maintains a list based on triannual inspections of facilities in need of minor maintenance, major remediation and retrofitting based on ongoing functionality. Recent changes have included a much more robust program to inspect, rate for needed

maintenance actions, and perform these actions. The team performing this work was expanded in size and new data management policies are being updated to track needed activities. Remediation work orders, including as-built procedures for better documentation of work performed, are currently also undergoing an update. Several new contracting mechanisms for how to perform both remediation and retrofit work are being explored and new discussions for minor maintenance contracts are starting across various MDOT SHA offices. A large increase in the number of SWM BMPs was seen in this time as many grass swales were added to the SWM BMP inventory after studies showed their effectiveness in treating roadside runoff. The maintenance of these facilities must be considered in the current planning stages.

The restoration component of GI at MDOT SHA (impervious restoration and TMDL WLA compliance) began October 2005 when MDOT SHA was issued its second MS4 Phase I permit that had new requirements to delineate impervious surfaces, quantify impervious treatment, and provide 25 restoration projects by October 2010, the permit expiration date. When the Chesapeake Bay TMDL was issued in December 2010, that same month MDE issued the Maryland Phase I Watershed Implementation Plan (WIP I) that required MS4 jurisdictions to restore impervious surfaces (Phase I MS4s at 30% and Phase IIs at 20%) to comply with the WIP I. In 2011, MDE also provided all the bay sectors (stormwater runoff, point sources, septic, and agriculture) with WLAs for nitrogen, phosphorus, and sediment. So, MDOT SHA initiated efforts to model, plan, and construct BMPs to both reduce pollutant loading and restore impervious surfaces. However, since the expired MS4 permit was still in effect until a new permit was issued, the impervious restoration requirement in the WIP I didn't apply to MDOT SHA. Therefore, our efforts centered on developing a WIP to demonstrate meeting the WLAs. In March 2012, MDOT SHA submitted its WIP to MDE for submittal to EPA under the MDE WIP II. The MDOT SHA WIP is available on the MDE website⁹⁷.

Although expired in 2010, the 2005 MS4 permit remained in effect until the issuance of the next MS4 Phase I permit in October 2015. The new permit added the requirement to account for and restore 20% of untreated impervious and develop implementation plans for all local TMDLs for which a WLA was assigned to MDOT SHA. From that point forward, MDOT SHA has been implementing tens of millions of dollars' worth of efforts annually to plan, design, and construct various types of BMPs to meet the 2020 deadline for 20% restoration. MDOT SHA set the implementation dates for all the local WIPs well beyond 2020. The MDOT SHA Impervious Restoration and Coordinated TMDL Implementation Plan and MS4 annual reports are available at MDOT SHA MS4 website⁸⁹.

97 Appendix E, Maryland State Agency Phase II WIP Reports, Maryland State Highway Administration, https://mde.maryland.gov/programs/Water/TMDL/TMDLImplementation/Documents/FINAL_PhaseII_Report_Docs/Final_Documents_PhaseII/Appendix_E_State_Agency_PhIIWIP_Reports_032112.pdf

MDE issued MS4 Accounting Guidance in 2011 and updated it in August 2014⁹² to provide consistent tracking, computation, and implementation guidelines to the MS4 jurisdictions. These guidelines provide graphs that translate the depth of rainfall runoff treated (preliminary engineering) for stormwater control structures to pollutant load efficiencies and also a table to impervious equivalencies and load-reduction efficiencies to alternative practices such as tree planting, inlet cleaning, stream restoration, pavement removal, and street sweeping. The guidelines also require all restoration BMPs be inspected every three years to ensure water quality treatment continues to be provided and inspection results are documented in spatial databases according MDE geodatabase guidelines. The MDOT SHA restoration BMPs are all functioning due to this requirement and remediation efforts are undertaken as needed.

Does your agency have a leader/champion for GI design practices and planning?

The director of the Office of Environmental Design, Sonal Ram

What is the leadership/champions role in promoting GI?

To continue to bring GI concerns to the administrators of MDOT SHA to meet compliance goals, further practical design solutions, and support coordination of maintenance efforts throughout.

What obstacles, concerns or barriers to GI exist in the agency?

- ◆ Lack of a holistic asset management program and communication software so all data on assets can be clearly and concisely communicated between offices.
- ◆ New and redevelopment road projects often do not account for additional R/W needed to implement BMP practices.
- ◆ Division of funding and labor from design to maintenance services creates a gap of information from the SWM Asset Management Team back to the maintenance crews to keep facilities maintained.
- ◆ Lack of knowledge transfer from design offices to maintenance shops of both location and procedures for maintaining SWM BMPS, inlets for cleaning, and invasive plant species.

Who identifies and selects potential projects? What criteria does your agency use for programming, prioritizing, and funding GI projects?

HHD designs structural stormwater controls, which are built in association with roadway projects to obtain SWM/ESC permits for the road project. The funding of these projects is included in the roadway project budget. These SW controls are part of the GI network, documented in the HHD NPDES geodatabase, and subject to triennial inspections, routine maintenance, and remediation.

Restoration projects are many BMP types and the criteria for selection vary by type.

In addition, the SWM Asset Management Team and Highway Hydraulics Division contribute to selecting SWM BMP projects based on the following:

- ◆ Triannual inspection results of SWM BMPs – facilities are rated as in need of remediation work to remain functioning as designed or facilities that are no longer functioning are turned into GI projects to maintain the baseline of SWM credit as well as enhance it with better functioning facilities.
- ◆ Drainage complaints and issues may lead to the discovery of SWM improvement opportunities.
- ◆ Stream restoration projects associated with major highway design projects may be initiated here as well.
- ◆ Projects falling under these criteria are funded through the Highway Drainage Fund, which is a state funding source. Rarely are federal funds available for these types of projects.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

Funding for restoration projects comes from state transportation trust funding with federal funds allocated for projects that exceed \$1 million construction at 80% federal/20% state.

Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?

GI is a priority for executive management generally when connected to the construction of totally new projects or major improvements along existing roads. This priority is partially set as a result of the state's environmental laws that require environmental permitting before jobs can move to a construction phase. Practical design practices have also become very important to executive management and, by the virtue of decreasing overall project size and therefore pavement proposed for improvements, the GI principles are followed well.

Challenge with innovative practices and management support include the following:

- ◆ Maintenance procedures for innovative practices such as pervious pavement have not been fully determined. Lack of equipment to perform these measures can be a problem but also many areas where this practice is used, such as sidewalks, are not regularly maintained by MDOT SHA; these are left for local jurisdictions and residents so the focus remains on the roadway.

- ◆ Tracking the installation of innovative practices such as pervious pavement to create maintenance plans.
- ◆ Management policies that separate SWM designers with the most knowledge of how SWM practices should function from the Maintenance crews responsible for completing the needed work to maintain functionality.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

The design team is multidisciplinary and can consist of the following members:

- ◆ Hydraulics engineer
- ◆ Landscape architect
- ◆ Environmental permitting specialists to determine tree requirements, critical area requirements, waters of the U.S., wetland/waterways delineations
- ◆ National Environmental Policy Act (NEPA) experts for historical and cultural significance studies
- ◆ Highway design engineer
- ◆ Structural engineers
- ◆ Highway safety and signage engineers, including lighting
- ◆ Materials engineers for pavement requirements
- ◆ Maintenance-of-traffic engineers
- ◆ Construction and Maintenance engineers/experts
- ◆ Planners and engineers to initiate the design process
- ◆ MDOT SHA Plan Review Division for SWM and ESC design review
- ◆ MDE for other environmental permitting reviews

Project team coordination and membership varies based on the specific type of project. Larger scale highway projects, which are also often subject to the full practical design process, may consist of all members included above. Smaller scale projects such as tree planting or SWM BMP remediation work order projects may consist of only a few as listed. In general hydraulics engineers and experts in all permitting for environmental purposes work together closely to bring GI projects to completion and take responsibility

for the GI design. These are experts in the GI practices primarily; however, other innovative practices such as pervious pavement will also rely heavily on materials engineers to provide good design information that meets safety and other requirements beyond the GI design. Depending on the type of project the GI experts may be involved from the very beginning or only become included after the planning stages, such as in major highway projects. In general this approach works well; the experts are better able to keep up with the changes in regulations and practices than those who would primarily be focused on something such as highway or bridge design. However, communication must be kept at a very high level to keep all the various disciplines working together in harmony. Often changes to larger aspects, such as pavement amount or type, can have a major impact on SWM BMP design.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them?

Hydraulics engineers are well trained in the practices needed for design of SWM BMPs, including the following criteria and methods:

- ◆ B.S. in civil or environmental engineering is required for entry-level positions.
- ◆ Interview questions for candidates are tailored to those who have a concentration in water resources and are purposely difficult for other disciplines to answer correctly.
- ◆ Once new staff has been hired they undergo significant on-the-job training through programs dedicated to their learning, as well as hands-on design.

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

Over time, practices have evolved to include more GI practices as regulations have become more restrictive. Replacement of concrete ditches and use of grass medians and median SWM practices have shown steady growth, particularly since the implementation of ESD practices in 2010.

What considerations does your agency take into account when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined? Are residents willing to put up with years of tunneling under their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?

In general gray infrastructure has been less expensive when it comes to building roadways. One of the largest costs to building a roadway is the land costs; without GI practices less land is needed for construction of a roadway. A combination of practices is being used with increasing frequency, especially with consideration of flooding issues. GI practices known as ESD are used on the surface in smaller areas to treat for water quality considerations, while larger underground gray practices have to be installed to

manage quantity concerns. Recent changes to dam safety practices within the MDE are likely to show a continued increase in this need. In addition, different pavement types, such as pervious and standard, can also be blended in one project. In many cases ROW is purchased to accommodate the needed GI for a new project. Many retrofit and TMDL projects more focused on GI are accomplished without purchase of any ROW. Better utilization of existing R/W has become a benefit of the programming for TMDL, which not only includes SWM quantity and quality practices, but also tree planting as well.

What current trends do you see – increases in implementation of GI? Increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

Current trends in GI generally have been including far more retrofits and enhancements to roadway projects than new construction. GI projects that do not involve roadways have been on steadily increasing, including new TMDL projects and tree-planting projects. In general funding is decreasing in areas for roadways and is often shifting toward the GI projects in general. The demand for new GI is great under the current Chesapeake Bay TMDL requirements. Some divisions have more luck than others at procuring this funding, those tied to the Office of Environmental Design have seen more consistent funding; future funding planning has also been consistent. Those associated with the Asset Management Team in the Office of Highway Development have seen increases but projected future funding is far too low. Work on dedicating maintenance forces toward GI has seen a sharp increase in the past couple years. Meetings between team members and maintenance staff and management have increased, which is supporting education and awareness of maintenance forces of both the need and the methods for maintaining GI. Preliminary conversations are starting to take place looking at additional funding allocations and a current shortfall in staff, knowledge, and support for GI maintenance. Legislation is currently being examined to update MDOT SHA-delegated authority for approval of pond designs. It is anticipated that this transition will take the next two to three years to complete. In addition, currently stricter dam safety analysis has been required and will be monitored in that time as well.

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

Why does your agency implement GI (i.e., vision, mission, resource agency demand, regulatory, TMDL, public demand, etc.)?

GI is implemented as part of the MDOT SHA mission and also complies with MDE permit requirements and TMDL goals imposed by a proactive regulatory community.

What criteria do you use to evaluate GI proposals?

What criteria do you use to select alternatives and practices?

Describe what is driving your decision to use GI.

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

The MDOT SHA designs projects in several various types of environments, including coastal, mountainous, urban, rural, and environmentally sensitive.

At what phase of project development do you begin identifying specific GI practices?

Some GI practices may be examined during design initiation. These include general environmental features such as streams and waterways, NEPA and historical locations, and some projects may have been initiated because of environmental concerns. Further into the process once design has begun, at approximately 10% design is when the majority of the environmental features are identified, such as wetlands, waters of the U.S., floodplains, and any additional environmentally sensitive areas. At this time SWM needs are assessed and preliminary designs of proposed GI solutions are submitted for concept. During the remainder of the design process, SWM needs, EnS needs, and coordination on any critical areas that will be disturbed are evaluated, tracked, computed, and permitted.

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

At this time no tool exists within our agency. Practical design criteria is in the process of developing this information and it is anticipated that metrics will be available in the near future.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

GIS is used heavily in the tracking, identifying, and evaluating GI locations. All SWM assets are placed in an expansive GIS database. Assets are tracked through their entire life cycle, which includes design, construction, acceptance, ongoing inspection and maintenance, retrofitting and enhancement, and decommissioning.

GIS is used to evaluate the feasibility of proposed plans for tree-planting initiatives. This ensures their survival and keeps them at safe distances from existing SWM and drainage facilities that may otherwise be damaged.

How does your agency convince management or stakeholders that GI is critical to roadside water management (or vice versa)?

In general compliance with SWM regulations is necessary for permitting to construct any type of new roadway project. This regulatory oversight alleviates any concern for lack of management support. Many stakeholders are far less supportive of GI efforts, especially when those efforts may impact their business directly. Homeowners often are concerned with roadside SWM causing mosquito or safety issues, while commercial developers are the most resistant, citing issues with sight lines, loss of property areas otherwise highly viable for roadside development to GI practices that must be near the road. Recent discussions with districts, the attorney general, and managers have favored adjustments to roadside measures to minimize impacts to commercial landowners while still providing treatment, often which is now offline rather than parallel to the roadway.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

Internal stakeholders have many ways of sharing information, including a ProjectWise database format for all design, permitting, and miscellaneous related activities. Further internal stakeholders will hold regular meetings, for both progress and to mark specific design milestones to review design plans with all disciplines involved. Lastly, standard office communication tools such as e-mail, phone, and smaller meetings are used. External stakeholders are often reached through public relations campaigns, such as flyers and on line, all of which culminate in public meetings.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

Multiple disciplines keep databases associated with GI. An NPDES database is maintained to track acres treated, facility types and life cycle, and baseline treatment and remediation efforts. In addition, a database of SWM bank credits and debits is kept to track by watershed the overall treatment balance and efforts. A tree database is also kept to help track planting efforts. Much of this information is kept private but is available for other DOTs upon request.

In your experience, what is the most crucial factor to consider in GI?

Public perception of the use of space for GI projects is usually the most crucial factor when considering design choices, public outreach, and other factors in design. The strict permitting requirements set forth by the MDE will become a crucial factor in the speed with which a project can be designed and allowed to be sent out for bid for construction.

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

Pilot projects are often a part of research. Research is performed as part of the permitting conditions as well as to address requirements by some state laws. Research on use of alternative materials, such as compost in SWM BMPs, and research on removal efficiencies of certain pollutants in various depth-engineered materials are two examples of systematic work that leads to pilot projects to determine full-scale viability of design changes in time.

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

There can be significant inconsistencies between agencies' SWM regulations and other environmental policies. With the granted delegated authority given to MDOT SHA in Feb 2015, many design criteria and approval policies previously used under just MDE were changed and became more restrictive. This slowed down the permitting process not just for new projects but also for retrofit, remediation, and enhancement projects as well. The slower permit process also included submission to several different review entities; the MDOT SHA PRD, the MDE Water Management Association, and the MDE Dam Safety Division all have to review certain SWM facility designs. In addition, there are other state and local agencies looking at SEC designs, depending on the exact location of the project. To remain in compliance with the NPDES permit, maintenance must be regularly performed on SWM BMP facilities. If this maintenance lapses some, the facility may require more major remediation within the same footprint. A general permit was previously granted for this type of work to simplify the permitting process for this type of work. The loss of this general permit has significantly slowed the process and reapproving the permit seems to be a low priority for the MDE. This permitting process has also added a level of complexity, with additional environmental feature designations and examinations for projects that will remain in the original footprint except for access and construction needs. Projects are funded in stages so that these types of conflicts can be examined as design progresses. It is not unusual for projects to be dropped midway through design because strict permitting requirements for construction of SWM facilities then also prevent their retrofitting. The intent to simply improve the functionality of an existing SWM BMP even if it still falls short of modern criteria is not valued so then no change is made and systems can continue to degrade.

Are there other design considerations your agency had considered that were not accepted by management? Why not?

What lessons have been learned from the GI installed?

One GI practice that has been shown to be less effective because of high maintenance needs which result in higher failure rates is the use of infiltration facilities. These facilities have been a large part of the remediation work orders that have been required over the past several years. Facilities will overgrow to a point of being indistinguishable and trash and clogging from leaves compound the problem. Current efforts include tracking the major remediation efforts needed on these trenches and after they have been worked on and regular maintenance tracked, if they are still in need of remediation they will be retrofitted to a new facility type.

Based on lessons learned, what project types are most feasible going forward for future projects?

Many lessons learned have shaped decisions on installation of SWM BMPs, including the following:

- ◆ Loss of groundwater recharge from the use of regional ponds created the change to SWM design overall from a regional to a localized (LID) approach.
- ◆ Higher failure rates of infiltration facilities have led to engineering of bioretention soils to use in facilities instead.
- ◆ Access to facilities is essential to maintenance efforts; facilities behind noise walls and guardrails without access for regular maintenance will have higher failure rates.

What were the unique challenges during construction? Overall timing of the construction/installation?

Several challenges during construction are encountered in building SWM facilities:

- ◆ Unique grading requirements take a skilled equipment operator to meet the grading design to allow for the proper drainage requirements of the facility. Further challenges can also often include dealing with steep slopes where equipment cannot navigate or easily access.
- ◆ Access issues because of the location of facilities within wooded areas
- ◆ Each facility is unique in size and type, requiring additional construction stakeout.
- ◆ Construction of the facilities must be staged to protect the facility from adjacent construction (i.e., unwanted compaction of infiltration trench material).
- ◆ Access for the construction/installation/maintenance of the facility has to be considered during design since the location may not be as accessible after construction is completed.

- ◆ Unique construction practices are sometimes used (i.e., use of material [e.g., BSM] that shouldn't be compacted). Subsoil that has become highly compacted from the use of large machinery can cause ultimate failure of the facility.
- ◆ They also often require special soil blends that must be kept at a specific moisture content, so storing the materials can be a challenge as well as acquiring it during rainy periods because manufacturers don't have weatherproof facilities.
- ◆ Other challenges come in when soil types encountered do not match for the entire facility with what was tested for during design; this can cause facilities to immediately begin flooding.
- ◆ Construction of in-stream facilities provides even more challenges as maintenance of stream flow needs to be accomplished, fish passage must be considered, and the overall disturbance to sensitive ecosystems is highly possible.
- ◆ Requirements for the certification of the construction by a third party impacts the timing of construction, leading to possible delays.
- ◆ Final landscaping/stabilization of the facilities are unique and the timing may be different than for the remainder of a project

When designing the GI, what metrics were used and were extreme weather events part of the calculation?

In general SWM BMPs are designed based on volumes for the following size storms:

- ◆ Water quality for the first 1 to 2.6 inches of rainfall depending on location and soil type as well as a theoretical computation of the impervious area requiring treatment
- ◆ Channel protection volume of two-year storm.
- ◆ Flood control measures vary based on location within the state and will include 10-year and 100-year storms.
- ◆ The final design, including the flood control measures of any SWM BMP, must have at least 9 inches of freeboard from the water surface as calculated to the centerline of the adjacent roadway.

In addition other research information provides flood plain locations as well as predicted sea level rise. The development of a research application where several of these climate layers can be overlaid to see all the possible issues of a potential site.

Does your design accommodate increased long-term flows? What is that based on?

Dam breach analysis is performed on larger quantity facilities for the 100-year and brim up storms based on the ultimate land development from Master Planning.

Describe coordination, training and outreach with the public including adjacent property owners.

Coordination efforts both within the agency, including seminars and meetings for maintenance staff, are included in the outreach efforts of the program. In addition, during design and development processes for larger highway projects, websites and letters are set up to inform the citizens and invite them to public meetings. Meetings include a presentation of the various aspects, including the GI of any project, and allow questions and answers to address public concerns.

Performance Measures

Do you require contractors to have a plant establishment period? If so, how long?

Contractors are required to have a minimum of one-year vegetation establishment period prior to final payment. For tree-planting projects it may be as many as five years.

What requirements do the regulatory agencies impose? Describe any programmatic agreements achieved through GI project design approach (e.g., mitigation credits).

Regulatory agency requirements are extensive, are covered by a NPDES MS4 permit, and include at minimum the following:

- ◆ SWM design criteria for water quality, channel protection and flooding
- ◆ Erosion/sediment control measures during construction on all projects larger than 5000 square feet or 100 cubic yards of earth disturbance
- ◆ Inspection of existing owned SWM BMPs on a triannual basis to show that functionality goals are met.
- ◆ Annual monitoring of remediation and maintenance activities of SWM BMPs
- ◆ Maintenance of a SWM quality bank for credit as needed. The bank has been in place since approximately 2000 and serves as a means of using mitigation credits for projects that otherwise would not meet requirements within their specific area.
- ◆ Additional regulations, such as tree clearing, wetland and floodplain coordination, and preservation, are also overseen by different divisions of MDE.

Have you developed a general rule of thumb for amount of \$ spent on GI?

Not at this time

Have you seen a difference in cost between GI and gray infrastructure?

One noticeable cost difference that is seen with GI is in land acquisition costs. The implementation of many GI practices requires more land area to incorporate so those

costs have gone up. In addition the facilities for SWM and other drainage assets require additional maintenance costs beyond the typical roadway items such as pavement, striping, signage, guardrail, and more. The maintenance work is more specialized for GI, which is also requiring the mobilization of specialized contracts to perform the work needed to keep GI functioning adequately.

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction.

The earlier GI can be considered in the process the better and cheaper it becomes. This has been a standard in roadway planning for a very long time. The earliest integrative practices began over 20 years ago in those types of projects and as regulations changed and updated, the earlier the GI experts have been involved in planning the easier it has been. Historically if inadequate space was provided it could cause delays in project development, increased land acquisition fees, and other problems that have primarily been handled by including the right people through the planning stages. By contrast, however, the TMDL portion of the GI programming has a large retrofitting component to it.

Have you documented a cost savings for these processes?

Does the cost/benefit of the project determine the funding amount?

GI cost/benefit analysis does not quite apply to system preservation projects. The funding amount is determined by the need and priority of the improvement. The general MDOT SHA priorities for funding of SWM and drainage assets are as follows:

- ◆ Safety
- ◆ Functional enhancements (which include TMDL)
- ◆ Environmental stewardship
- ◆ Visual enhancements (aesthetics)

The cost /benefit does not determine the funding amount but it does help in prioritizing the projects when funding is limited. We are always looking for solutions that could meet several objectives to stretch the budget and find the most effective way to properly allocate our limited resources.

Do you have any issues with establishing permanent vegetation after construction of GI?

Issues associated with establishment of permanent vegetation after construction of GI vary depending on the type of facility. The facilities that demonstrate the highest

amount of issues with establishment are the bioretention-type facilities. These plants must be able to withstand both flooded and dry conditions based on the functionality of the facilities, which are quite dry and sandy during no rain, but are flooded and often remain saturated for up to two full days prior to fully draining. These plant types are difficult to find in native MD species so establishment can be difficult.

Native Maryland species of plants generally have a long establishment period. This lengthy period is also a difficult factor in plant establishment. Other species that are considered more invasive may in fact grow significantly faster than the native Maryland plants and can easily take over a facility prior to the full establishment of the native species.

Finally, the location of practices can make a big difference as well. Specifically median facilities often struggle with salt overload on plants that are not salt-tolerant. The use of salt/brine on roadways for deicing purposes will then be washed off the roadway and into nearby facilities. This high salt concentration can easily kill off establishing plants and has been a topic for discussion for several years.

How many acre-feet of water per year are captured by GI techniques?

Determining the total acre-feet of water per year that is captured by GI techniques is an ongoing process. There is good accounting for runoff storage volume or water quality volume for all TMDL facilities and all facilities in the baseline treatment provided by MDOT SHA as of 2010. The runoff storage volume is used to calculate the target rainfall used for sizing ESD practices (known as preliminary engineering), which is then applied to the impervious surfaces that are known to drain to the facilities in those two listed categories. This overall amount is to be provided by the MS4/TMDL Restoration Program Team.

In addition to this tracking, MDOT SHA also has a Water Quality Bank that tracks the acres of pavement treated for water quality. Not all pavement treated is explicitly owned by MDOT SHA and not all treated pavement that belongs to MDOT SHA is treated in facilities owned by it. This tradeoff is a close approximation to the overall pavement area treated in facilities. The bank acreage is subdivided by 18 distinct six-digit watersheds as follows:

Watershed Number	Watershed Name	Approved Projects Balance + Reconciled
02-12-02	Lower Susquehanna River Area	-0.22
02-13-01	Coastal Area	13.27
02-13-02	Pocomoke River Area	3.32
02-13-03	Nanticoke River Area	3.65
02-13-04	Choptank River Area	-1.56
02-13-05	Chester River Area	2.73
02-13-06	Elk River Area	7.96
02-13-07	Bush River Area	8.15
02-13-08	Gunpowder River Area	5.32
02-13-09	Patapsco River Area	8.20
02-13-10	West Chesapeake Area	16.58
02-13-11	Patuxent River Area	18.08
02-14-01	Lower Potomac River Area	26.49
02-14-02	Washington Metropolitan Area	8.60
02-14-03	Middle Potomac River Area	19.14
02-14-05	Upper Potomac River Area	6.43
02-14-10	North Branch Potomac River Area	1.54
05-02-02	Youghiogheny River Area	-1.80

The approximate total acreage credited is 146 acres.

Do you use a scoring tool to prioritize projects, funding, and programming?

SWM BMP maintenance projects have a very detailed prioritization system. Once triannual inspections are gathered within a county, separate SWM engineers examine inspection records, ratings, recommendations, and photos to determine an engineering action rating of I to IV, which determines the priority and depth of work needed on a specific facility. The ratings break down as follows:

- ◆ I – No Action – The asset is functioning as designed.
- ◆ II – Minor Maintenance – The asset is functioning as designed, but routine and preventive action should be performed to sustain effective performance.
- ◆ III – Remediation or Work Order – The asset has severely compromised functionality and significant repair is necessary to restore original functionality. The facility repairs can be performed so they remain within the existing facility footprint.
- ◆ IV – Retrofit Design – The asset is no longer functioning as designed and cannot be restored to the original function as designed without a complete redesign and reconstruction of the facility with a larger footprint.

Once these ratings have been assigned, SWM facilities are divided up based on rating and worked on as individual programmatic functions.

The **Minor Maintenance** facilities are sent out to the maintenance personnel for light repairs, litter cleanup, and other routine maintenance. A manual to help guide maintenance personnel on the needed repairs and maintenance to these facilities was distributed in 2015 for their use. The coordination effort of this type of work has been an ongoing struggle for program managers and workers in the field who do not have access to the same type of data nor a good tracking mechanism to the work completed. Plans are to implement a global asset management system in the very near future.

The **Remediation/Work Order** facilities are put into a process for reviewing these facilities more closely. Facilities are reinspected this time, paying careful attention to what will be required during repair. Work orders, including site photos, descriptions, original construction plans that have been marked up for the contractor, a punch list of items needed to complete, a work order as-built summary table, and any other relevant data are prepared. These work orders have to go through a permitting process that can take additional time prior to advertisement of contracts for construction. The processing time for these work orders can vary greatly and can be supported by the issuance of a general approval under the current regulations. At this time the process to approve the general approval is moving slowly so individual work orders must still be screened and processed for permitting.

The **Retrofit/Enhancement** facilities are put into a redesign process, which is the lengthiest of all. These facilities will be completely redesigned; they will receive a new footprint and heavy construction. They also require full permitting and no use of a general approval would be allowed. These are turned into projects that are equal to new design projects for SWM BMPs.

The Drainage and SWM Asset Management Program also includes outfall stabilization programming as well. The outfalls are inspected under similar criteria as previously described and the planning and improvement programming is still in the development stages for modernization to keep up with inventory and demand. The benefits of outfall stabilization are numerous and this development is on a list of priorities.

What environmental problems have been solved and what supporting data can you provide?

Was there habitat enhancement after project completion? How long did it take for the enhancement to occur?

Did any endangered species benefit or thrive or were they reintroduced to the site after project completion?

Did 303d listed water bodies for pollutants of concern prioritize selecting the project site? Was the quantity of pollutants removed measured and identified? Over time, did the pollutants decrease?

Reduction in basement flooding and fewer days of missed school (or other quality of life/public safety and convenience responses)?

Was land acquired outside of the right of way to meet the GI objective?

Construction of many SWM facilities for new roadway projects requires expanding the MDOT SHA's ROW. Early in the design phase of new projects preliminary sizing of all facilities needed on a project is completed to establish ROW needs. Upper management in the Office of Highway Development then evaluates these needs to determine what will be acceptable and what facilities may need substitutions, such as use of the water quality bank credits to meet permit requirements for water quality treatment. The acquisition period can be lengthy so it is best started early in the process as designs are finalized. Recent SWM techniques no longer require the acquisition of entire parcels of land for large, more regional facilities but instead generally involve smaller slivers of land along the roadway for more linear-style facilities. This makes the process that much more complex as many owners are now involved. In addition, commercial developers often are difficult to deal with because the loss of prime space at the front of their property along the roadway will reduce their visibility and parking to install facilities that may incur the growth of tall grasses and small brush or trees that would otherwise obscure view of the business. Finding this balance between installing GI where it is both needed and functions most effectively while also accommodating other priorities is an ongoing evolution.

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals, water quality concerns?

For each new roadway project that is developed, several regional needs are identified and broken into increasingly smaller areas to identify individual points of investigation that are determined in any location water leaves the MDOT SHA ROW. Regionally Maryland is broken into 18 six-digit watersheds where the balance of water quality that has been treated and further is banked for MDOT SHA use on future projects. This approach was summarized previously (see How many acre-feet of water per year are captured by GI techniques?) and provides regional stewardship of localized projects. The main objective of current SWM designs is to treat roadside runoff as close to the source of pollution as possible and to recharge groundwater in those areas as well. Longer term studies have shown that this combined approach on a local level leads to better regional

outcomes as water can then travel through the ground for further clarifying and local vegetation, much of which can be more swamp-like in nature, is protected.

Maintenance

How does your maintenance personnel take care of GI – no maintenance, equipment (mechanical, handheld, other – please describe) Does your GI take more maintenance than normal, or less? Seasonal requirements?

Coordination with maintenance staff on GI needs is an ongoing struggle. While the maintenance of the SWM facilities is outlined in the MDOT SHA business plan as follows.

Objective: 5.3 Environmental Compliance and Stewardship in SHA Highways and Facilities Integrate sustainable strategies to maintain SHA highways, buildings, and maintenance facilities in an environmentally sensitive manner and ensure 100% compliance with applicable environmental regulations and standards

Performance Measure 5.3 PM5: Percentage of SWM facilities rated as functionally adequate each fiscal year – GOAL 90%

Compliance by maintenance staff can be difficult. While it is stated in the business plan, the upper administration that directly coordinates with the staff is primarily focused on roadway functions only in maintenance objectives and measures of success. Pavement condition, striping, lighting, and snow removal often have much higher priorities than GI maintenance, which is considered invisible from the roadway. Trash pickup and mowing activities are performed at least four times per year and can be relied upon for many facilities directly adjacent to the roadway; however, but larger facilities or those further down slope that are still in the ROW but may be more than 20 yards from the roadway are often neglected.

To help support these issues, in 2015 manuals were distributed to all maintenance shops in the NPDES counties. These manuals not only outlined facility types, needed equipment for mowing, and mowing heights, but also included maps of each facility location to aid in finding those that are further off the roadways or in fences. In general, triannual inspections reveal at least one-quarter of all SWM BMPs are in current need of at a minimum this type of maintenance. They are still rated as functioning adequately but are flagged to have shop maintenance performed in the upcoming season. This system is still in its infancy as a more comprehensive asset management system is currently being evaluated and tested for all of MDOT SHA. It is anticipated that this will help with this coordination effort in the future; currently it is a lot of one-on-one coordination from drainage and SWM asset management staff, who track the functionality, to the maintenance staff, who perform the work.

How is maintenance funded?

Maintenance is primarily funded through the operational budget; the maintenance operating budget for FY18 is \$267 million. Of that, \$66 million is for winter maintenance and approximately \$80 million is allocated to statewide offices, leaving approximately \$120 million for routine maintenance work, including for example minor patching, roadway sweeping, vegetation management, litter pick up, drainage maintenance, sign maintenance, line striping and pavement markings, guardrail repair, and minor structure repair. This budget is kept completely separate from the capital improvement budget that is used to design and build the SWM and any other GI facilities. The drainage and SWM asset management programming is all done through the same divisions as design, which causes complexity in funding. Larger scale remediation efforts will require updated permits and tracking so those were historically done through the capital budgets because those directly involved in the decisions and designs were easily able to remain the guiding force for reconstruction as well. Recent changes in MDOT SHA policies on these types of projects have made maintenance increasingly difficult to coordinate and fund. In addition, capital money has been transferred as an enhancement into operational funds to help support efforts specifically toward SWM facility maintenance. These enhancements have been approximately \$4 million thus far, which is just over 3% of the overall operational budget dedicated as above. This makes the GI maintenance lower priority than other maintenance items. Coordination to adjust this system is increasing but continues to be slow. Discussions at higher levels of upper management are starting to look at new possible contracting mechanisms and organizational structure to help better allocate appropriate funds and personnel to the work.

Has funding increased as a result of GI? Is there a dedicated funding source for maintenance of GI?

The operating budget has not increased to accommodate the additional GI maintenance responsibilities. No dedicated funding source is currently available for GI maintenance. The capital enhancements to the operational budgets have thus far been the only places where increases and dedicated sources have been occurring and they have gone largely untracked thus far. Currently systems are being put in place to better track this. They began with intermittent meetings among staff from both asset management teams operating primarily under capital funding and maintenance personnel operating under operational funding. These meetings have helped improve communication and coordination of these efforts, but still there are often large gaps to be closed in this effort. Increased communication and tracking will offer more opportunities to help coordinate funding and, there is hope, potentially create a system for dedicated funding as well as other resources for GI maintenance. Discussions are ongoing at several levels and across multiple MDOT SHA offices. According to the Office of Maintenance, MDOT has been

receptive to maintenance requests for enhancement funding for mandated initiatives in the past; however, no mandates on this work currently exist within the organization. This will be something asset managers investigate as progress is made based on the recent increased communication.

What is the skill set of maintenance personnel?

Maintenance personnel vary in skill levels, with many of the team leaders and other maintenance managers having college degrees and even engineering licenses. The majority of facility maintenance technicians have a high school degree but the minimum requirement is completion of 8th grade. At all levels crews are not often working with a lot of technology to automate or effectively track the maintenance of GI practices.

Is it a dedicated crew for GI or part of general maintenance?

Currently, there is not a dedicated crew for GI maintenance. However, it is becoming obvious as more planning and coordination happen between maintenance personnel and asset managers that there is a definite need. The skills required to identify GI practices within the ROW are beyond the average of workers hired to perform the duties. In addition, there are often too many other tasks of higher importance to the performance metrics of the workers on the list to be accomplished so GI maintenance often falls short. New discussions about hiring project managers or having “super teams” for GI maintenance have begun. In the upcoming fiscal year it is anticipated that this will change and some specialized forces will be deployed for more consistent GI maintenance.

How do you plan for maintenance?

Much of the maintenance planning by the Drainage and SWM Asset Management Team is focused on overall triannual inspections and remediation efforts of the SWM facilities that require work beyond the capacity of the MDOT SHA forces. A master list of the facilities statewide is kept for just facilities that have been marked and assessed as marginally functioning; this tracks permitting, design, and construction activities on any given BMP. In addition, the list of minor maintenance needs is cross-referenced with location information so it can be shared with the Office of Maintenance managers, who can support maintenance shops in getting the minor repairs performed. Other maintenance such as mowing and trash are done on a cyclical basis. In addition, maintenance planning is flexible so maintenance shops can respond to emergency repairs and citizen complaints of needed maintenance.

Do you coordinate between other/multiple agencies for maintenance?

In general MDOT SHA Maintenance does not use other agencies to perform maintenance work. A couple exceptions to this include the use of inmates from the Department of Public Safety and Correctional Services to perform unskilled and semiskilled work such

as trash collection. Another program that is known to support vegetative maintenance is the County Weed Control Boards, which are used in some areas for herbicide spraying.

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

At this time MDOT SHA does not have a vector control program through the Office of Maintenance.

Is special equipment required for maintenance of GI elements? If so, how is this funded?

Some special mowing equipment and other special equipment are needed and are outlined in our SWM Facility Operation and Maintenance Guide, which has been given to most maintenance personnel. The remaining personnel are scheduled to receive manuals prior to the end of 2017. Equipment purchased for MDOT maintenance work is purchased through the operational budget. In addition, MD SHA often hires contractors to maintain these facilities; they are, therefore, able to provide needed equipment without SHA having to directly procure it.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

Continued coordination between the teams and the Office of Maintenance is working on developing a more comprehensive, integrated strategy. Currently various aspects of GI maintenance are in different stages of this process. For SWM facilities, the inspection program is well established; however, remediation and minor maintenance activities have been in flux a bit for the past year. The implementation of several remediation contracts throughout the state, as well as some areawide contracts for multiple districts are currently being developed and advertised for execution in 2018. The Drainage and SWM Asset Management team maintains the list and helps coordinate various aspects of the maintenance needed with Office of Maintenance.

In addition a video pipe inspection program has been created to help identify pipe conditions in advance of failures so that replacement of pipes can accompany future resurfacing projects. While this program deals primarily with grey infrastructure, it is integral to the outfall stabilization portion of the program, which is beginning its coordination through first acquiring a complete inventory of outfalls and their conditions.

The conversations have also been looking at more programmatic approaches through project managers specific to coordinate efforts with the Office of Maintenance and their districts on inlet cleaning and SWM facility maintenance. These discussions are beginning after the implementation of a memorandum of understanding with another quasi-state agency to oversee drainage and SWM maintenance and remediation in one of the more remote districts, where contractor support of this type of effort was lacking. The

success of this program has become of great interest to the Office of Maintenance as an effective and efficient way to handle the specific needs of GI maintenance coordination.

Miscellaneous Questions

Does your agency only focus on small-scale design specific to an area or take a regional approach?

Within the Office of Highway Development, primarily work is focused on specific designs for specific projects rather than regional GI solutions. For each roadway project the SWM needs are computed and facilities added accordingly. The water quality banking credits for each project, however, do contribute to a regional approach being part of each specific design project. With each specific location, the contribution to or debit from the Water Quality Bank must be tracked, recorded, and approved for the appropriate watershed. This tracking does create a watershed approach, but primarily in the three that are in a deficit situation.

Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

Within the Office of Highway Development GI sites are all evaluated per available appropriate land within a project. They are screened for low-lying areas generally free of obstructions and preferably void of woods in good condition, as well as homes, businesses, and other structures. Selection of the SWM facility type will then depend on many of the factors of the area, such as soil type, drainage area, infiltration rates, shape of available space, accessibility, clear zone proximity, and several other factors. Areas with water quality credits may also receive fewer facilities than areas with a near zero credits or a negative balance. When space is available, additional facilities that exceed project needs will be added to increase Water Quality Bank balances. GI such as pervious pavement also depends on infiltration rates of subsoils and agreement of local jurisdictions to provide proper maintenance. Outfall and retrofit projects are generally selected based on need or inspections ranking their functionality. These items are part of a more programmatic approach to GI as complementary to the Drainage and SWM Asset Management Program.

What did we miss? Is there some better technique or approach to GI planning, design,

construction, maintenance, or inventory of GI locations that we did not address?

The ongoing evolution of GI through regulatory changes, technology changes, and public involvement cannot be emphasized strongly enough. The MDOT SHA Drainage and SWM Program has existed for nearly 20 years and has seen explosive growth as regulations have changed and become more comprehensive. Ongoing research, as well as changes to weather patterns, have necessitated many new aspects to the program.

Advancements in technology have made taking inventory, doing inspections, tracking, coordinating, designing, and maintaining facilities both easier and more complex. In the past a single person could track all the facilities and know their status. Now a large team across two offices with a select few with extensive GIS experience is needed to keep it all coordinated.

Learning which facility types are less successful and why and whether to adjust designs or replace them with newer technology is an ongoing challenge. Layers of permitting complexity stretch out design and repair processes, none of which could have been foreseen when the program kicked off.

Do you test soils prior to design to identify the best solution?

Soils are tested as part of the design process; however, this is generally done at approximately 60% design completion. Soils testing takes place at sites as designated by the plans and will include infiltration testing in addition to soil typing. This data is used to verify the design courses and it is not unusual to have to adjust designs based on the soils report once it is received from the geotechnical engineers.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

Maryland has several laws that support GI. Some examples are:

- ◆ COMAR 26.17.02 for SWM requirements for 5000 square foot or larger sites or larger than 100 cubic yards disturbed
- ◆ 2007 Stormwater Management Law requiring environmental site design

Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?

The Maryland Department of the Environment has been involved in all GI processes across the state from the beginning of all implementation. In addition, project-specific groups supporting various causes may become involved during the planning stages of a project. Such groups include the Save the Bay Foundation, the Department of Natural

Resources, Local Soil Conservation Districts, Clean Harbors, and others. MDOT SHA holds public meetings during roadway design planning to offer the opportunity of all interested citizens and groups to become involved in the planning process.

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

Primarily the Drainage and SWM Asset Management Team focuses on internal education and outreach. It spends time coordinating with internal customers at MDOT SHA, including the Data Governance Division, to continue applying expanding technology to programmatic needs for tracking, data management, GIS, coordination, asset-management software programming, and other evolving technologies, such as the use of drones for SWM inspections. It also spends time educating maintenance staff on the proper care for SWM facilities to ensure long-term functionality. It will also focus efforts outside of the headquarters locations to the remote district offices that need support on understanding the complex laws and permitting requirements for project development.

What obstacles still exist (e.g., organizational culture, lack of buy-in from designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

The two largest obstacles to GI that still exist are:

- ◆ Overlapping regulations within MDE that often conflict with compliance with the SWM regulations. This is primarily seen when SWM facilities require remediation. This remediation will remain within the original footprint of a facility previously permitted by MDE and constructed under this permit. Once constructed the facility is considered part of the baseline for treatment that must be maintained. When facilities require larger scale remediation, the permitting process to allow contractors to perform the work is very close to as extensive as permitting for a brand new facility. This large and layered permit process severely limits the ability for contractors to get out to perform remediation quickly and therefore risks further degradation of facilities with already compromised function.
- ◆ Organizational culture has focused primarily on practical design, which emphasizes efficiency in construction of roadway projects, but does not continue to include environmental stewardship as a pillar of project evaluation. In the recent past policymakers for this system were not from Maryland and did not appear to spend extensive time with program managers or others to learn the complex environmental needs for good programming. New leadership appears to be unaware of these issues and program managers, chiefs, and directors are often seeking ways to work around organizational policies to continue to inventory, inspect, plan, and ultimately construct SWM facilities and other restoration facilities. Maintenance coordination being extremely difficult historically also can be tied back to organizational culture because program managers are requesting services and work from district personnel with whom they have neither any association nor the authority to direct. Continued

outreach and coordination is anticipated to help solve this problem.

Nevada Department of Transportation (NDOT)

LA Landscape Architecture

Agency Information:

Please identify types of GI required to be implemented under regulatory programs (i.e., NPDES, etc.) versus voluntary GI initiatives i.e., community rain gardens.

The types of GI are not specifically identified by any regulatory programs; rather, the outcome is. We need to meet requirements but we choose the method. For projects that impact impaired receiving waters and, depending on your definition of GI, we might use rock mulch cover, detention areas, microcatchments, riprap, erosion blankets, soil roughening, seeding, planting, track walking, and rain-water harvesting at plant basins. Depending on the permit type the goal may differ; however, impaired receiving waters require water quality compliance.

Does your agency have rule/ordinance making authority? Do your GI efforts distinguish from a stormwater (SW) program? Are there distinct duties, responsibilities, and designated staff between GI and SW? Are they distinguished as different sections or are they so integrated they are considered to be the same section? Describe any recent organizational changes made to implement the program.

GI is a joint effort with the Landscape Architecture and Stormwater Division; they are two different sections. Stormwater was recently created and its goal is to increase GI implementation.

NDOT does not have ordinance-creating authority. Landscape Architecture (LA) does not have the duty of implementing GI to meet permitting requirements; however, due to the impact and the ability to mitigate for air and water quality efforts within the scope of our projects, we provide designs that strive to achieve this intent. LA develops GI methods that both provide an aesthetic quality while mitigating for erosion, water quality, and air quality.

What types of GI have been installed by your agency? How does your agency track GI type and location? How do you track function and performance to understand if constructed GI is working as designed? Describe any recent changes made or recommended.

Retention/infiltration facilities, permeable pavement (discontinued), vegetated swales, dry swales, disconnect impervious areas. We have also installed rock microcatchments on slopes, soil tilling/roughening, salvaged and seeded topsoil placed on top of large riprap,

hydromodification, rainwater harvesting basins, and replanting of salvaged plants. We informally monitor projects in subsequent years for success and failure of vegetation cover from seed, salvaged planting, erosion, weeds, and impacts to gray infrastructure.

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

Yes, we have a Stormwater Planning and Design Guide.

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

Yes – update water quality design storm and improve BMP design guidance. We believe a smaller design storm may be warranted and would allow facilities to be more effective and implanted in more projects.

Green Infrastructure best management practices have been in use for many years as part of comprehensive stormwater management strategies. When did your agency begin implementation of a GI Program?

In general, GI was not incorporated in projects as a stormwater management practice outside the Lake Tahoe basin until 2015. Some worked well and some did not. Infiltration rates not meeting design values has been an issue. Most of the GI used on projects outside the Tahoe basin were not done to manage stormwater for water quality reasons; rather, they were employed for slope stability, erosion control, and an applied aesthetic.

Does your agency have a leader/champion for GI design practices and planning?

The LA and Stormwater managers are champions for GI.

Obstacles: culture (“We just build roads”), funding, lack of vegetation success, lack of research into arid environment growth, lack of training for inspection and installation of native vegetation, lack of maintenance funding, and temporary or permanent irrigation is often not provided.

What is the leadership/champions role in promoting GI?

Yes. Stormwater is the lead division for GI in projects that impact impaired receiving waters and coordinates with the other teams like hydraulics, roadway design, landscape architecture, environmental and maintenance. For projects that include a landscape architectural component, LA will lead the design for GI and will coordinate with appropriate disciplines. LA will usually promote the use of vegetation as an integral part of the GI.

What obstacles, concerns or barriers to GI exist in the agency?

Educating and training staff is a concern. We are working on developing a GI design training program. Currently it is a mentorship program. Other barriers include working within the confines of a large governmental agency. Sweeping decisions are made due to budgetary constraints that affect all state agencies whether or not there is a genuine need that may save money in the long run.

Who in your agency identifies and selects potential GI projects? Did you encounter resistance from certain groups? If so, how did you overcome this resistance?

GI is looked at for all projects and is implemented when it is determined to be cost effective, maintainable, and provides a benefit to surface water quality. LA uses GI to help promote plant growth and, in general, slope stability. Hydromodification has been used for both aesthetic reasons as well as to provide low basin areas for water infiltration, slow peak flows, and improve plant growth. In the past the resistance has been to effectively provide designs for a contractor to bid and build from using the existing pay items. We have now overcome that barrier by improving our plans, details, and specifications.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

A combination of federal and state. GI is not funded separately but is inclusive of the overall funding for the design for any roadway project unless it is exclusively a project on Stormwater's high priority list.

Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?

GI is a priority for executive management when it may be a solution for decreasing the number of projects we are maintaining the permits for or a solution for stabilizing failing slopes. Management often does not have the expertise in erosion control and will allow the engineers and landscape architects to provide solutions. That being said, both engineers and landscape architects in the department are not trained erosion control experts or GI experts but are allowed to try innovative approaches when practical.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

We use a collaborative approach whenever possible. It is not formalized but a subgroup of

the overall project team. We find the expertise comes from a combination of disciplines, stormwater engineers, landscape architects, geotech, roadway engineers, and sometimes structural engineers.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them? Does your training extend to external customers, such as local agencies, MPOs, consultants, and contractors?

We are not formally trained in the design of GI; rather, we use combined experience, hired consultants, applicable courses when available, expositions, and professional conferences.

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

GI has not become the standard but is perceived as a useful addition to larger traditional gray infrastructure. I don't believe there is enough data for GI to satisfy hydraulic engineers. When using a living medium there is always a level of risk. We use GI both as a method or tool to meet permit requirements and for general performance of the landscape areas to slow the corrosive movement of water and further protect any gray infrastructure.

What considerations does your agency take into account when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined? Are residents willing to put up with construction in their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?

Both gray and green infrastructure have their place; one or the other may be the best option, depending on the project. As mentioned above, both can be used in combination with one another, lessening the impacts on each separately.

What current trends do you see – increases in implementation of GI? Increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

I see an increased use of GI. We are now becoming more familiar with the use of GI and which methods are best used in differing climates. I do not see an improvement in maintenance to train and dedicate forces to GI. The permitting agencies in southern Nevada have become more stringent on air quality requirements, which means better methods of suppressing blowing dust.

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

Why does your agency implement GI (i.e., vision, mission, resource agency demand, regulatory,

TMDL, public demand, etc.)? What criteria do you use to evaluate GI proposals?

Criteria are provided in the PDG to determine when it is a requirement, otherwise it is a cost/maintenance analysis. The use of GI can add to the aesthetic quality of a project – landform manipulation, rock mulch patterns, native flora, and sculptures that capture water. The goal of improving the quality of life of the traveling public is always a goal and GI is often used simply as a method of achieving that goal.

What criteria do you use to select alternatives and practices? Is your agency willing to purchase right of way or condemn property solely for use as GI?

No.

Describe what is driving your decision to use GI.

Environmental permits, improvement to water quality, and reduced cost

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

All except coastal

At what phase of project development do you begin identifying specific GI practices?

Project planning phase

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

No, but we are evaluating INVEST.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

Yes. We inventory GI locations using GIS.

Does your agency leadership support the use of GI on transportation projects? Does your agency engage stakeholders to evaluate the use of GI for roadside water management? If so, how do they engage the stakeholders? Do your regulators promote and support the use of GI? If yes, how do they work with your agency to select, develop and fund GI?

We are working on that; basically now we tie it to meeting permit conditions.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

Web page, Facebook, YouTube, booths at conferences, etc., and we have a public outreach coordinator.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

GI practices are beginning to be tracked on a spreadsheet that just lists what was done.

In your experience, what is the most crucial factor to consider in GI?

The most crucial factor is making sure maintenance can and will be done.

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

Yes, we have done that in the past. It helps with implementation when it is successful.

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

Inconsistencies in stormwater management regulation have not yet created a conflict in funding or design of GI.

Are there other design considerations your agency had considered that were not supported? Why not?

No.

What lessons have been learned from the GI installed? Have different BMPs performed better than others? Have any GI types been eliminated from use? If yes, why?

Lessons learned – We need infiltration testing for design and need to evaluate if there is a significant amount of sediment generated on roads with untreated cut slopes and this greatly increases maintenance. We need more information on water quality impact benefits of filter strips and swales that are not vegetated.

Based on lessons learned, what project types are most feasible going forward for future projects?

Source control projects

What were the unique challenges during construction? Overall timing of the construction/installation?

Challenges during construction are getting contractors to properly install and care for revegetation, training inspectors on revegetation practices, and closing out contracts without having the contractor be responsible for vegetation for three years until it has grown enough to permanently stabilize the disturbed area.

Have there been issues with successful vegetation establishment related to specific BMPs? What were the specific challenges associated with vegetation on the urban roadside?

GI is designed for an average storm; extreme events are not used.

When designing the GI, what metrics were used and were extreme weather events part of the calculation?

No.

Does your design accommodate increased long-term flows? On what is that based?

No.

Describe coordination, training and outreach with the public, including adjacent property owners.

Stormwater staff performs public outreach.

Performance Measures

What requirements do the regulatory agencies impose? Describe any programmatic agreements achieved through GI project design approach (e.g., mitigation credits).

Achieving the 70% pre-existing plant coverage is difficult to do in an arid climate. It will take a minimum of three years for plants to establish to the point of stabilizing disturbed areas. This is further constrained by the contracting community's desire to remove the plant establishment period for projects that need to be at least one year.

Have you developed a general rule of thumb for funding spent on GI?

No.

Have you seen a difference in cost between GI and gray infrastructure?

Need more data.

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction?

Not yet.

Have you documented a cost savings for these processes?

No.

Do you conduct a cost/benefit analysis of the GI proposed for a specific project to determine the efficacy of the BMP? Is the funding amount tied to GI performance measures?

No.

Do you require contractors to have a plant establishment period? If so, for how long?

Typically, it's one year from substantial completion or two years for LA projects.

Are there any challenges associated with setting a plant establishment period? How is the plant establishment period handled? (e.g., Is it in the contract? Is it covered by a bond? Do state forces assist?

The plant establishment period is determined on a project-by-project basis. Challenges include the seeding or planting window we have, taking advantage of the cooler, wetter seasons. It is covered in the cost building the project.

Do you have any issues with establishing prescribed permanent vegetation after construction of GI? Have invasive species presented any challenges with a particular GI type? Location? How has this been resolved?

Permanent vegetation is difficult to establish whether in a microcatchment or on any other landscape area of the project. The best resolution has been to write into the specifications for the contractor to remove invasive and noxious weeds as part of the construction and plant establishment. Knowledge on how best to treat specific weed species is helpful.

Has there been pushback on the appearance of GI in urban areas?

Yes, many of our native plants look weedy to the public. Dense urban areas are not the best places to design expansive seeded areas.

How many acre-feet of water per year are captured by GI techniques?

Unknown.

Do you use a scoring tool to prioritize projects, funding, and programming?

Decision Lense has been used.

Can you provide data demonstrating how GI implementation has helped to mitigate impacts or improve environmental outcomes?

No.

Was land acquired outside of the right of way to meet the GI objective?

303d sites are prioritized but the quantity of pollutants is not measured.

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals and/or water quality concerns?

No.

Maintenance

How does your maintenance personnel take care of GI (no maintenance or equipment [mechanical, handheld, or other])? Please describe. Does your GI take more maintenance than gray infrastructure, or less? Are there seasonal requirements?

- ◆ Typically mechanical equipment is used to clean out basins.
- ◆ State highway funds
- ◆ Some manpower has been added to take care of GI but those resources are currently focused on cleaning big culverts, flooding, and safety issues.
- ◆ Currently the stormwater maintenance crews have special training to run vector trucks and large equipment to clean out basins and culverts
- ◆ A dedicated crew runs vector trucks.

How is maintenance funded?

State general funds

Has funding increased or decreased as a result of GI? Is there a dedicated funding source for maintenance of GI?

Increased funding has not resulted with the use of GI.

Are maintenance personnel trained on GI maintenance requirements?

No, excepting vector trucks.

Is there a dedicated crew for GI or is it considered part of general maintenance? Does your agency maintain GI as part of larger roadside maintenance contracts or agreements?

No.

How do you inspect GI to ensure function is maintained? Does each GI type have a scheduled maintenance plan in place? How is this delivered? Do you coordinate between other/multiple agencies for maintenance?

Yes. We have recently completed a Stormwater O&M manual that has maintenance triggers. We are working on improving those forms based on feedback from the field.

Do you have a method to identify maintenance triggers?

Yes. We have recently completed a Stormwater O&M manual that has maintenance triggers. We are working on improving those forms based on feedback from the field.

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

The DOT has not identified any.

Is special equipment required for maintenance of GI elements? If so, how is this funded?

Vector trucks – they are funded by the overall maintenance budget.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

We are working to identify projects where GI can be incorporated with already scheduled maintenance projects.

Miscellaneous Questions

Does your agency only focus on small-scale design specific to an area or take a regional approach?

Only small-scale design due to the small footprint of DOT ROW in the watershed. We are beginning discussions with the state environmental agency and other jurisdictions on partnering to do watershed-wide mitigation efforts.

Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

No key alliances.

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

Criteria are identified in the PDG.

What did we miss? Is there some better technique or approach to GI planning, design, funding, construction, maintenance, or inventory of GI locations that we did not address? How do innovative contracting methods affect GI implementation strategies?

Design-build projects need to have strong, enforceable performance measures to make sure the GI is built correctly and is effective.

Do you test soils prior to design to identify the best solution?

We do through our consultants for LA projects. It needs to be done more consistently.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

No.

What obstacles still exist (e.g., organizational culture, lack of buy-in from managers, designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

Organizational culture, lack of buy-in from designers, and lack of training

Oregon Department of Transportation (ODOT)

DEQ Department of Environmental Quality

Agency Information

Please identify types of GI required to be implemented under regulatory programs (i.e., NPDES, etc.) versus voluntary GI initiatives i.e., community rain gardens.

None required, but LID is encouraged by both NMFS and the Oregon Department of Environmental Quality (DEQ).

Does your agency have rule/ordinance making authority?

No.

Do your GI efforts distinguish from a stormwater (SW) program?

No.

Are there distinct duties, responsibilities, and designated staff between GI and SW?

No.

What types of GI have been installed by your agency?

Filter strips, CAVFS, amended soil bioswales, and bioretention facilities

How does your agency track GI type and location?

We do not differentiate LID from other stormwater treatment BMPs.

How do you track function and performance to understand if constructed GI is working as designed?

We don't.

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

Our ODOT Hydraulics Manual has an appendix on LID⁹⁸. Generally the BMPs in the manual all include elements that are necessary for LID/GI BMPs.

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

We intend to keep the manual up to date and in the meantime provide technical guidance bulletins; nothing big is on the schedule.

Green Infrastructure best management practices have been in use for many years as part of comprehensive stormwater management strategies. When did your agency begin implementation of a GI Program?

No program, but inclusion of LID techniques began at least 10 years ago.

Does your agency have a leader/champion for GI design practices and planning?

Sort of, in that the lead environmental stormwater and hydraulics engineers encourage the practice, but no formal effort beyond education.

What obstacles, concerns or barriers to GI exist in the agency?

98 Chapter 14: Water Quality, Hydraulics Manual, Oregon Department of Transportation,
https://www.oregon.gov/ODOT/GeoEnvironmental/Docs_Hydraulics_Manual/Hydraulics-14.pdf

No institutional, but some skepticism from older engineers and uncertainty in Maintenance about requirements that could add to their burden

Who in your agency identifies and selects potential GI projects? Did you encounter resistance from certain groups? If so, how did you overcome this resistance?

N/A

What criteria does your agency use for programming, prioritizing, and funding GI projects? Is GI considered for all projects? Is GI required for specific watersheds in your state? How does the regulatory authority convey GI requirements to the transportation agency?

N/A

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

N/A

Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?

Executive management recognizes that stormwater is an issue but they have generally stayed out of the conversation about approaches.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

Individual facility design is usually done by the hydraulics engineer with input from Environmental (about permit criteria) and LA for soil, seeding, and other issues.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them? Does your training extend to external customers, such as local agencies, MPOs, consultants, and contractors?

The agency doesn't offer any specific training.

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

We incorporate LID when it makes sense and fits the location, particularly when it is lower maintenance than gray BMPs.

What considerations does your agency take into account when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined?

The selection of BMPs is context sensitive – low maintenance and low life-cycle costs are important.

What current trends do you see – increases in implementation of GI?

Increase as we get more information about GI and gain experience.

Increase or decrease of funding? Dedicated maintenance forces to maintain GI?

We don't have dedicated funding for stormwater BMP maintenance of any sort and are not likely to anytime soon.

Any changes to legislation or permitting agencies increased requirements?

Not aware of any.

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

What criteria do you use to evaluate GI proposals?

Site feasibility, cost, life cycle, and maintenance.

What criteria do you use to select alternatives and practices? Is your agency willing to purchase right of way or condemn property solely for use as GI?

We would for a new alignment or a major enlargement that already included lots of ROW purchases, but we generally would like to avoid that.

Describe what is driving your decision to use GI.

Site feasibility, cost, life cycle, and maintenance, plus regulatory acceptance or encouragement.

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

Urban is the least likely.

At what phase of project development do you begin identifying specific GI practices?

Pre-preliminary design.

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

No.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

No.

Does your agency leadership support the use of GI on transportation projects? Does your agency engage stakeholders to evaluate the use of GI for roadside water management? If so, how do they engage the stakeholders? Do your regulators promote and support the use of GI? If yes, how do they work with your agency to select, develop and fund GI?

We are transportation, so yes, we do.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

Internal training, Hydraulics Manual.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

No.

In your experience, what is the most crucial factor to consider in GI?

Site feasibility.

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

No.

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

We have worked with NMFS and the Oregon DEQ to establish consistent expectations. Local jurisdictions are a different matter and it is sometimes unclear to what extent we are subject to their rules. They are subject to our stormwater criteria for federal aid projects.

What lessons have been learned from the GI installed? Have different BMPs performed better than others? Have any GI types been eliminated from use? If yes, why?

No evaluation so far.

Based on lessons learned, what project types are most feasible going forward for future projects?

No evaluation so far.

What were the unique challenges during construction? Overall timing of the construction/installation?

No evaluation so far.

Have there been issues with successful vegetation establishment related to specific BMPs? What were the specific challenges associated with vegetation on the urban roadside?

The biggest vegetation establishment problems tend to come from poor enforcement of specifications and issues with poor plantings.

Does your design accommodate increased long-term flows? On what is that based?

No.

Describe coordination, training and outreach with the public, including adjacent property owners.

Only internal training.

Performance Measures

What requirements do the regulatory agencies impose? Describe any programmatic agreements achieved through GI project design approach (e.g., mitigation credits).

Stormwater management criteria worked are out with NMFS and the Oregon DEQ. Endangered Species Act requirements are included in BAs and the programmatic FAHP Programmatic Biological Opinion. Requirements are negotiated with NMFS and DEQ and are consistent.

Have you developed a general rule of thumb for funding spent on GI?

No.

Have you seen a difference in cost between GI and gray infrastructure?

No.

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction.

No.

Have you documented a cost savings for these processes?

No.

Do you conduct a cost/benefit analysis of the GI proposed for a specific project to determine the efficacy of the BMP? Is the funding amount tied to GI performance measures?

No.

Do you require contractors to have a plant establishment period? If so, for how long?

Yes, usually a year but it can vary.

Has there been pushback on the appearance of GI in urban areas?

Not for ODOT.

How many acre-feet of water per year are captured by GI techniques?

Not tracked.

Do you use a scoring tool to prioritize projects, funding, and programming?

For GI? No.

Was there habitat enhancement after project completion? How long did it take for the enhancement to occur?

Not monitored.

Did your GI project support efforts to address 303d listed water bodies pollutants of concern? Was funding made available to prioritize the use of GI when in association with the transportation project? Was the quantity of pollutants removed measured and identified? Over time, did the pollutants decrease?

Not monitored

Was land acquired outside of the right of way to meet the GI objective?

Only if the project was already acquiring ROW.

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals and/or water quality concerns?

No.

Maintenance

How does your maintenance personnel take care of GI (no maintenance or equipment [mechanical, handheld, or other])? Please describe. Does your GI take more maintenance than gray infrastructure, or less? Are there seasonal requirements?

For filter strips the area is treated like a normal roadside area and mowed. We have not collected data on the effort required to maintain bioretention facilities to determine what extra costs might be incurred beyond what an old-style detention pond would require.

How is maintenance funded?

State transportation funds. Note that there is no specific allocation for maintenance of stormwater facilities.

Has funding increased or decreased as a result of GI? Is there a dedicated funding source for maintenance of GI?

GI has not affected funding in any way; stormwater facility maintenance is not broken out from regular maintenance.

Are maintenance personnel trained on GI maintenance requirements?

No. In theory standard maintenance tables and O&M manuals should provide adequate information on their maintenance.

Is there a dedicated crew for GI or is it considered part of general maintenance?

General maintenance.

Does your agency maintain GI as part of larger roadside maintenance contracts or agreements?

No.

How do you inspect GI to ensure function is maintained? Does each GI type have a scheduled maintenance plan in place? How is this delivered? Do you coordinate between other/multiple agencies for maintenance?

Stormwater BMPs have standard maintenance tables and site-specific O&M manuals, at least in theory. Maintenance crews follow those tables and the maintenance schedule to the extent that they do not interfere with higher priority roadway maintenance.

Do you have a method to identify maintenance triggers?

Standard maintenance tables include list of conditions triggering maintenance, along with the recommended action.

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

This is a concern but we haven't had a problem yet that has required a specific response. This would be an issue with treatment wetlands, of which we have few if any, and wet detention or retention ponds, of which we have few.

Is special equipment required for maintenance of GI elements? If so, how is this funded?

No.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

We install stormwater BMPs, LID or otherwise, when a project includes specific elements, such as increasing impervious surface area. Replacing infrastructure under a street by itself would not trigger the installation of BMPs.

Miscellaneous Questions

Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

We have just begun investigating collaboration with local jurisdictions to address watershed and transportation system scale approaches.

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

Site conditions, including topography, land use, and conflicting resources.

Do you test soils prior to design to identify the best solution?

If infiltration is a prime component of the BMP, we test permeability and will test soils to see if amendments are needed to support plant growth.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

No.

Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?

N/A

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

N/A

What obstacles still exist (e.g., organizational culture, lack of buy-in from managers, designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

Some engineers might be uncomfortable with some of the “softer” approaches. GI/LID will meet resistance if ROW requirements are greater than for standard gray BMPs. This may be counterbalanced, particularly when choosing between LID and proprietary treatment systems if the maintenance requirements for LID are substantially less than for the proprietary systems.

Pennsylvania Department of Transportation (PennDOT)

Agency Information

Do your GI efforts distinguish from a stormwater program? Are there distinct duties, responsibilities, designated staff between GI and SW? Do they think of themselves as a different section or are they so integrated it is unrecognizable as two different sections? Describe any recent organizational changes made to implement the program.

PennDOT does not have separate GI and SW programs. Until recently we did not have any positions dedicated to SW. We have historically relied upon consultant expertise to advise on SW-related policies and guidance. GI is generally integrated into the project design as a need to satisfy permit/regulatory requirements.

What types of GI have been installed by your agency, and how many of each type?

Stormwater control measures have almost all been constructed as a requirement of an NPDES permit and/or state regulations to offset the project impacts. PennDOT currently has the following stormwater control measures inventoried:

- ◆ 472 Dry Detention Basins
- ◆ 209 Infiltration Basins
- ◆ 101 Wet Basins
- ◆ 197 Bioretention

- ◆ 189 Infiltration Trenches
- ◆ 84 Infiltration Berms
- ◆ 510 Vegetated Swales
- ◆ 20 Vegetated Filter Strips
- ◆ 114 Manufactured Treatment Devices
- ◆ 13 Media Filter Drains
- ◆ 10 Stormwater Wetlands

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

Yes. PennDOT has a post-construction stormwater management policy that outlines acceptable stormwater controls for highway projects⁹⁹.

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

Yes. Since the current stormwater policy is 10 years old, it is being updated to expand the suite of practices that can be used for projects.

When did your agency begin implementation of GI? Is the existing, constructed GI working as designed? Describe any recent changes made or recommended?

Implementation of GI, most notably stormwater controls other than traditional dry detention basins, began in approximately 2007. Most of the stormwater control measures in the ground have not been thoroughly enough inspected to determine if they are working as designed.

What obstacles, concerns or barriers to GI exist in the agency?

Agency leaders generally support GI but there is no identifiable champion for GI design practices and planning.

Who identifies and selects potential projects? What criteria does your agency use for programming, prioritizing, and funding GI projects?

GI is implemented as needed to satisfy regulatory/permit requirements. PennDOT has

⁹⁹ Chapter 13 – Erosion and Sediment Pollution Control, Publication 13M (DM-2), Pennsylvania Department of Transportation, <https://www.dot.state.pa.us/public/Bureaus/design/PUB13M/Chapters/Chap13.pdf>

not undertaken standalone GI projects to date. The prioritization and funding are based on the project-specific need.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

Again, PennDOT has not funded projects that are strictly GI. Federal and state funds have been used to pay for projects that utilize GI to help address permit/regulatory requirements.

Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?

GI is beginning to be driven by MS4 permit requirements. As adjacent planning partners (municipalities) also face MS4 requirements, executive leadership is emphasizing agency cooperation/coordination with planning partners, which may lead to more GI projects.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

Not exactly. The engineering consultant responsible for the SW design and NPDES permit on a project is normally the lead on GI design. The consultant will pull in the appropriate expertise as the design progresses. Though not a common practice in the past, maintenance is being brought into the design discussion more frequently.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them?

The engineering consultants hired by PennDOT are generally well trained in GI design. PennDOT has its own four-day training course on stormwater design and NPDES permits. Stormwater is more integrated into civil engineering curriculums than it has been in the past.

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

GI practices are generally only included when required by permit. However, past practices such as concrete-lined ditches have been phased out and replaced with reinforced vegetated channels.

What considerations does your agency take into account when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined? Are residents willing to put up with years of tunneling under their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?

GI is normally only implemented when required by a permit or regulation. Comparisons of green and gray infrastructure are difficult to make because GI is implemented wherever needed to satisfy permit/regulatory requirements. Cost comparisons are not made unless justification is needed not to implement GI.

What current trends do you see – increases in implementation of GI? Increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

Due in large part to state regulatory stormwater requirements and MS4 permit conditions (e.g., pollutant reduction plans), GI is becoming commonplace on most projects. Funding is slow to catch up with need/demand. PennDOT does not have any maintenance forces dedicated to GI. The same operators and foremen performing road-patching work will likely also be performing GI maintenance work.

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

Why does your agency implement GI (i.e., vision, mission, resource agency demand, regulatory, TMDL, public demand, etc.)?

PennDOT implements GI primarily to address regulatory requirements (i.e., NPDES construction permits, MS4 permit).

What criteria do you use to evaluate GI proposals?

N/A

What criteria do you use to select alternatives and practices?

Does it satisfy the regulatory requirements (e.g., volume, rate, and water quality control)? Is it practicable? What are the long-term operation and maintenance costs?

Describe what is driving your decision to use GI.

Regulatory requirements.

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

All applicable environments in Pennsylvania.

At what phase of project development do you begin identifying specific GI practices?

Preliminary design, which occurs before environmental clearance.

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI?

No.

Have you developed your own scoring mechanism?

No.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

Not yet, but we plan in the future to identify potential GI projects to reduce sediment loading in sediment-impaired streams.

How does your agency convince management or stakeholders that GI is critical to roadside water management (or vice versa)?

Obtaining NPDES permit coverage for a project is often on a critical path in the project schedule. Explaining how GI is necessary to satisfy permit requirements links GI to project delivery.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

PennDOT conducts stormwater design/NPDES training for employees and consultants. Other stormwater-related information is shared on PennDOT's website.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

PennDOT has a database of stormwater control measures. Data tracked includes type, location, receiving water body, and area treated. Economic/social benefits are not tracked. It is a spreadsheet data entry with an Oracle database, where the information is visualized in a GIS application developed for PennDOT called Maintenance-IQ.

In your experience, what is the most crucial factor to consider in GI?

Maintenance.

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

PennDOT has recently begun to monitor pilot projects. It is too early to draw conclusions.

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

Within Pennsylvania, the stormwater management regulations/requirements are fairly consistent. PennDOT has developed guidelines based on the requirements. The Philadelphia Water Department (for the City of Philadelphia) has its own set of standards. Municipal requirements vary substantially, which makes local land development design a challenge.

Are there other design considerations your agency had considered that were not accepted by management? Why not?

N/A

What lessons have been learned from the GI installed?

Infiltration stormwater controls are extremely sensitive to construction methods and require careful oversight. Vegetative survival is difficult to predict and often other species take over.

Based on lessons learned, what project types are most feasible going forward for future projects?

N/A

What were the unique challenges during construction? Overall timing of the construction/installation?

N/A

When designing the GI, what metrics were used and were extreme weather events part of the calculation?

Extreme weather events (assuming greater than 100-year magnitude) have not been taken into account in design.

Does your design accommodate increased long-term flows? What is that based on?

N/A

Describe coordination, training and outreach with the public including adjacent property owners.

Affected property owners are involved through the NEPA process.

Performance Measures

Do you require contractors to have a plant establishment period? If so, how long?

Typically the only requirement is for the contractor to replace plants that are showing a decline in health or have died at the time of the final construction inspection (to authorize final payment). It is also at this time that the contractor is released as the co-applicant on the NPDES permit.

What requirements do the regulatory agencies impose? Describe any programmatic agreements achieved through GI project design approach (e.g., mitigation credits).

GI projects are basically necessary to achieve pollutant reductions associated with pollutant-reduction plans for MS4 permits. PADEP is generally amenable to mitigation and offsetting agreements, though the agency has not established a formal crediting program.

Have you developed a general rule of thumb for amount of \$ spent on GI?

No.

Have you seen a difference in cost between GI and gray infrastructure?

We have not compared costs unless it is necessary to justify the implementation of GI as impracticable for a project.

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction.

We do not have the information available to make such a comparison.

Have you documented a cost savings for these processes?

No.

Does the cost/benefit of the project determine the funding amount?

It will likely affect future projects. For example, PennDOT is exploring a P3 agreement in which interested vendors will submit a cost per annual pounds of sediment load reduced.

Do you have any issues with establishing permanent vegetation after construction of GI?

It is normally not a problem unless construction of the stormwater control measure is completed in the late fall (at the end of the growing season).

How many acre-feet of water per year are captured by GI techniques?

We do not have this information available.

Do you use a scoring tool to prioritize projects, funding, and programming?

No, not at this time; however, we anticipate developing something to evaluate sediment-reduction projects in the future.

What environmental problems have been solved and what supporting data can you provide? For example:

- ◆ Was there habitat enhancement after project completion? How long did it take for the enhancement to occur?
- ◆ Did any endangered species benefit or thrive or were they reintroduced to the site after project completion?
- ◆ Did 303d listed water bodies for pollutants of concern prioritize selecting the project site? Was the quantity of pollutants removed measured and identified? Over time, did the pollutants decrease?
- ◆ Reduction in basement flooding and fewer days of missed school (or other quality of life/public safety and convenience responses)?

We do not have the information to answer these questions at this time.

Was land acquired outside of the right of way to meet the GI objective?

On roadway reconstruction/widening projects, land has been obtained outside of the existing ROW to construct stormwater control measures necessary to obtain NPDES permit approval and satisfy regulatory requirements.

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals, water quality concerns?

The roadway improvements drive the project; GI is incorporated into the design to the extent practicable. The types of stormwater controls for those projects were, in part, selected based on local water quality concerns.

Maintenance

How does your maintenance personnel take care of GI – no maintenance, equipment (mechanical, handheld, other – please describe) Does your GI take more maintenance than normal, or less? Seasonal requirements?

Maintenance activities include a variety of tools and equipment. Each of the 67 counties has the necessary equipment for maintaining most stormwater control measures.

How is maintenance funded?

The same as other maintenance – through the state’s liquid fuels tax.

Has funding increased as a result of GI? Is there a dedicated funding source for maintenance of GI?

No, and this is a major obstacle to implementing GI beyond the minimum regulatory requirement.

What is the skill set of maintenance personnel?

Minimal experience with GI.

Is it a dedicated crew for GI or part of general maintenance?

General.

How do you plan for maintenance?

Currently, it primarily involves some routine/preventive maintenance (e.g., mowing) and as-needed/corrective maintenance. Mowing is scheduled a certain number of times per year; corrective work is scheduled as needed.

Do you coordinate between other/multiple agencies for maintenance?

No.

Do you have a method to identify maintenance triggers?

Inspections.

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

No.

Is special equipment required for maintenance of GI elements? If so, how is this funded?

No, not at this time because the types of GI allowed on projects is limited to those that do not normally require special equipment.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

This is something that may be considered in the future to help address pollutant reduction plans for PennDOT's MS4 permit.

Miscellaneous Questions

Does your agency only focus on small-scale design specific to an area or take a regional approach? Until recently, the focus was strictly location/project specific.

With new pollutant reduction plan requirements for MS4 permits, the focus will be broadened somewhat to address both project-specific requirements (NPDES construction permit) and water body/watershed requirements (MS4).

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

Currently, GI is used as needed to satisfy regulatory/NPDES permit requirements. When PennDOT's MS4 permit is renewed, additional GI will be targeted in areas with sediment-impaired streams.

What did we miss? Is there some better technique or approach to GI planning, design, construction, maintenance, or inventory of GI locations that we did not address?

No.

Do you test soils prior to design to identify the best solution?

More often than not, no.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

N/A

Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?

To a degree, yes, via the NEPA process.

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

The NEPA process.

What obstacles still exist (e.g., organizational culture, lack of buy-in from designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

Compared to our neighboring state DOTs, PennDOT has few dedicated resources to GI relative to the size of the state roadway system. Lack of internal expertise/knowledge and set-aside funding for GI projects are obstacles. PennDOT is slowly ramping up its program to deal with long-term stormwater control measure maintenance.

Philadelphia Water Department (PWD)

GARP Greened Acre Retrofit Program

GCCW Green City, Clean Waters

GSI Green Stormwater Implementation

SMIP Stormwater Management Incentives Program

Agency Information

Do your GI efforts distinguish from a stormwater program? Are there distinct duties, responsibilities, designated staff between GI and SW? Do they think of themselves as a different section or are they so integrated it is unrecognizable as two different sections? Describe any recent organizational changes made to implement the program.

GI represents only one part of the City's overall stormwater management programs. The city has a variety of programs deployed to manage stormwater across the city and regionally. Activities in the Municipal Separate Sewer System (MS4) range from track-down and elimination of dry weather flow from stormwater outfalls to municipal and industrial good housekeeping and implementation of pollution prevention practices. The department uses regulations to require private developers to build GI in both the MS4 and the combined sewer system sewer-sheds and provides monetary incentives for stormwater retrofits as well. However, the department's Public Retrofit Program, which represents the projects that the city designs, builds, and maintains, is only implemented within the combined sewer system.

PWD established an Office of Watersheds in the 1990s that oversaw GI activities, Long-Term Control Plan Update (LTCPU) compliance, the MS4 permit, and stream restoration along waterways. GI development, regulations, and incentives are now under a new Green Stormwater Implementation unit (GSI Unit); The Office of Watersheds manages permit compliance and other MS4 activities: and GI maintenance activities have been subsumed by the department's Operations and Maintenance units.

What types of GI have been installed by your agency, and how many of each type?

PWD has three implementation arms that determine GI development within Philadelphia (see page D-112), the:

- ◆ Public Retrofit Program (PWD designed, and built)
- ◆ Private Development Program (projects built in response to regulatory requirements)
- ◆ Incentive Program (the Stormwater Management Incentives Program [SMIP] or the Greened Acre Retrofit Program [GARP] grant programs)

Between 2011 and 2017 PWD built over 500 GI projects:

Project Type	Cumulative Number of Projects (FY11-FY17)	Cumulative Greened Acres (FY11-FY17)
Public Retrofits	152	198
Private Development	296	456
SMIP/GARP	55	301
Total	503	955

PWD’s public retrofit program has classified its output by project type:

GI Type	Approximate Number of Projects (FY11 - FY17)
Stormwater Tree	10+
Pervious Paving	6+
Rain Garden	50+
Stormwater Tree Trench	200+

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

- ◆ Green Stormwater Infrastructure Planning & Design¹⁰⁰
- ◆ Resource Directory¹⁰¹ (includes our complete catalogue of all resources needed to provide GSI planning and design services to PWD)
- ◆ Introduction, Philadelphia Stormwater Management Guidance Manual¹⁰²
- ◆ Stormwater Grants¹⁰³

100 Green Stormwater Infrastructure Planning & Design, Philadelphia Water Department, <http://philadelphiawater.org/gsi/planning-design/>

101 Resource Directory, Philadelphia Water Department, http://philadelphiawater.org/gsi/planning-design/resource_directory.html

102 Introduction, Philadelphia Stormwater Management Guidance Manual, Philadelphia Water Department, <https://www.pwdplanreview.org/manual/introduction>

103 Stormwater Grants, Water Utility, City of Philadelphia, <https://www.phila.gov/water/wu/stormwater/Pages/Grants.aspx>

Are you considering revising/changing current guidance, tools? If yes, describe the change, and process and why.

PWD revises its design and monitoring guidance regularly, utilizing feedback loops from the department's Maintenance and Construction units, often (but not exclusively) through a series of meetings called the Field-Based Observation meetings (FBOs). Furthermore, the GI unit's pilot program explores technical solutions to different challenges, which are then incorporated into PWD design guidance.

Such input supports changes to planning and design guidance utilized by PWD staff and consultants. Such changes can result in changes to specific system elements (inlet design and loading ratios) and lead to larger planning decisions (prioritize storage of run-off on parcels for ease of maintenance, avoidance of curb-line changes to reduce review time).

The following represent a few tests used by PWD to support its evaluations (as mentioned above)

- ◆ Simulated Runoff Test (SRT)
Performance testing – using a flow meter to have the system take on a design storm volume and flow and using the water level data to see what is happening in the subsurface. This can validate the system to either be over-performing, performing correctly, or have loss of infiltration.
- ◆ Capture Efficiency – Discharge a flow rate using the head in the tank to be similar to the design storm intensity. This is then discharged in various areas of the drainage area to validate that from multiple points the water will enter the system and that there is positive drainage. This is a post-construction inspection method
- ◆ Porous Pavement Testing – ASTM methods are followed for this.

When did your agency begin implementation of GI? Is the existing, constructed GI working as designed? Describe any recent changes made or recommended?

PWD began building GI in the early 2000s. The 2006 update to the city's stormwater management regulations and the city's parcel-based billing initiative were put in place to leverage a great deal of private stormwater management implementation toward the city's Clean Water Act commitments. At this point the city began to see broader scale application of GSI on private properties; on average PWD GI performs better than designed. A selection of recent changes includes, but is not limited to, utilizing advanced sewer inspections to make sure there are no undocumented laterals in impacted linear assets and updating welding specifications for liners.

Does your agency have a leader/champion for GI design practices and planning? What is the leadership/champions role in promoting GI?

The Water Department, and its associated agencies and partners, champions GI. Internally the heads of the individual implementation arms are the external points of contact that lead each form of GI implementation as well as the development of standards and practices

What obstacles, concerns or barriers to GI exist in the agency?

GI must prove its cost effectiveness and ensure that triple bottom-line benefits are met within the confines of the department's affordability requirements. Furthermore, many projects require a significant amount of coordination between agencies and property owners and the development of agreements therein is another obstacle met on an ongoing basis.

Who identifies and selects potential projects? What criteria does your agency use for programming, prioritizing, and funding GI projects?

There are three implementation arms that determine GI development within Philadelphia. The city leads one-third of site selection and others lead the other two-thirds.

- ◆ Regulatory – Stormwater management on development of over 15,000 square feet are required for compliance with the City of Philadelphia's stormwater management regulations, maintained by the private entity;
- ◆ Incentives – Retrofits of non-city-owned property to manage stormwater from impervious surfaces and maintained by the property owner to achieve stormwater billing credits. These may be supported by funding from the Stormwater Management Incentives Program (SMIP) or the Greened Acre Retrofit Program (GARP) grants. Planners in the public program (see following) are also encouraged to identify opportunities for incentivized GSI for the incentives team.
- ◆ Public Program – GSI projects implemented on public property, primarily in the public ROW (including GSI completed in conjunction with water/sewer projects) and parks, where stormwater infrastructure is the primary purpose of the project and is initiated, funded, designed, constructed, inspected, and maintained by PWD or one of its partners. PWD's public program regularly studies entire neighborhoods in what are called area of opportunity analysis studies. These study areas look at clusters of public land or at clusters of neighborhoods with significant stakeholder activity or interest. This enables GI planners to prioritize projects:
 - That are cost effective. Cost effectiveness is a function of the amount of stormwater that can be managed at that location, as well as the ease of design and the ability to combine the project with other projects within that section of the city into a construction package.
 - To which the department has easy access. GI in public streets is typically a by-right project, whereas GI on parks, schools, vacant lands, or other parcels may require more complex agreements and negotiations to build and maintain.

- That support partner needs and projects as identified during the area of opportunity analysis planning process or review of partner agencies capital improvement plans.

In doing so the public program is developing a queue of potential projects to implement.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

Dedicated funds are utilized for the development of publicly owned and maintained projects. Federal, foundation, and grant funding have been used to construct public GI. In addition, PWD has a dedicated funding stream for public retrofit projects in the tens of millions of dollars per year. At present the incentives program has an annual budget of \$15M that may soon increase to \$25M per year.

Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?

Absolutely. As a key component of the city's Clean Water Act compliance obligations, this is a priority for PWD and the city's executive management. In terms of problems, none faced to date have proven insurmountable; however, implementation costs have proven the most challenging to project (for understanding total program burden over a 25-year horizon) and to decrease by a significant measure over time.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

Yes, a multidisciplinary team that consists of a stormwater planner, design engineers, landscape architects, and Maintenance personnel are responsible for managing the project once the opportunity has been identified and scoped by the planners. Hydrology plays a much stronger role than hydraulics.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them?

PWD hires engineers with a wide berth of experience, not limited to any specific field. Consultants hired for on-call contracts generally are already well versed in GI. However, both staff and consultants are taken through an onboarding process that involves training and various levels of orientation.

Does your agency include GI practices only when required by permit or are GI practices the

preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

Neither. The city's obligation to comply with the Clean Water Act includes a commitment to GSI that works well in conjunction with traditional infrastructure also planned as a part of this Green City, Clean Waters (GCCW) program. The City of Philadelphia had oversized systems that needed to be adjusted with regulator balancing. Additional traditional improvements, such as the addition of a third barrel in our water treatment plants, are examples of traditional infrastructure modifications that are done in conjunction with our green program. For the City of Philadelphia, GSI is not viewed to be either/or.

What considerations does your agency consider when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined? Are residents willing to put up with years of tunneling under their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?

PWD's alternative analysis of gray versus green infrastructure can be found in its Philadelphia Combined Sewer Overflow LTCPU¹⁰⁴

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

What current trends do you see – increases in implementation of GI? Increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

PWD is increasing its deployment of GI to meet regulatory requirements. This growth in GI will necessitate increases in funding for construction and maintenance. As more projects are built in response to regulatory requirements and to take advantage of incentives, PWD's SMIP and GARP grant programs are seeing increased demand and entrepreneurs are launching businesses to support GI maintenance.

PWD publicly funded and managed projects are consistently more expensive (for the department) than privately managed projects developed to meet regulatory requirements or take advantage of incentives.

The department also regularly evaluates its own regulations, considering such changes as reducing GI triggers from 15,000 square feet of earth disturbance, to 5,000 square feet therein.

Why does your agency implement GI (i.e., vision, mission, resource agency demand, regulatory, TMDL, public demand, etc.)??

104 Section 9: Development and Comparison of Alternatives, Philadelphia Combined Sewer Overflow Long Term Control Plan Update, http://www.phillywatersheds.org/ltcpu/LTCPU_Section09_Alternatives.pdf

PWD's GI program was developed to meet its regulatory requirements as outlined in its Long Term Control Plan Update (LTCPU). See our answer to this question on page D 96.

What criteria do you use to evaluate GI proposals?

PWD chooses projects that maximize the drainage area managed, that can maximize the amount of surface expression (i.e., vegetated component of GI), and that can either manage the drainage area of disparate systems in one location or can be built adjacent to each other (to minimize cost either of construction, or of mobilization). PWD's GI planning process is detailed on page 13¹⁰⁵ of the Green Infrastructure Planning & Design Manual. Another resource is the Green Stormwater Infrastructure Planning & Design website¹⁰⁶. Simply put the PWD objectively maximizes drainage area and water quality benefits, consolidates SMP's when possible, and maximizes surface practices.

What criteria do you use to select alternatives and practices?

Cost effectiveness, support of community, ability to align with partner needs

Describe what is driving your decision to use GI.

PWD's GI program was developed to meet its regulatory requirements as outlined in its LTCP, support a triple bottom line benefit to communities across the city, and provide incremental environmental benefits as each individual GI system comes online.

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

Urban.

At what phase of project development do you begin identifying specific GI practices?

We identify practices during the planning process but confirm their use at a given location at the completion of 50% design, after the results of geotechnical testing and utility conflicts are confirmed.

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

No. As a whole, our public GSI program does not use a scoring tool. PWD initially developed

105 Green Infrastructure Planning & Design Manual, Version 2.0 April 2018, Philadelphia Water Department, http://documents.philadelphiawater.org/gsi/GSI_Planning_and_Design_Manual.pdf#page=13

106 Green Stormwater Infrastructure Planning & Design, Philadelphia Water Department, <http://philadelphiawater.org/gsi/planning-design/>

a scoring method for choosing green streets that evaluated the number of laterals and street trees, slope, proximity to inlets, discharge area size, sidewalk condition, and other factors. However, while this method was useful in getting a better sense of the overall scope of green street opportunities and identifying a few low-hanging fruit, it was not useful at identifying project-ready opportunities at scale. PWD abandoned this approach for a comprehensive planning effort that supports identifying more opportunities in a given neighborhood.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

GIS is utilized to identify and evaluate GI locations predesign. PWD also stores and tracks project information using ArcMap and other GIS systems. PWD stores information about potential opportunities as well as missed opportunities (and the reasons therein) in GIS systems. This enables PWD to routinely review missed and potential opportunities as solutions to technical challenges are developed. We realized we need to use GIS as part of comprehensive planning but not exclusively.

Missed opportunities push policy issues and design innovation. They show what is possible in the future for our program Private sites are a good example of a policy and programmatic change. We initially focused on public sites and streets, later we realized that there were ideal location for management on sites we didn't have access to. This helped us develop other programs and incentives to have these sites contribute to our mission.

How does your agency convince management or stakeholders that GI is critical to roadside water management (or vice versa)?

In 2012, a steering committee, the Water Department, the Streets Department, the city's legal office, the mayor's office, and many other city agencies came together to develop the GSI Design Manual. This initial meeting of the minds facilitated conflict resolution and coordination from the start of our program. Additionally, a variety of working groups and policies facilitate constant collaboration and joint investment in projects.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

The PWD Public Affairs staff manages a portfolio of media, social media, and other communications tools (from websites to mailers). Public Affairs also convenes and manages three working groups used to support clean waters and GI activities.

The Green City, Clean Waters Advisory Group comprises close to 200 neighborhood groups, registered community organizations, and environmental nonprofits and serves as a forum for PWD to share information related to its GI program.

The Green City, Clean Waters Steering Committee comprises active and engaged environmental nonprofits with a history of engaging city and state administrations on regulatory matters. Members of this committee were all active in sending letters to the newly elected mayor, Jim Kenney, in support of the GI program. Committee members regularly review PWD permit renewals and provide advice and support for the GI program.

The Clean Waters Task Force is made up of city agencies and functions as a cross-departmental forum to encourage compliance with Clean Water Act regulations across bureaucratic silos.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

Section 2.2 from our FY16 Annual Report

2.2 Green City, Clean Waters Program Tracking System

To facilitate the integration of existing databases and systems into the Green City, Clean Waters program tracking system, effort was focused on improving the linkage between the various project stages (planning, design, procurement, and construction) and streamlining the reporting process for internal and external data requests. Status updates on the existing databases and systems are provided in **Table 2**.

Existing Databases and Systems	Status
PlanIT	PWD’s tracking system that stores information from site evaluations conducted on locations throughout Philadelphia. All sites must undergo an initial evaluation to determine the feasibility of green infrastructure before they can be transferred to GreenIT to begin design phase. PlanIT Version 2.0 was finalized in FY16 and includes new fields to track policy and outreach information, upgraded mapping features, and connectivity with GreenIT and CAPIT.
GreenIT	PWD’s tracking system for all public green stormwater infrastructure projects from the concept through construction phases, GreenIT, tracks designated compliance metrics. During FY16, the development of a Version 3 scope was started for integration into the new CAPIT.
Plan Review Database	PWD’s tracking system that stores metrics, including detailed SMP data, related to private development project compliance with the Philadelphia Stormwater Regulations as well as voluntary Stormwater management retrofit projects. The database is designed to track workflows related to reviews and inspections, including the status of conceptual and technical reviews, record drawing reviews, and active and post-construction inspections.

Existing Databases and Systems	Status
CAPIT	PWD's Capital Project Tracking System will be upgraded to meet PWD's growing needs. In FY16, PWD worked towards understanding the requirements and doing configuration of the system that will replace CAPIT.
Geographic Information System (GIS) Asset Tracking	GIS is used to track the location all PWD Department assets including green infrastructure.
Maintenance Management Systems	Green stormwater infrastructure maintenance activities have been fully incorporated into PWD's Cityworks work order management system, which is linked to the City's GIS and provides tools to track and manage work performed on PWD's assets such as fire hydrants, inlets, water mains, sewers, and green stormwater infrastructure.

Table 2 *FY16 status updates for existing databases and systems used for program tracking*

2.2.1 Reporting Metrics

The information in GreenIT is used to produce compliance reporting outputs for the completed and planned public project tables. The reporting format is illustrated in Table 3. Information from the Stormwater Plan Review Database is used to produce reporting outputs for the private complete projects. The reporting format is illustrated in Table 4.

Public Project Tracking Metrics										
Project Name	Status	Storage Volume (cf)	New Trees	Drainage Area (sq. ft)	Greened Acres (acre-inch)	SMP Type	Program	Construction Cost	Partner(s)	Watershed

Table 3 *Public Project Tracking Metrics and Reporting Format*

Private Project Tracking Metrics						
Tracking Number	Sewer Type	Category	Watershed	Zip Code	SMP Type (s)	Greened Acres (acre-inch)

Table 4 *Private Project Tracking Metrics and Reporting Format*

In your experience, what is the most crucial factor to consider in GI?

Space (to build GI) and drainage area are the most crucial factors (i.e., do you have open spots at low points?).

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

PWD does document, monitor, and evaluate pilot projects. Use of monitoring (e.g., of system water level and ponding and stimulated run-off tests) support changes to design standards and construction specs. Refer to the Pilot Program Section of our evaluation and adaption plan¹⁰⁷.

107 Consent Order and Agreement, Evaluation and Adaption Plan, Green City, Clean Waters, City of Philadelphia Water Department, October 20, 2016, http://phillywatersheds.org/doc/Year5_EAPBody_website.pdf

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

No. Regulated projects disturbing an acre or more of land are required to obtain an NPDES permit from the Pennsylvania Department of Environmental Protection (DEP) in addition to an approval from PWD. As Philadelphia is both a city and county in Pennsylvania, it largely functions as a conservation district with the Pennsylvania DEP rather than as a local municipality, which provides opportunity for coordinated reviews. For active construction stormwater controls, a formal state DEP review is necessary for an acre or greater sites, and the requirements are very similar to those of PWD. For post-construction stormwater management reviews, the state DEP allows for sites to use PWD's regulations as alternative criteria for meeting the NPDES permit requirements. This functions as a deferral as a result of proactive coordination between the agencies and with how PWD's regulations are slightly more stringent (15,000 square feet), for both over and under 1-acre sites.

Are there other design considerations your agency had considered that were not accepted by management? Why not?

With long-term (45-year) maintenance obligations on the GCCW program, there is a lot of healthy discussion between designers and maintainers. This is not a matter of rejecting design concepts but rather determining the best approaches to meet short-term objectives while also maintaining long-term maintenance obligations.

What lessons have been learned from the GI installed?

PWD's maintenance and construction team provide significant ongoing feedback related to everything from loading ratios to preferred slopes. These feedback loops are developed through regular field-based observation meetings, life-cycle tracking, and retrofit evaluation of projects. This feedback loop has enabled PWD to significantly revise its design specifications and construction methods. In fact, the establishment of this feedback loop has proven to be the most important lesson learned because it has enabled the department to revise its design processes, encouraged the use of CCTV investigations before designing systems (to identify abandoned infrastructure), helped the department limit the amount of surveying done prior to construction, and helped the department anticipate when systems will need to be lined.

Additionally, there have been positive design improvements from GI installed, for example, storage below the orifice on slow-release systems. We have observed that these systems are holding or infiltrating more water than they were originally credited/designed. This has created a positive impact on our program.

Based on lessons learned, what project types are most feasible going forward for future projects?

PWD does not design and build as many stormwater planters as it did in the GI program's beginning; planters are expensive to build, hard to maintain, and are considered a tripping hazard in the urban Philadelphia environment. Furthermore, the percentage of planned GI associated with curblines changes as part of the overall portfolio of publicly built GI has been reduced to avoid external review and project costs.

What were the unique challenges during construction? Overall timing of the construction/installation?

PWD has had to develop new construction methods for infrastructure it was not familiar with building in advance of the program's development. However, the most recurrent challenge has been to aligning project construction with planting seasons in the spring or fall. PWD must regularly build a project, only to plant it later in the year. This can sometimes prove problematic with neighbors.

When designing the GI, what metrics were used and were extreme weather events part of the calculation?

PWD GI is sized to store the first 1.5 to 2 inches of runoff for its projects, its main metric for designing systems; however, all systems must also safely convey runoff produced in a 10-year storm. Where possible, PWD places its systems upstream from inlets and thus utilizes standard inlets as the mechanism by which overflow is managed.

Does your design accommodate increased long-term flows? What is that based on?

N/A .

Describe coordination, training and outreach with the public including adjacent property owners.

PWD's public affairs unit has established a workflow to support community outreach on a project-by-project basis. This workflow includes regular meetings with communities at varying stages of project development and updating neighborhood groups on projects within their community. Projects with significant impact on specific properties may be subject to even more and more-detailed community outreach.

Performance Measures

Do you require contractors to have a plant establishment period? If so, how long?

PWD has a provisional maintenance period that lasts eight weeks after planting, during which time contractors are required to ensure that the systems remain free of trash and

are watered and weeded. Guidance is available in our Green Stormwater Infrastructure Planning & Design manual¹⁰⁸.

What requirements do the regulatory agencies impose? Describe any programmatic agreements achieved through GI project design approach (e.g., mitigation credits).

The Clean Water Act requires the creation of an LTCPU, the framework Philadelphia abides by to manage its GI program. Additional regulations are imposed by the Wissahickon TMDL shape PWD's GI and stormwater programs.

Have you developed a general rule of thumb for amount of \$ spent on GI?

PWD aims to spend \$230,000 per greened acre (the first 1 inch of runoff from an acre of impervious surface) for design and construction. Our Stormwater Incentive Grants awards about \$100,000 per greened acre¹⁰⁹.

Have you seen a difference in cost between GI and gray infrastructure?

N/A

Have you seen a difference in cost when GI is a part of the planning process versus incorporated during design/construction.

N/A. PWD-constructed GSI is always part of the planning process.

Have you documented a cost savings for these processes?

N/A; however, PWD has a goal for reducing the cost of GSI implementation over time.

Does the cost/benefit of the project determine the funding amount?

N/A. PWD has a goal for reducing the cost of GSI implementation over time. Projects that were deemed too expensive are saved in a repository for the future, when we may have more advanced technologies or different strategies that no longer make that project out of financial reach.

Do you have any issues with establishing permanent vegetation after construction of GI?

Yes; however, our program is within an urban setting, which provides its own challenges. We have a robust maintenance program that monitors and regulates our sites (either through physical visits or remotely, through soil moisture sensors). Tracking systems

108 Green Stormwater Infrastructure Planning & Design, Philadelphia Water Department, <http://philadelphiawater.org/gsi/planning-design/>

109 Stormwater Incentive Grants Awarded!, Philadelphia Water Department, <https://www.phila.gov/water/PDF/SMIP-GARP-11.14.pdf>

and feedback loops are developed and facilitate the continual improvement of our plant establishment and post-construction processes. An example is our extensive maintenance manual¹¹⁰, which we have developed to identify the best plants for each site; this can depend on loading ratio to geographic location. All of these lead to successful vegetated sites.

Additionally, PWD is revising how it classifies its plantings in its specifications, turning them into line items, to enable the department to withhold payment if they are not properly installed and maintained during the eight-week provisional maintenance period.

How many acre-feet of water per year are captured by GI techniques?

Our annual targets can be found in our annual report¹¹¹. This year we reported 955 greened acres (a greened acre is used to measure the volume of capturing 1 inch of rainwater over a drainage acre per storm). Since the inception of our program we have prevented 199.5 million gallons of polluted water from entering the stormwater outfalls though GI and our gray enhancements. Please reference our EAP for our greened acre targets.

From Year 5 EAP

Metric	Units	Base Line Value	First 5-Year WQBEL Target	Cumulative Amount as of Year 5 (2016)
NE WPCP Improvements	Percent Complete	0	See Section 2.1.1	
SE WPCP Improvements	Percent Complete	0	See Section 2.1.2	
SW WPCP Improvements	Percent Complete	0	See Section 2.1.3	
Miles of Interceptor Lined	Miles	0	2	7.5
Overflow Reduction Volume	Million Gallons Per Year	0	600	1,710
Equivalent Mass Capture (TSS)	Percent	62%	Report value	70.5%
Equivalent Mass Capture (BOD)	Percent	62%	Report value	88.9%
Equivalent Mass Capture (Fecal Coliform)	Percent	62%	Report value	72.0%
Total Greened Acres	Greened Acres	0	744	837.7

110 Green Stormwater Infrastructure Maintenance Manual, Version 2.0 September 2016, Philadelphia Water Department, http://documents.philadelphiawater.org/gsi/GSI_Maintenance_Manual.pdf

111 Stormwater Management Program Annual Report, Combined Sewer Management Program Annual Report, Reporting Period July 1st 2016 to June 30th 2017, Philadelphia Water Department, http://phillywatersheds.org/doc/FY17_CS0_MS4_withAppendices_FINAL_website.pdf

Do you use a scoring tool to prioritize projects, funding, and programming?

No; there is no scoring mechanism within Green Cities, Clean Waters. Given the long-term control plan update and the scope of its mandates, PWD does not prioritize projects, funding, or programming on a departmental basis. Both PWD’s incentives and public programs prioritize projects that are both cost-effective and help the department reach its annual targets laid out in the long-term control plan update.

What environmental problems have been solved and what supporting data can you provide?

N/A; our program is aimed at water quality over 25 years.

Was there habitat enhancement after project completion? How long did it take for the enhancement to occur?

N/A

Did any endangered species benefit or thrive or were they reintroduced to the site after project completion?

NA; the program is focused on implementation within the urban environment.

Did 303d listed water bodies for pollutants of concern prioritize selecting the project site? Was the quantity of pollutants removed measured and identified? Over time, did the pollutants decrease?

No. All of Philadelphia’s water bodies are severely impaired (303D listed); thus, the listing therein does not impact the prioritization of site selection¹¹². Philadelphia measures its capture of TSS, BOD5, *fecal coliform*, and the percent volume captured. In 2016, the department reported its year five equivalent mass capture, which measures the amount of pollutants (and volume of water) captured by GI, equivalent to what would have been captured via traditional methods. PWD can already report increases therein and that 1.7 billion gallons of stormwater overflow have been diverted.

	2011 Baseline “Equivalent Mass Capture”	Year 5 (2016) “Equivalent Mass Capture”*
TSS	62%	70.5%
BOD5	62%	88.5%
<i>Fecal Coliform</i>	62%	72.0%
Percent (Volume) Capture	62%	66.6%

Table 2-7 Year five equivalent mass capture

112 Consent Order and Agreement, Green City, Clean Waters: Evaluation and Adaptation Plan, Philadelphia Water Department, http://phillywatersheds.org/doc/Year5_EAPBody_website.pdf

Reduction in basement flooding and fewer days of missed school (or other quality of life/public safety and convenience responses)?

N/A. PWD does not measure basement flooding impacts of its GI practices deployed to reduce its citywide stormwater runoff.

Was land acquired outside of the right of way to meet the GI objective?

PWD has occasionally acquired ownership of vacant land upon which to store runoff but by and large gains access to parcels via easements, access agreements, and other legal tools therein.

Were regional hydrology needs identified when selecting the project site and did it help meet local/regional plan goals, water quality concerns?

No.

Maintenance

How does your maintenance personnel take care of GI – no maintenance, equipment (mechanical, handheld, other – please describe) Does your GI take more maintenance than normal, or less? Seasonal requirements?

PWD utilizes a variety of methods to maintain GI. PWD's GI Maintenance Unit must maintain surface features, subsurface GI, and porous GI. Surface features require standard landscaping tools (blowers and mowers), while subsurface maintenance utilizes specialized trucks (vac trucks, combo trucks, jetters, and flushers), and porous GI requires specialized sweeping, vacuuming, and regenerative air. For more information please see the Green Infrastructure Maintenance Manual¹¹³.

How is maintenance funded?

For publicly built projects, PWD funds the maintenance. For projects built through regulation or our incentivized grants programs, property owners maintain the systems.

Has funding increased as a result of GI? Is there a dedicated funding source for maintenance of GI?

With the establishment of the GCCW program, a GSI maintenance program was created and the resources, staffing, and budget are increased accordingly with the volume of projects completed each year. The unit in charge of GI maintenance uses GI attributes

113 Deliverable VIII, Consent Order & Agreement, Green Infrastructure Maintenance Manual, Green City, Clean waters, Philadelphia Water Department, June, 1, 2014, http://phillywatersheds.org/doc/GSIMaintenanceManual-1stEdwpreamble_HRes.pdf

(e.g., staffing, materials, and contracts; miles of piping; and number of grates) to predict its budgetary needs for staffing, vehicles, contracts, and emergency maintenance reserve needs.

What is the skill set of maintenance personnel?

Maintenance personnel range from professional to skilled and unskilled workers (large spectrum of individuals; it's not good to have high skill levels across the board). Professional staff are typically engineers and scientists responsible for program management and logistics (maintaining at scale, work order management system, mini call center, and the Finance Department are within the unit), while skilled maintenance staff investigate utilities, conduct geotechnical investigations, repair masonry and concrete, perform landscaping, and conduct CCTV monitoring. Unskilled labor picks up trash and weeds the GI surface features. PowerCorpsPHL¹¹⁴ starts here (16 to 20 people doing six-month rotations).

Is it a dedicated crew for GI or part of general maintenance?

There are dedicated GI maintenance staff within the general M&O units. PWD program staff manages eight service contracts of various sizes and specialties, as well as 16 to 20 PowerCorpsPHL volunteers a year.

How do you plan for maintenance?

Planning for maintenance requires:

- ◆ Individual project review during the design process
- ◆ Life-cycle assessment of GI systems, planning for replacements
- ◆ Ongoing inspections, repair, and reactive maintenance
- ◆ Performing preventive maintenance at GI installations adjacent to active construction site
- ◆ On-site construction coordination
- ◆ During procurement: buying, storing, and stocking of materials (Such planning supports appropriate development of unit's stock, purchased 1.5 years in advance.)
 - While you are reviewing plans, or sometimes it's done before the project is in the ground
- ◆ Mechanical maintenance

114 PowerCorpsPHL (a City of Philadelphia AmeriCorps initiative, operated in partnership with EducationWorks), <http://powercorpshl.org/>

- Vehicle, tools, mulch, fasteners
- ◆ Inlet protection
 - Pretreatment
 - Looking at nonrelated construction sites that could be part of your drainage area
- ◆ Site protection (i.e., baseball fields are an issue with the grit entering the SMP; silt socks needed permanently)

Do you coordinate between other/multiple agencies for maintenance?

PWD interacts with multiple agencies and units to ensure proper GI maintenance. Interacting with Public Affairs (for PWD) and the city's 311 system provides real-time feedback associated with different systems. Protocols associated with GI on partner property governs maintenance activities therein, ensuring that PWD only maintains GI, while partners maintain other property, including, but not limited to, benches and lighting, for example. Best practices require that these protocols are enshrined in Memoranda of Understanding, agreements, and/or work flows where appropriate.

Do you have a method to identify maintenance triggers?

PWD regularly maintains its GI through a robust maintenance program and schedule independent of triggered maintenance. PWD regularly monitors and tests its infrastructure, part of several protocols including, but not limited to, an inspection-to-repair workflow. For instance, automated rain gauge data provides PWD information that enables GI Maintenance staff to develop work orders in advance to support expedited resolution. Practices include on-site inspection, simulated runoff tests, and performance testing, all of which inform field-based observation meetings and other roundtables and meetings PWD uses to improve standards and identify maintenance triggers.

Are you experiencing any vector control issues associated with the use of GI elements? If so, please describe what they are.

PWD's robust maintenance program keeps vectors in check. We have hotlines for unforeseen issues or to resolve potential issues before they become a problem. A larger issue for our city is keeping litter out of our inlets.

Is special equipment required for maintenance of GI elements? If so, how is this funded?

Yes, at times specialized equipment is needed for GSI maintenance. All special equipment (e.g., vac trucks, inlet cleaning trucks, toolboxes, and wenches) is paid for out of the general fund. However, occasionally PWD requests replacement filter bags or other components during a construction project and thus utilizes capital funding to purchase back-up assets for a given system.

Do you examine integrating GI into already-scheduled maintenance projects to reduce costs or to retrofit an area, e.g., replacing or repairing infrastructure under streets?

PWD does its best to integrate GSI into water/sewer infrastructure work when we will be undertaking large construction in the street.

Miscellaneous Questions

Does your agency only focus on small-scale design specific to an area or take a regional approach?

The GCCW program is regional in that it is focused on the entirety of the combined sewer service area of the city. However, design is approached on a site-by-site, project-by-project, individual basis.

Describe key alliances, partnerships and tools used to integrate planning and landscape scale planning and coordination.

PWD partners with city and regional agencies to coordinate investments within the ROW and on stakeholder parcels. PWD maintains working relationships with area nonprofits to increase visibility and support for the department's GI program. We work with strategic partners to align capital work that may be happening and present some benefit to the park or partner.

What criteria do you use in selecting a site for GI (e.g., does it contribute to a specific body of water, traffic patterns, etc.)?

PWD's site selection process can be viewed on the "What is Green Stormwater Infrastructure?" page¹¹⁵ of our GSI Planning & Design Manual.

What did we miss? Is there some better technique or approach to GI planning, design, construction, maintenance, or inventory of GI locations that we did not address?

<http://philadelphiawater.org/gsi/planning-design/>

Do you test soils prior to design to identify the best solution?

Yes. We test to decide whether or not to infiltrate or store and release at a given location. Testing helps identify bedrock or contaminated soil concerns.

Are there any laws, statutes, ordinances, action plans, forums, or resolutions that support GI? If so, what is the funding budget to meet compliance and what are the units of measurements for compliance?

115 What is Green Stormwater Infrastructure?, GSI Planning & Design Manual, Version 2.0 April 2018, Philadelphia Water Department, http://documents.philadelphiawater.org/gsi/GSI_Planning_and_Design_Manual.pdf#page=13

PWD's GCCW program was formalized through a consent order and agreement with the state and was further formalized through an administrative order for compliance on consent with the U.S. EPA. These agreements include metrics and benchmarks for GI to be implemented by the city over a 25-year period beginning in June 2011. The unit of measure specific to GSI is the greened acre. The consent order and agreement defines a greened acre as an acre of impervious cover that is retrofitted to use GSI and manages stormwater using source controls such as infiltration, evaporation, transpiration, decentralized storage, alternative stormwater routing, and reuse. One greened acre is equivalent to 1 inch of managed stormwater from one acre of drainage area or 27,158 gallons of managed stormwater.

Were other public or private groups involved from the beginning for input or support/outreach for the project? If not, why, and were there consequences for not including them?

A robust public engagement process was initiated during development of the LTCPU. Section 7.2 of our annual report details and outlines our public education and outreach programs¹¹⁶.

Public Affairs hosts community meetings, engages the public through stormwater art, provides a stormwater handbook for homeowners, developed the Soak It Up adoption program, hosted urban water curriculum at our Fairmount Water Works to help educate the community, and works with students through GreenSTEM.

Is there a framework or forum for continued community engagement/awareness and/or economic consideration?

See previous response.

What obstacles still exist (e.g., organizational culture, lack of buy-in from designers, stakeholders or the public, long-term stable funding, coordination, lack of vision)?

Most challenges to the development of Philadelphia's GI program relate to program development and management and include:

- ◆ Staffing and consultant management: High turnover among city and consultant staff incurs projects delays. Additionally, consultant quality control concerns may add time to project delivery.
- ◆ Gaining city buy-in, which includes proactive collaboration with PWD, continues to be a challenge.
- ◆ Meeting LTCPU targets while developing a program to meet said targets is an obstacle.

116 Stormwater Management Program Annual Report, Combined Sewer Management Program Annual Report, Reporting Period July 1st 2016 to June 30th 2017, Philadelphia Water Department, http://phillywatersheds.org/doc/FY17_CS0_MS4_withAppendices_FINAL_website.pdf

For Cities/MPOs

Has your city/agency made zoning requirements to enforce GI?

The Water Department's regulatory requirements, which require projects that disturb more than 15,000 square feet of earth to develop an earth and sediment removal plan, supports the construction of GI where applicable, as opposed to any zoning requirements therein.

Zoning, instead of being used to regulate the creation of GI is used to incentivize it. Projects on lots that are in specific zoning districts (namely RM-1, CMX-2, and CMX-2.5) are eligible for density bonuses if they install a green roof that covers at least 60% of the building rooftop's area¹¹⁷. A zoning bonus was also created for Philadelphia's Callowhill neighborhood that enables developers to claim a density bonus if they engage in activities that include managing ROW runoff on their property¹¹⁸.

Are there incentives offered for implementing GI?

PWD offers incentives for developers and companies to develop or aggregate GI projects under the SMIP and GARP programs¹¹⁹.

Do you:

Start by including small-scale green infrastructure practices in individual municipal projects that are currently in the planning stage.

Yes. PWD's work to include GI practices with individual municipal projects is part of the department's programmatic efforts to meet its compliance targets.

Consider requiring that all local road projects allocate a minimum amount of the total project cost to green infrastructure elements?

No.

Do you have stormwater fees based on impervious surfaces?

Yes¹²⁰.

117 Green Roof Density Bonus Review Process, Philadelphia Water Department, June 2016, https://www.pwdplanreview.org/upload/pdf/Green_Roof_Density_Bonus_Factsheet_20160624.pdf

118 Bill #150505, Committee on Rules, City Council, City of Philadelphia, November 12, 2015, <https://phila.legistar.com/LegislationDetail.aspx?ID=2322504&GUID=40BF774D-A853-4046-92EA-44B60B10CF60>

119 Stormwater Grants, Philadelphia Water Department, City of Philadelphia, <https://www.phila.gov/water/wu/stormwater/Pages/Grants.aspx>

120 Non-Residential Stormwater Billing, Philadelphia Water Department, City of Philadelphia, <https://www.phila.gov/water/wu/stormwater/Pages/NonResidentialStormwaterBilling.aspx>

Have pilot projects?

Yes.

How did you achieve leadership/champion of the cause?

Early departmental leadership was the champion for GI.

Do you have buy-in from all municipal infrastructure departments?

Municipal infrastructure departments work with PWD GI staff on both a project-by-project and systemic basis. The buy-in of any given department need not be memorialized by a Memorandum of Understanding (PWD has few complete ones between departments memorializing cooperation) but is a function of strong working relationships developed by PWD GI staff. Interdepartmental buy-in and collaboration are functions of both of these strong working relationships and the ability to align both project and programmatic needs with partner agencies.

Are your projects documented? Is there documentation on both a design and construction level and on a citywide tracking level?

Yes.

What resources do you have for financing GI?

Capital bonds fund construction, while operating funds support incentive programs.

Is the visibility of a project a consideration for GI?

Project visibility is a design consideration; however, it is not an investment or development criteria.

Are cost comparisons made to doing the same with gray infrastructure?

N/A. See previous answers on this topic.

Do you consider the cost/benefit ratio in these comparisons? Do you consider environmental, health benefits in these comparisons?

No. / N/A

Over what time frame do you consider these comparisons/benefits?

N/A

Southeast Michigan Council of Governments (SEMCOG)

Agency Information

Please identify types of GI required to be implemented under regulatory programs (i.e., NPDES, etc.) versus voluntary GI initiatives i.e., community rain gardens.

SEMCOG establishes regional policies and actions that guide our work in the region and in partnership with our members and road agencies.

Does your agency have rule/ordinance making authority? Do your GI efforts distinguish from a stormwater (SW) program? Are there distinct duties, responsibilities, and designated staff between GI and SW? Are they distinguished as different sections or are they so integrated they are considered to be the same section? Describe any recent organizational changes made to implement the program.

SEMCOG does not have rule-making authority. The policies and actions guide the regional priorities and implementation activities. Stormwater management is a significant priority across all local members and as part of the transportation planning process.

What types of GI have been installed by your agency? How does your agency track GI type and location? How do you track function and performance to understand if constructed GI is working as designed? Describe any recent changes made or recommended.

Does your agency have policies, guidance or tools for designers to use when designing GI projects? If so, can you provide a link?

SEMCOG led the development of the Low Impact Development Manual for Michigan. The SEMCOG Great Lakes Green Streets Guidebook provides example transportation projects across the Great Lakes watershed that have implemented green infrastructure.

Does your agency have a leader/champion for GI design practices and planning?

SEMCOG is a champion in the region for GI planning and implementation.

What is the leadership/champions role in promoting GI?

By establishing regional policies and actions, the local members and respective community leaders improve their understanding and can communicate priorities at the local level.

What obstacles, concerns or barriers to GI exist in the agency?

SEMCOG is consistently training staff to understand how GI can be incorporated in all of our work, including transportation, environment, economic development, placemaking, and education.

Who in your agency identifies and selects potential GI projects? Did you encounter resistance from certain groups? If so, how did you overcome this resistance?

SEMCOG works with our members to help identify GI opportunities and coordinate sources of funding. SEMCOG also encourages applications for the Transportation Alternatives Program (the transportation enhancement funding program) to include GI where feasible.

What criteria does your agency use for programming, prioritizing, and funding GI projects? Is GI considered for all projects? Is GI required for specific watersheds in your state? How does the regulatory authority convey GI requirements to the transportation agency?

In Michigan, those agencies covered under the MS4 permit program generally need to consider GI for any increase in impervious cover 1 acre or more.

What resources are used for funding GI projects? Federal, state, local funds? Combinations? What are the least and most restrictive funding sources you use?

The Great Lakes Restoration Initiative has provided over \$400 million for projects in the region. The State Revolving Fund program has an aspect of funding that allows for low-interest loans and can include stormwater management projects. SEMCOG implements the Transportation Alternatives Program, which supports projects with GI components under the environmental mitigation category.

Is GI a priority for executive management? Are there any specific problems with innovative practices and getting management approval?

Executive management at SEMCOG is very supportive of encouraging GI across the region and in communicating with our members.

Does the design consist of a multidisciplinary team (hydraulics, design engineers, landscape architects, permitting agencies, stormwater engineers, maintenance, and local agencies)? If not, who is responsible for the GI design and why? At what point do the different disciplines come into the planning and design process? Which discipline typically takes the design lead? Do you find this to be an effective strategy?

N/A to SEMCOG since our organization does not lead GI designs.

How well informed/trained are your designers in GI techniques/practices and what methods do you utilize to train them? Does your training extend to external customers, such as local agencies, MPOs, consultants, and contractors?

SEMCOG offers workshops that include GI practices for planners, engineers, consultants, and others.

Does your agency include GI practices only when required by permit or are GI practices the preferred standard over traditional gray infrastructure (concrete lined ditches, piping, etc.)?

Across the region in general, yes. Typically when required by permit, unless grant funding is available.

What considerations does your agency take into account when considering gray versus green infrastructure: Do both approaches work equally as well? Is one less expensive? Can they be combined? Are residents willing to put up with construction in their neighborhoods? Conversely, does the agency have enough unbuilt land to capture water on the surface?

Evaluating GI opportunities is generally to address the small rain events. In our region, gray infrastructure is still a priority to address the larger events.

What current trends do you see – increases in implementation of GI? Increase or decrease of funding? Dedicated maintenance forces to maintain GI? Any changes to legislation or permitting agencies increased requirements?

Two primary challenges to address stormwater management for the transportation network include the lack of available road funding for needed road maintenance and improvements and the lack of a dedicated funding source for stormwater infrastructure. Road agencies need to use transportation funding for priority road projects and maintenance. Unlike typical water and sewer fees that residents pay on local water bills, there is no dedicated funding source for stormwater infrastructure.

GI Techniques, Lessons Learned, Best Management Practices, and Emerging Practices

What criteria do you use to evaluate GI proposals?

GI proposals for TAP applications must demonstrate a reduction in runoff volume and a commitment to maintenance. Additionally, the TAP applications must address multiple outcomes, not just GI (e.g., using GI as a method of traffic calming addresses both environmental and safety outcomes).

What criteria do you use to select alternatives and practices? Is your agency willing to purchase right of way or condemn property solely for use as GI?

N/A

Describe what is driving your decision to use GI.

N/A

For what type of environments (urban, rural, desert, mountain, flatland, coastal, etc.) does your agency design GI?

N/A

At what phase of project development do you begin identifying specific GI practices?

SEMCOG is encouraging road agencies to consider GI early in the transportation planning process.

Does your agency utilize a scoring tool such as FHWA's INVEST to help you incorporate GI into your projects and/or prioritize projects based on how well they incorporate GI? Have you developed your own scoring mechanism?

SEMCOG is updating the environmental sensitivity analysis transportation planning requirement to evaluate potential environmental impacts early in the process. As it relates to stormwater, this analysis will reflect on watershed conditions and offer stormwater opportunities.

Does your agency utilize GIS or other technology/data to identify and evaluate GI locations pre- and post-design? Is GIS used on a larger regional scale to help determine GI planning?

SEMCOG uses GIS for regional planning purposes.

Does your agency leadership support the use of GI on transportation projects? Does your agency engage stakeholders to evaluate the use of GI for roadside water management? If so, how do they engage the stakeholders? Do your regulators promote and support the use of GI? If yes, how do they work with your agency to select, develop and fund GI?

Yes. SEMCOG leadership supports the use of GI on transportation projects. This priority is conveyed through the long-range transportation planning program and communicated to local road agencies.

What tools or techniques does your agency use for information sharing with internal and external stakeholders (public outreach)?

SEMCOG regional plans, newsletters, listserv mailings, and maps are used to communicate.

Is there a database to keep track of GI projects? What do you track? Acres treated? Types of benefits to the environment after completion? Economic benefits after completion? Social benefits after completion? Other items? Is the database proprietary or open to DOTs?

N/A

In your experience, what is the most crucial factor to consider in GI?

For transportation agencies, funding and available space are the most crucial factors.

Do you document and monitor pilot projects? Does this encourage better and increased implementation?

N/A

Do you find inconsistencies between agencies' stormwater management regulations? Has this created conflict in the design or funding of projects?

There are inconsistencies across the region with local stormwater management regulations. The biggest conflict is the determination of pre-runoff conditions. Some counties define predevelopment as the last land use condition (i.e., could be an existing developed site) versus others define predevelopment as historic natural conditions.

Are there other design considerations your agency had considered that were not supported? Why not?

N/A

What lessons have been learned from the GI installed? Have different BMPs performed better than others? Have any GI types been eliminated from use? If yes, why?

N/A

Based on lessons learned, what project types are most feasible going forward for future projects?

N/A

What were the unique challenges during construction? Overall timing of the construction/installation?

A common construction challenge is keeping heavy equipment from compacting the GI soils that are designed for infiltration. Requiring staged construction inspections for different phases of GI construction is also important.

Have there been issues with successful vegetation establishment related to specific BMPs? What were the specific challenges associated with vegetation on the urban roadside?

- ◆ Selecting roadside vegetation that does not create line-of-sight issues
- ◆ Selecting salt-tolerant plants
- ◆ Ensuring all stakeholders understand that native vegetation takes at least three years for establishment: Year one they sleep; Year two they creep; Year three they leap.

When designing the GI, what metrics were used and were extreme weather events part of the calculation?

Typically metrics in the region are focused on the smaller-rain events (one-year to two-year) and the amount of runoff reduction. Extreme weather events are not typically part of the calculation.

Does your design accommodate increased long-term flows? On what is that based?

N/A

Describe coordination, training and outreach with the public, including adjacent property owners.

N/A as it relates to specific projects since SEMCOG does not construct.

Performance Measures

N/A for SEMCOG

Maintenance

N/A for SEMCOG

Miscellaneous Questions

N/A for SEMCOG

For Cities/MPOs:

Has your City/Agency made zoning requirements to enforce GI?

SEMCOG does not have zoning requirements.

Are there incentives offered for implementing GI?

N/A

Do you:

Start by including small-scale green infrastructure practices in individual municipal projects that are currently in the planning stage.

Consider requiring that all local road projects allocate a minimum amount of the total project cost to green infrastructure elements?

Do you have stormwater fees based on impervious surfaces?

Have pilot projects?

SEMCOG communicates with local members to educate about GI opportunities across multiple municipal projects.

How did you achieve leadership/champion of the cause?

N/A

Do you have buy-in from all municipal infrastructure departments?

N/A

Are your projects documented? Is there documentation on both a design and construction level and on a citywide tracking level?

N/A

What resources do you have for financing GI?

Transportation Alternatives Program

Is the visibility of a project a consideration for GI?

N/A

Are cost comparisons made to doing the same with gray infrastructure?

N/A

Do you consider the cost/benefit ratio in these comparisons? Do you consider environmental, health or social benefits in these comparisons?

N/A

Over what time frame do you consider these comparisons/benefits?

N/A

Appendix E: Scan Workshop Agenda

APPENDIX E: SCAN WORKSHOP AGENDA

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
	5-Nov	6-Nov	7-Nov	8-Nov	9-Nov	10-Nov	11-Nov
Meeting Room	TBD	TBD	TBD	TBD	TBD	TBD	
Breakfast		7am-8am breakfast in Bahia Café	7am-8am breakfast in Bahia Café	7am-8am breakfast in Bahia Café	7am-9am breakfast in Bahia Café	7am-8am breakfast in Bahia Café	
Meeting Room		SHELL	SHELL	SHELL	SHELL	SHELL	
AM	Invited participants and Scan team fly to San Diego, CA	*8:00am - 8:45am Introduction *8:45am - 11:45am Maryland SHA Presentations	*8:00am - 10:00am Pennsylvania DOT Presentation *10:00am - 10:15am Break *10:15am - 12:15pm City of Philadelphia Presentation	*8:00am - 10:00am Arizona DOT Presentation *10:00am - 10:15am Break *10:15am - 12:15pm Southeast Michigan Council of Governments (SEMCOG) and Michigan DOT (web meeting) Presentation	*9:00am - 12:00pm Group Discussion for findings (Breakouts for 4 small groups)	(Invited participants fly home) 8:00am-12:00pm Final team meeting (Scan team ONLY)	ScanTeam fly home
Lunch		11:45 am-12:45 pm Lunch	12:15pm -1pm Lunch	12:15pm -1pm Lunch	12:00 pm-1:00 pm Lunch	12pm-1:00pm Lunch	
PM		*12:45pm - 2:45pm New York City Presentation *2:45 pm - 3:00pm Break *3:00pm - 5:00pm Maine DOT and Long Creek Watershed Management District Presentation *5:00pm - 5:30pm Daily wrap up	*1:00pm - 3:00pm Oregon DOT presentation *3:00pm - 3:15pm Break *3:15pm - 4:45pm Nevada DOT Presentation *4:45pm -5:15pm Daily wrap up	*1:00pm -2:30pm Washington State DOT Presentation *2:30pm - 2:45pm Break *2:45pm - 4:45pm King County Presentation *4:45pm -5:15pm Daily wrap up	*1:00pm - 4:00pm Group Discussion for conclusion and recommendations (Breakouts for 4 small groups) *4:00pm - 5:00pm Workshop closing comments by Chair and PI	1:00pm - 4:00pm Final team meeting (Scan team ONLY)	
Evening	Meeting room: Shell 7 -8 pm team kick off meeting (Scan team ONLY)				Invited participants fly home	Scan Team fly home	

Appendix F: Key Contacts

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Appendix G: Additional Resources

Arizona

- City of Tucson/Pima County
 - <http://webcms.pima.gov/cms/one.aspx?pageId=65263>
 - <https://wrrc.arizona.edu/LID-green-infrastructure>
- Active GI Guidelines
[https://www.tucsonaz.gov/files/transportation/Green Streets APG Signed by Director.pdf](https://www.tucsonaz.gov/files/transportation/Green%20Streets%20APG%20Signed%20by%20Director.pdf)
- Arizona Nonprofit Organization
<https://watershedmg.org/>

California/Caltrans

- Erosion Control Toolbox
<http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/toolbox.html>
- Biostrips
 - [http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/stormwater/biofiltration swale.html](http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/stormwater/biofiltration_swale.html)
 - [http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/stormwater/biofiltration swale.html](http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/stormwater/biofiltration_swale.html)
 - <http://www.dot.ca.gov/design/lap/landscape-design/erosion-control/lid/overview.html>
- Low-Impact Development Guidance
[http://www.dot.ca.gov/hq/LandArch/16 la design/research/hwy planting.htm](http://www.dot.ca.gov/hq/LandArch/16_la_design/research/hwy_planting.htm)
- Native Grass Sod
[http://www.dot.ca.gov/hq/LandArch/16 la design/research/soils.htm](http://www.dot.ca.gov/hq/LandArch/16_la_design/research/soils.htm)
- Highway Soil Improvement
[http://www.dot.ca.gov/hq/LandArch/16 la design/research/erosion control.htm](http://www.dot.ca.gov/hq/LandArch/16_la_design/research/erosion_control.htm)
- Biostrips and LID Research
[http://www.dot.ca.gov/hq/LandArch/16 la design/research/irrigation.htm](http://www.dot.ca.gov/hq/LandArch/16_la_design/research/irrigation.htm)
- Stormwater Quality Guidance
<http://dot.ca.gov/hq/oppd/stormwtr/treatment.htm>

Stormwater Treatment BMP Design Guidance (Bio filtration and Infiltration)
[http://dot.ca.gov/hq/oppd/stormwtr/training/treatment/Biofiltration Introduction.pdf](http://dot.ca.gov/hq/oppd/stormwtr/training/treatment/Biofiltration_Introduction.pdf)
- Infiltration Calculator
- Low Impact Development Stormwater Management at Sacramento State
<https://www.owp.csus.edu/csus-lid/>

Conservation Law Foundation

- <https://www.clf.org/serving-new-england/maine/>
- <http://www.restorelongcreek.org>

Economic Benefits

- Economics American Rivers, Water Environment Federation, the American Society of Landscape Architects, and ECO Northwest. 2012. Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide. A Joint Report, April 2012. Accessed December 2014.
<https://www.americanrivers.org/conservation-resource/banking-on-green/>
- Center for Neighborhood Technology and American Rivers. 2010. The Value of Green Infrastructure: A Guide to Recognizing its Economic, Environmental, and Social Benefits. Accessed December 2014.
<https://www.americanrivers.org/conservation-resource/value-green-infrastructure/>
- Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs.
https://www.epa.gov/sites/production/files/2015-10/documents/lid-gi-programs_report_8-6-13_combined.pdf

EPA

- Green Infrastructure
<https://www.epa.gov/green-infrastructure>
- Enhancing Sustainable Communities with Green Infrastructure
<https://www.epa.gov/sites/production/files/2016-08/documents/green-infrastructure.pdf>
Green Infrastructure Costs and Benefits
 - https://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking%20on%20Green%20HighRes.pdf
 - https://www.epa.gov/sites/production/files/2015-10/documents/lid-gi-programs_report_8-6-13_combined.pdf
 - https://www.epa.gov/sites/production/files/2015-10/documents/2008_01_02_nps_lid_costs07uments_reducingstormwatercosts-2.pdf
 - https://www.cnt.org/sites/default/files/publications/CNT_Value-of-Green-Infrastructure.pdf
- Water Quality Scorecard: Incorporating Green Infrastructure Practices at Municipal, Neighborhood, and Site Scales. Accessed December 2014
 - http://www.epa.gov/dced/pdf/2009_1208_wq_scorecard.pdf

- http://water.epa.gov/polwaste/green/upload/lid-giprograms_report_8-6-13_combined.pdf.
- https://www3.epa.gov/npdes/outreach_files/webcast/march0614/sw_030614_transcript.pdf
- Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices. Publication Number EPA 841-F-07-006, December 2007. Accessed December 2014.
- Tools, Strategies and Lessons Learned from EPA Green Infrastructure Technical Assistance Projects
- https://www.epa.gov/sites/production/files/2016-01/documents/gi_tech_asst_summary_508final010515_3.pdf
- City Green: Innovative Green Infrastructure Solutions for Downtowns and Infill Locations
 - https://www.epa.gov/sites/production/files/2016-06/documents/city_green_0.pdf
 - http://water.epa.gov/polwaste/green/costs07_index.cfm.
- Managing Wet Weather with Green Infrastructure Municipal Handbook: Funding Options https://www.epa.gov/sites/production/files/2015-10/documents/gi_munichandbook_funding.pdf
- Getting to Green: Paying for Green Infrastructure: Financing Options and Resources for Local Decision-Makers <http://www.epa.gov/nep>.
- Water: Green Infrastructure—Cost/benefit Resources http://water.epa.gov/infrastructure/greeninfrastructure/gi_costbenefits.cfm.
- Water: Green Infrastructure—Funding Opportunities
 - <https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities>
 - http://water.epa.gov/infrastructure/greeninfrastructure/gi_funding.cfm.
- EPA Green Infrastructure Planning
 - <https://www.epa.gov/npdes/stormwater-planning>
 - <https://www.epa.gov/nps/urban-runoff-low-impact-development>
- AASHTO Call for Transportation and Environmental Research Ideas
 - <http://environment.transportation.org/global/announcements.aspx>
- The Importance of Operation and Maintenance for the Long-Term Success of Green Infrastructure: A Review of Green Infrastructure O&M Practices in ARRA Clean Water State Revolving Fund Projects https://www.epa.gov/sites/production/files/2015-04/documents/green_infrastructure-om

[report.pdf](#)

- Water: Green Infrastructure—Design and Implementation Resources. Accessed December 2014
http://water.epa.gov/infrastructure/greeninfrastructure/gi_design.cfm.
- Water: Green Infrastructure—Modeling Tools. Accessed December 2014.
- Water: Green Infrastructure—Policy Guides
http://water.epa.gov/infrastructure/greeninfrastructure/gi_policy.cfm
- Where Can I Get More Training?
 - http://water.epa.gov/infrastructure/greeninfrastructure/gi_training.cfm
 - https://www.epa.gov/sites/production/files/2016-06/documents/city_green_0.pdf

FHWA

- <https://www.sustainablehighways.org/779/case-studies.html>

Maine

- Maine government LID (not DOT- for smaller projects/municipalities) LID Guidance Manual for Maine Communities
<https://www1.maine.gov/dep/land/watershed/materials/lid-guidance-manual.pdf>

Maryland

- Maryland DOT
 - <http://dnr.maryland.gov/land/Pages/Green-Infrastructure.aspx>
- Maryland Department of Natural Resources/GIS work
 - http://www.conservationfund.org/images/programs/files/Marylands_Green_Infrastructure_Assessment_and_Greenprint_Program.pdf
 - http://www.conservationfund.org/images/programs/files/Marylands_Green_Infrastructure_and_Greenprint_Program.pdf
- Better Site Design: A Handbook for Changing Development Rules in Your Community. Center for Watershed Protection
<http://chesapeakestormwater.net/wp-content/uploads/downloads/2012/03/Better-Site-Design-Handbook.pdf>

Michigan

- Michigan DOT and SEMCOG
 - https://www3.epa.gov/npdes/outreach_files/webcast/march0614/sw_030614_transcript.pdf
 - <http://www.semcog.org/Plans-for-the-Region/Transportation/Environmental#6103-green-infrastructure> (good contact info)

- http://www.gcdcswm.com/PhaseII/LID_Ordinance/lid_manual_intro.pdf
- <https://www.swmpc.org/downloads/lidmanual.pdf>
- https://semcog.org/Reports/GLGI_Guidebook/files/assets/basic-html/page-1.html#.
- <http://www.semcog.org/Plans-for-the-Region/Environment/Green-Infrastructure>

New Hampshire

- University of New Hampshire – Economic Benefits for GI
 - Robert Roseen, PhD, D.WRE, PE
rroseen@geosyntec.com
(617) 992-9067
 - http://efc.muskie.usm.maine.edu/docs/roseen_right_practice_right_place.pdf

New York

- NYC Green Streets Program
Since 2010, DEP has been constructing GI assets throughout the City’s combined sewer tributary areas, both on publicly and privately-owned land, including the ROW. The types of GI assets include but are not limited to bioinfiltration, permeable paving, subsurface retention systems, stormwater harvesting and reuse systems, and green roofs.
 - <https://onenyc.cityofnewyork.us/visions/sustainability/>
 - http://www.nyc.gov/html/dep/html/press_releases/13-026pr.shtml#.WK5V0G8rKM8
 - http://www.nyc.gov/html/dep/html/stormwater/using_green_infra_to_manage_stormwater.shtml
- Standards, Details, Etc.
http://www.nyc.gov/html/dep/html/stormwater/green_infrastructure_standards.shtml
- Data, Performance Metrics, Etc. on GI
http://www.nyc.gov/html/dep/html/stormwater/nyc_green_infrastructure_plan.shtml
- GIS Mapping of GI Program
<http://www.arcgis.com/home/webmap/viewer.html?webmap=a3763a-30d4ae459199dd01d4521d9939&extent=-74.3899,40.497,-73.3757,40.9523>

Oregon

- The Oregon Department of Transportation is a leader in sustainability planning and initiatives and has a sustainability program focused on health and safety, social responsibility, environmental stewardship, land use and infrastructure, energy/fuel use and climate change, material resource flow, and economic health (ODOT, 2012)
https://www.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/docs/Stormwater_Program/Stormwater%20Management%20Program%20TTS.pdf
- Oregon DEQ

<https://www.oregon.gov/deq/FilterDocs/EligibleGreenProjects.pdf>

- Portland, Oregon, Green Infrastructure
 - http://www.werf.org/liveablecommunities/studies_port_or.htm
 - <https://www.portlandoregon.gov/BES/34598>
 - <https://www.portlandoregon.gov/BES/article/107808>
 - <https://www.portlandoregon.gov/bes/31000>
 - <https://www.portlandoregon.gov/bes/31002>
 - <https://www.portlandoregon.gov/BES/38965>

Pennsylvania

- Philadelphia Green Infrastructure Stormwater
 - http://phillywatersheds.org/what_were_doing/documents_and_data/cso_long_term_control_plan
 - http://www.phillywatersheds.org/what_were_doing/green_infrastructure
 - http://www.phillywatersheds.org/doc/GCCW_AmendedJune2011_LOWRES-web.pdf
 - <http://www.phila.gov/water/wu/stormwater/Pages/StormwaterManagement.aspx>
- A Benefit-Cost Analysis of Combined Sewer Overflow Control Options
Philadelphia Water Department (PWD), Philadelphia, Pennsylvania
PWD is committed to the development of a balanced “Land-Water-Infrastructure” approach to achieve its watershed management and CSO control goals. The PWD program includes traditional gray infrastructure, as well as land-based LID/GI stormwater management techniques and projects involving the physical reconstruction of aquatic habitats. The LID/GI land-based approaches include disconnection of impervious cover, bioretention, subsurface storage and infiltration, green roofs, swales, green streets (including permeable pavement), and tree canopy. The water-based approaches include streambed and bank stabilization and reconstruction, aquatic habitat creation, plunge pool removal, improvement of fish passage, and floodplain reconnection. The PWD conducted a BCA analysis that demonstrated the full range of costs and social benefits of LID/GI to regulators and the public. The PWD uses the term “Triple-Bottom-Line,”
- Center for Watershed Protection: Pennsylvania
<http://www.cwp.org/wp-content/uploads/2015/07/PA-marketing.pdf>
- NRDC Cities Composite Case Studies Report; Rooftop to Rivers II: Green Strategies for Controlling Stormwater and Combined Sewer Overflows
<https://www.nrdc.org/sites/default/files/rooftopstoriversII.pdf>

Washington D.C./District Department of Transportation

- <https://ddot.dc.gov/GreenInfrastructure>

- <https://ddot.dc.gov/GreenInfrastructure>
- <https://ddot.dc.gov/page/nannie-helen-burroughs-project>
- <https://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/2014-Final%20DDOT%20Green%20Infrastructure%20Standards.pdf>
- <https://ddot.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/ECONW%20Final%20Report%202011-0628.pdf>

Washington State

- Seattle
 - http://www.conservationfund.org/images/programs/files/Mountains_to_Sound_Greenway_Seattle_to_the_Cascades.pdf
 - <http://www.seattle.gov/util/EnvironmentConservation/Projects/GreenStormwaterInfrastructure/index.htm>
 - http://www.seattle.gov/util/cs/groups/public/@spu/@conservation/documents/webcontent/01_015334.pdf
 - <http://www.seattletimes.com/seattle-news/environment/whats-killing-coho-study-points-to-urban-road-runoff/>
 - Green Stormwater Infrastructure in Seattle: Using an Asset Management System
http://www.seattle.gov/Documents/Departments/OSE/GSI_Strategy_Nov_2015.pdf
- City of Bellevue
 - <http://your.kingcounty.gov/solidwaste/greenbuilding/green-infrastructure.asp>
 - <http://www.kingcounty.gov/services/environment/water-and-land/stormwater/documents.aspx>

Wisconsin

- Wisconsin Department of Transportation
 - https://dot.wa.gov/Design/Roadside/Green_Infrastructure.htm
 - https://dot.wa.gov/Design/Roadside/Stormwater_Management.htm
 - <http://www.wsdot.wa.gov/Projects/SR520Bridge/>
 - <http://www.wsdot.wa.gov/Projects/Viaduct/>

Other Resources

- ASLA Green Infrastructure
<https://asla.org/search.aspx?q=Green%20Infrastructure> <https://www.asla.org/greeninfrastructure.aspx>

- ASLA Seminar on Complete Streets- shaping space
https://www.asla.org/uploadedFiles/CMS/Meetings_and_Events/2010_Annual_Meeting_Handouts/Fri-D4%20Complete%20Streets%20-%20Shaping%20Public%20Space.pdf
- Green Infrastructure: Cities
https://www.asla.org/sustainablelandscapes/Ed_WaterManagement.html
- Sustainability Education Resources
https://www.asla.org/sustainablelandscapes/Ed_WaterManagement.html
- Seminar on rain gardens in Denver
https://www.asla.org/uploadedFiles/CMS/Meetings_and_Events/2014_Annual_Meeting_Handouts/FRI-B03%20Bioretention%20in%20the%20Desert.%20You%E2%80%99re%20Joking%20Right.pdf
- Staying Green: Joint Reports On Operations And Maintenance Of Green Infrastructure In The Chesapeake Bay
<https://www.americanrivers.org/conservation-resource/operations-maintenance-green-infrastructure/>
- Stormwater Center—Maintenance. University of New Hampshire Stormwater Center. Accessed December 2014
<http://www.unh.edu/unhsc/maintenance>
- Field Guide: Maintaining Rain Gardens, Swales and Stormwater Planters + Multiple Green Infrastructure information
https://slidelegend.com/green-infrastructure-epa_59fab23d1723dd74c0ce3051.html
- Sustainable Cities – “Envision” report from Harvard
 - http://research.gsd.harvard.edu/zofnass/files/2015/06/Envision-Manual_2015_red.pdf
 - <https://sustainableinfrastructure.org/event/isi-presentation-sustainable-infrastructure-using-envision-to-plan-design-and-rate-infrastructure-projects/>
 - <http://zofnass.gsd.harvard.edu/planning/#page-top>
- NCHRP report 25-37 on stormwater impacts
<http://apps.trb.org/cmsfeed/trbnetprojectdisplay.asp?projectid=3189>
- American Planning Association(APA): How Cities Use Parks for Green Infrastructure
<https://www.planning.org/publications/document/9148673/>

