A Survey of Green Infrastructure Maintenance Programs in the United States

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1 Abstract

Green infrastructure (GI) refers to a set of stormwater management practices that collect, infiltrate, and reuse stormwater runoff as it is created when rain falls on the streets, roofs, and other impervious areas found in cities. Cities across the United States are making significant commitments to the implementation of GI as part of their regulatory requirements to reduce untreated stormwater from flowing into waterways. While the use of GI is growing, little has been written on the need for and the importance of maintenance to keep these GI projects performing over time.

As part of a summer 2013 internship, eight of the cities in the United States leading the trend of GI implementation were surveyed about the current state of each city's GI maintenance program. Consistent questions were asked of each program and the information collected included: GI maintenance program roles and responsibilities; the maintenance program's structure; specific maintenance activities and frequencies for those activities; the methods for tracking the completion and results of maintenance activities; and maintenance program costs. This paper documents the results of those conversations and provides a summary of GI maintenance programs based on the eight different maintenance program examples.

2 Introduction

Green infrastructure (GI) refers to a set of stormwater management practices that collect, infiltrate, and reuse stormwater runoff as it is created when rain falls on the streets, roofs, and other impervious areas found in cities (O. of W. EPA 2013). Common examples of GI include:

- Bioretention, including bioswales, rain gardens, enhanced tree pits, and green roofs;
- Rain barrels and cisterns;
- Downspout disconnection;
- Permeable pavements; and
- Land conservation (O. of W. EPA 2013).

By capturing stormwater where it falls, GI works to reduce the amount of stormwater from entering and overwhelming sewer systems. Cities across the United States are making significant commitments to the implementation of GI to meet regulatory requirements to reduce untreated stormwater and combined sewage from entering waterways. A review of eight cities (New York, Philadelphia, Seattle, Portland, Cleveland, Kansas City, Los Angeles, and Detroit) showed a commitment to GI from these cities totaling over $3.7 billion over the next 25 years (National Resource Defense Council 2013).

While the use of GI is growing, little has been written on the need for and importance of maintenance for GI performance. There are examples of gray literature on likely maintenance activities, which includes examples like weeding for vegetation and sediment removal, with suggested frequencies (American Rivers 2013; Philadelphia Water Department 2012; Seattle

Public Utilities 2009; Department of Water Environment Protection 2012). However, cities still are lacking an understanding of how these suggested activities and frequencies might change from site to site, depending on differing conditions. Additionally, the optimal crew sizes and the necessary staff to maintain these projects over time are still unknown. To meet the need of maintaining their newly constructed and prepare for future GI projects, cities with GI programs have started to create maintenance programs according to their needs. In the absence of definitive research on maintenance, many of these cities are choosing to create programs with the ability to adapt maintenance activities as their understanding of the exact maintenance activities and associated frequency to reach the performance levels grows. As these cities grow their maintenance efforts, there is an opportunity to document the development of maintenance programs for other cities to use.

Washington, D.C.'s water agency, DC Water, is in the process of considering the use of GI to meet its combined sewer overflow regulatory requirements. As part of the program development process and a summer 2013 summer internship, DC Water chose to reach out to cities in the United States to learn about GI maintenance programs. A survey was conducted to understand how cities implementing GI programs are planning for maintenance. Eight cities in the United States were asked about the current state of each city's GI maintenance program. This paper documents the results of those conversations and provides a summary of GI maintenance programs based on the eight different maintenance program examples.

3 Overview of Contacted Green Infrastructure Programs

To gather information for this paper, U.S. cities with GI programs underway were contacted to discuss their current maintenance program structure and activities. In July 2013, phone discussions were conducted with GI program contacts from the following eight cities:

- Cincinnati, OH
- Kansas City, MO
- Montgomery County, MD
- New York, NY
- Onondaga County, NY
- Philadelphia, PA
- Portland, OR
- Seattle, WA

This paper focuses on the maintenance performed on GI owned by each of the GI programs in these cities. Table 1 below provides an overview of those agencies and details on their maintenance programs including:

- Program's age;
- Agency responsible for implementing GI and ensuring that maintenance is completed;
- Entity currently performing maintenance on GI;
- Regulatory drivers (whether the program is part of a combined sewer overflow (CSO) management strategy or Municipal Separate Storm Sewer (MS4) Permit requirement); and
- Number, types, and location of GI found in each city as part of the program (may have additional GI projects from other programs).

Table 1. Overview of Surveyed GI Programs and Associated Maintenance Efforts

City	Agency Responsible for Ensuring Maintenance Completion	Maintenance Entity Responsible for Performing Maintenance	Regulatory Driver for GI	Agency Agreements	Quantity and Types of GI Maintained	Notes
Cincinnati, OH	Metropolitan Sewer District of Greater Cincinnati (MSD)	MSD is responsible for the maintenance of its own GI assets and may elect to contract with Parks to assist in maintenance.	Consent Decree signed by USEPA and MSD (2010; with GI plan approved 2013)	Cincinnati Parks Board	The program is in early stages with few MSD-owned GI projects. Inspection services (no maintenance) are currently provided for the 30 private property projects completed as part of pilot phase including bioretention facilities, porous pavement projects, and rainwater harvesting systems	As MSD-owned GI assets increase with the consent decree projects, and MSD further develops its maintenance program, MSD will build in-house expertise and may elect to supplement with existing Parks resources.
Kansas City, MO	Kansas City Water Services Department (WSD)	Contractors with oversight from WSD	Consent Decree signed by USEPA and Kansas City (2012)	N/A	135 10 feet by 40 feet bioretention facilities in the Right-of-Way	Facilities are under warranty currently, WSD crews provide supplemental services.
Montgomery County, MD	Montgomery County's Department of Environmental Protection (DEP)	DEP (Stormwater Facility Maintenance Program)	MS4 Permit issued by Maryland Department of the Environment (original issue in 1998; more stringent permit issued in 2010)	N/A	62 blocks with bioretention facilities ranging in size	Contractors currently maintain sites; considering other maintenance program models as number of projects increase.
New York City, NY	Department of Environmental Protection (NYCDEP)	NYC Parks and Recreation (Parks)	Order on Consent between NYCDEP and New York State Department of Environmental Conservation (2012)	MOU with NYCDOT, NYCDEP, and Parks	60 bioretention facilities in the Right-of-Way (5 feet by 10-20 feet)	Facilities under 2-year contractor warranty; Parks crews provide supplemental services during this period, then will take over maintenance at the end of the warranty period
Philadelphia, PA	Philadelphia Water Department (PWD) – Green Stormwater Infrastructure (GSI) Maintenance Group	Contractors (one landscape and one subsurface) with oversight from PWD; PWD does preliminary subsurface inspection and delegates work to contractors. Surface maintenance is scheduled (without preliminary inspection).	Consent Order and Agreement signed by Philadelphia, PWD, and Pennsylvania Department of Environmental Protection (2012)	N/A	175 stormwater management practices (SMPs), including pervious pavement, bioretention facilities (rain gardens, swales, stormwater bump-outs, vegetated basins, and stormwater planters), infiltration trenches, tree trenches, stormwater trees, (also stormwater bump-out - tree trench hybrid SMP's). Approximately 30% or ~45 projects are bioretention facilities in the Right-of-Way thus far ranging from a minimum of 12ft² to a maximum of 22,000ft².	129 SMP's waiting on punch list items before chain of custody can be transferred to GSI Maintenance (expected by Philadelphia's third Maintenance Quarter (Jan -March) of FY2014.
Onondaga County, NY	Onondaga County Department of Water Environment Protection (WEP)	Syracuse Parks Department (for GI projects in parks), Onondaga Earth Corps (a nonprofit), contractors, and an in-house crew	Amended Consent Judgment signed by USEPA and Onondaga County (2009)	Agreement with the City of Syracuse	~100 projects including green roofs, porous pavement projects, bioretention facilities	Using four entities to conduct maintenance currently; in the process of moving toward greater use of nonprofits for maintenance work.
Portland, OR	City of Portland's Bureau of Environmental Services (BES)	Three contractors over a three year contract and one nonprofit, all with BES oversight	Amended Stipulation and Final Order signed by Portland and Oregon Department of Environmental Quality (1994)	N/A	1,200 blocks with bioretention facilities ranging in size (small swales and planter-type devices)	Most experienced maintenance program relative to other programs; considering other maintenance program models.
Seattle, WA	Seattle Public Utilities (SPU)	SPU responsible for bioretention within the right-of-way installed by the City or private development for stormwater code compliance. SPU currently contracts out to Seattle Conservation Corps, a job skills training program within Seattle's Parks Department, but functions to SPU like a contractor. Seattle's DOT is responsible for permeable pavement installed for stormwater code compliance within the right-of-way.	MS4 Permit issued by Washington State Department of Ecology (original issue in 1997, more stringent permit issued in 2007), Consent Decree signed by USEPA and SPU (2013)	Seattle mayor recently signed executive order to facilitate interagency coordination	On public property, there are 501 bioretention facilities, 50 biofiltration, and 117 pervious pavement installations in the Right-of-Way ranging in size. On private property, there are 674 bioretention facilities, 50 biofiltration, 95 green roofs, and 142 pervious pavement, 31 rainwater harvesting.	Seattle Conservation Corps has reached maintenance capacity; SPU is investigating uniting DOT, SPU, and Parks Department's GI efforts and investigating other maintenance program models.

4 Overview of GI Maintenance Programs

To better understand each maintenance program, consistent questions were asked of each program and the information collected included: GI maintenance program roles and responsibilities; the program's structure; specific maintenance activities and frequencies for those activities; the methods for tracking the completion of maintenance activities and observed GI project conditions; and maintenance program costs. Because the majority of these cities are in the beginning stages of implementing their GI programs, many of the details for maintaining their current GI projects are currently in development. Additionally, the number of GI projects in these cities is projected to grow significantly in the next few years, creating greater unknowns for how each maintenance program will evolve. With the projected growth of GI implementation throughout cities and the relative newness of the current GI programs in the country, it is important to note that much of the information gathered for this paper is based on current knowledge of GI. It is likely that this understanding will be significantly improved upon in the future as these programs progress.

The information collected on each GI program's experience resulted in the identification of key components of maintenance program, including:

- Maintenance program roles and responsibilities;
- Maintenance activities and the necessary frequencies;
- Administrative and maintenance crew staffing needs;
- Maintenance activity and GI project condition documentation and tracking; and
- Maintenance program costs.

The following sections of the paper highlight those key components.

5 The Structure of Maintenance Programs

The first step in developing a maintenance program is deciding the entity or entities that will maintain the GI projects. This step includes specifying the role and responsibilities of each group and creating the contracts and agreements to document those roles and responsibilities. The conversations with GI programs confirmed the importance of this step. Each of the other components of maintenance, such as developing maintenance crews and determining how activities will be documented, is dependent on the entity performing the maintenance. Looking across the surveyed GI programs, the entities performing maintenance including one or a combination of the following:

- An in-house crew within the same agency responsible for the GI program;
- Another city department, including the city's parks department;
- Contractors – either the general contractors that constructed the GI projects or landscape contractors;
- Non-profits focused on developing education or green jobs programs; and
- City residents.

Based on the surveyed GI Programs, selecting the maintenance entity appeared to be driven by a number of factors: the timing of the maintenance and the location of GI constructed in a given city. For all of the GI programs included in the paper, the maintenance entity was often decided at least initially according to the stages of project construction. Following the completion of the GI projects, there is generally a short-term maintenance period which is typically performed by the general contractor according to the construction contract. This phase is referred to as the initial warranty period in this paper and discussed in the following section. After that period, the GI programs implemented the program's long-term maintenance program. This period is the primary focus of this paper.

Beyond considerations for different maintenance entities over a GI project's design life, the location of the GI implementation (whether it is located on public or private property) seemed to dictate different approaches to the maintenance program's structure. The majority of the GI programs have multiple approaches for constructing GI in their cities. The predominant approach for GI programs is the implementation of agency-owned GI on public property. Beyond public property, many GI programs include some focus on getting GI constructed onto private property through either stormwater permit requirements for new development or GI incentive programs.

From the GI program examples, these differences in property ownership have created differences in the current approach to maintenance. Maintenance on private property projects tends to be more difficult to perform and enforce because of the need to gain site access. The GI programs that are incentivizing GI on private property generally have developed contracts with the private property owners that require those owners to perform maintenance. The formal maintenance programs, discussed in this paper, tend to be focused on the agency-owned GI projects while the GI programs rely on enforcement of contracts to require that maintenance is performed on private property GI. Table 2 below highlights the range of potential maintenance entities. There is some overlap in these programs through stewardship programs and nonprofit companies in several cities that are educating residents on GI and training them on how to help with the maintenance of both public and private property projects.

Table 2. Maintenance Entities across GI Project Life and Project Location

<table>
<tr><th rowspan="2">Timing</th><th colspan="2">Location</th></tr>
<tr><th>Public Property</th><th>Private Property</th></tr>
<tr><td>Initial Warranty Period</td><td>General or Landscape Contractors</td><td rowspan="2"></td></tr>
<tr><td rowspan="3">Long-term Maintenance</td><td>Formal Program Partners: GI Program Agency, Other City Agencies, General or Landscape Contractors, Non-profits</td></tr>
<tr><td colspan="2">Informal Program Partners: Non-profits, Community Groups, City Residents</td></tr>
<tr><td></td><td>Incentive Program Participants (Commercial, Institutional, and Residential Properties), Stormwater Permit Holders for New Development</td></tr>
</table>

For each of these potential maintenance entities, there are associated considerations for establishing the maintenance framework depending on the selected entity. The following sections describe each of the maintenance entities and the associated program needs to create the framework.

5.1 Initial Contractor Warranty and Maintenance Periods

Depending on the type of GI practice, maintenance should begin immediately following installation. This step is particularly important for vegetated GI practices. The newly-planted vegetation requires irrigation and protection from weeds while the root systems establish. As planting is generally the final step in construction of GI projects, this first maintenance effort and the establishment period usually start with construction completion. The majority of the GI programs indicated that as part of the construction contract for agency-owned GI projects, there is a warranty period that begins when construction is substantially complete. For the majority of the cities, this warranty period includes a contractually-obligated period where the contractor is also responsible for maintenance on the GI project. For the majority of the programs that included a warranty, the warranty and maintenance periods were identical and tended to have durations of 2-3 years with the exception of Philadelphia's program, as is shown in Table 3.

Table 3. Construction Contractor Maintenance and Warranty Periods for Agency-owned GI Projects

City	Maintenance and Warranty Period
Cincinnati, OH	Contracts for MSD GI include a 1 to 2- year warranty and maintenance period depending on the type of vegetation used for the GI project.
Kansas City, MO	3-year warranty and maintenance period.
Montgomery County, MD	1-year warranty period for plants; no maintenance period associated with GI projects.
New York City, NY	3-year warranty and maintenance period.
Onondaga County, NY	1-year warranty and maintenance period.
Philadelphia, PA	1-year warranty for surface level maintenance with 8-week maintenance period; 1 year warranty for "craftsmanship" warranty for subsurface features of projects.
Portland, OR	2-year warranty and maintenance period.
Seattle, WA	1-year warranty and maintenance period.

Most of the GI programs that were surveyed are still within the warranty and maintenance periods for a large portion of their GI projects. As indicated by several of the programs, this period in the maintenance process is accompanied by challenges that are important considerations for any maintenance program. Several cities noted the inclusion of a retainage (generally 10%) in the construction contract to ensure that maintenance is performed.

5.2 The Formal Maintenance Program

With the completion of the warranty period, a more formal and long-term approach to maintenance is required. As previously described, all of the GI programs are required to perform maintenance on the GI projects that contribute to their CSO or stormwater reduction requirements for their regulatory agreement (per long-term control plans and MS4 permit requirements). The term "Formal Maintenance Program" is meant to differentiate between regulatory-required maintenance activities and the other maintenance efforts that these cities may have in place, such as those explained in the following sections.

Each of the GI programs had unique aspects to their formal maintenance programs, but there were some common elements to the framework they used. Each GI program's formal maintenance program framework can be categorized by one of the four following framework models or a combination of two or more models.

- **Model 1 – Agency Responsible for GI Program performs maintenance**: In the first framework model, the agency responsible for the GI program acts as both the administrative entity and the maintenance entity. The agency performs maintenance activities through the deployment of an in-house crew to maintain GI projects.

  To establish a Model 1 program framework, it is necessary to consider that:
  - The GI program agency's leadership must agree to the maintenance program setup;
  - Current maintenance staff for other agency needs will need to be trained and educated on GI projects and the maintenance that they require; and
  - The position of oversight authority over maintenance staff's activities and responsibility for maintenance performance must be defined.

- **Model 2 – Contractor as Maintenance Entity with oversight from Agency Responsible for GI Program**: In the second model, the agency responsible for the GI again serves as the administrative and oversight entity. A contractor now serves as the maintenance entity. Generally, landscape contractors are used to perform maintenance as activities are generally similar to grounds maintenance. Due to their use of perforated pipes in GI projects, Philadelphia's GI program also includes the use of contractors that perform sewer inspections and sewer cleanings. Based on the GI programs interviewed, this model is the most widely used model for maintenance at this stage in GI programs.

  To establish a Model 2 program framework, it is necessary to consider that:
  - The GI implementation agency must establish maintenance contracts detailing specific maintenance activities and required frequencies, protocol(s) for documenting activities, protocol(s) for responding to work orders, the contract's length, and any other details associated with conducting maintenance.

- **Model 3 – Another City Agency as Maintenance Entity with oversight from Agency Responsible for GI Program**: In this model, the agency responsible for the GI again serves as the administrative and oversight entity. Another city agency performs the actual maintenance activities as part of an agreement with the GI program agency. The GI programs using this model tend to establish agreements with their respective city's parks departments to serve in the maintenance role as they often are the most familiar with maintaining vegetation, have necessary maintenance protocols in place, and have skilled staff and equipment required to maintain GI practices.

  To establish a Model 3 program framework, it is necessary to consider that:
  - The GI implementation agency and city agency must reach an agreement that specifies roles and responsibilities for performing maintenance; and

- The formal agreement should include: specifying protocols for maintenance activities; the required frequency of activities; the protocol for documenting activities; the protocol for responding to work orders; and any other details associated with conducting maintenance.

- **Model 4 – Nonprofit as Maintenance Entity with oversight from GI Implementation Agency**: Consistent with the other models, the GI implementation agency serves as the administrative and oversight entity in the fourth model. A nonprofit serves as the maintenance entity to accomplish maintenance activities. Based on the GI programs that were surveyed, this model is currently used in combination with another entity, like a contractor.

  To establish a Model 4 program framework, it is necessary to consider that:

  - Similar to using a contractor to conduct maintenance, the GI program agency and the nonprofit must develop a contract that specifies roles and responsibilities; and
  - The contract should include: specific maintenance activities and required frequencies; protocol(s) for documenting activities; protocol(s) for responding to work orders; the contract's length; and any other details associated with conducting maintenance.

Selecting the most appropriate agency to conduct the maintenance is an essential first step of developing a maintenance program, but based on the surveyed GI programs, the decision can be revisited in later stages as the program evolves. Based on discussions with the programs included in this paper, the current models being used are not necessarily the same models that will be used for maintenance in the future. Many GI programs indicated considering different models in the future as each model has both strengths and weaknesses. Table 4 identifies the model or models each program uses for maintaining agency-owned GI projects.

Table 4. Summary of Formal Maintenance Program Models

Model	Example
Model 1: GI Implementation Agency as the Maintenance Entity	
Model 2: Contractor as Maintenance Entity with oversight from GI Implementation Agency	Philadelphia, Kansas City, Montgomery County, Portland, Seattle, Onondaga County
Model 3: Other City Agency as Maintenance Entity with oversight from GI Implementation Agency Oversight	New York City (Parks department), Cincinnati (Parks department), Onondaga County (Parks department) supplements other crews
Model 4: Nonprofit Agency as Maintenance Entity with oversight from GI Implementation Agency	Portland, Onondaga County

5.3 Informal Partnerships and Stewardship Programs

Beyond the formal maintenance program development, there are other entities with potential resources and skill sets that can be leveraged to formally or informally support GI maintenance. Although maintenance performance is required on GI projects, many GI programs indicated informal partnerships and stewardship programs were potential ways to reduce the frequency of maintenance. These types of programs can not only support a maintenance program (i.e.,

perform actual maintenance activities) but can also provide additional benefits such as public outreach and education on GI. The two types of programs include:

- **Partnerships with nonprofits and community groups:** Because nonprofits and community groups tend to have mission statements centered on developing programs that improve neighborhoods, economies, and the environment, nonprofits offer the ability to develop programs linked to creating a green jobs workforce and developing other synergies (i.e., outreach activities, voluntary clean-up events around green infrastructure, etc.); and
- **Stewardship Programs:** These programs (as part of a partnership with other city agencies, nonprofits, or as a standalone program) offer the potential to educate and train residents on GI practices and maintenance.

Examples of current programs are described in Table 5, below.

Table 5. Examples of Informal Maintenance Programs

Maintenance Group	Example	Program Description
Nonprofits and Community Groups	Kansas City's Green Works	Green Works is a local non-profit charity that educates high school students about the environment and places them in Kansas City Department of Parks jobs to both create a parks workforce and help the students learn green skills.
Stewardship Programs	New York City's Bioswale Care and TreeLC Program	NYCDEP has partnered with MillionTreesNYC and the New York City Housing Authority to offer workshops on how to care for bioswales and street trees in neighborhoods.
	Portland's Green Street Steward Program	In response to requests from residents on how they can help with green streets maintenance, Portland created a program to train "Green Streets Stewards" to assist the City in picking up trash, removing debris, and weeding and watering.

5.4 Maintenance on Private Property

As previously discussed, GI implementation is currently heavily focused on public property. The private property focused programs are mostly accomplished through incentive programs and stormwater permits for new development. In the incentive programs, private property owners (residential, commercial, and institutional) are provided with grants to construct GI on their own property. These projects generally include an application specifying that the program participant is responsible for maintenance. The agreements included in the applications tend to have language that specifies details on the following:

- Party that is responsible for maintenance (private property owner or GI implementation program entity);
- Expected maintenance frequency;

- Whether or not the GI implementation agency will perform inspections of the GI project to ensure that maintenance is being performed and at what frequency the agency will inspect;
- Details on how the GI implementation agency will access the project for maintenance and/or inspections;
- Consequences if maintenance is not performed;
- Process for recording the maintenance agreement (deed record filing or easement); and
- Permission(s) (i.e., photographing the project, etc.).

For development projects, these aspects are often incorporated into the permitting process.

6 Maintenance Program Activities and Activity Frequency

Once a maintenance program framework is determined, it is necessary to specify the activities and tasks associated with maintaining GI features. The purpose of this section is to provide an overview of the maintenance activities and associated frequency for optimal performance as these aspects of the program are likely to dictate staffing needs and program costs. This section is not intended to be an in-depth survey of all tasks necessary for maintenance.

6.1 Maintenance Activities and Frequency

When discussing the actual activities necessary to maintain a GI project, activities are generally divided into two categories: routine maintenance and non-routine maintenance. The definitions of these categories and examples of specific tasks associated with the activities are provided below.

- **Routine Maintenance:** Routine maintenance includes the activities associated with preventative maintenance that should be conducted at regular intervals. Though routine maintenance items vary according to each GI technology, activities for vegetated practices tend to include weeding and removing trash and sediment, while activities for pervious pavement include sediment removal. Not all routine activities are required to be performed on the same schedule, and schedules can range from weekly to annually.
- **Non-routine Maintenance:** Non-routine maintenance activities can be defined as the activities that are performed as a reaction to a particular performance issue. Examples of non-routine maintenance include repairing damage from unexpected events (residents sometimes mow GI projects or replace plants), replacing a sign or traffic delineator that has been damaged, or irrigating a project during a drought. Though more difficult to predict, some part of the maintenance program cost estimate should consider the costs associated with these non-routine maintenance items.

In addition to the tasks necessary to maintain a GI project, a maintenance program should establish frequencies for inspecting the site and performing maintenance activities. The following elements should be considered when establishing maintenance and inspection frequencies:

- GI practice type (i.e., bioretention, pervious pavement, rain barrel, etc.);

- Site specific factors (dependent on actual site conditions such as runoff volume, traffic loading, sediment loading, litter/debris loading, etc.);
- Seasonal variations (i.e., fall leaf drop, snow removal, etc.);
- Temporary adjacent site activities (i.e., construction); and
- Irregular weather events (i.e., hurricanes, wind storms, etc.).

Because these factors are different from site to site, the necessary maintenance frequency for each site is likely to vary geographically and could vary throughout the year. (At the same time, these factors have greater variation between two cities, even two cities in the same region.) The contacted programs provided their current minimum frequency for site visits. These site visits could include both site inspections and maintenance activities (Table 6). As described earlier, these programs are in the beginning stages of implementation and the frequencies are likely to change as maintenance experience and knowledge grows.

Table 6. Minimum Frequency of Site Visits

City	Frequency*
Cincinnati, OH	No set frequency established yet.
Kansas City, MO	Weekly (Mar. through Nov.); Monthly (Dec. through Feb.)
Montgomery County, MD	Monthly
New York City, NY	Weekly
Onondaga County, NY	Weekly
Philadelphia, PA	Surface/Landscaping – 9-12 maintenance events/visits/year; subsurface min 1/yr, does not include site inspections
Portland, OR	3-4 times a year
Seattle, WA	Based on need to achieve Level of Service which varies from site to site

*May include site inspections and/or maintenance task performance

6.2 Materials and Resources

In consideration of developing the protocol for maintenance crews to accomplish maintenance activities, it is necessary to consider the potential equipment and resources required to perform maintenance. For most vegetated practices, these resources will include the equipment necessary for landscaping maintenance, such as shovels and trash bags. However, Philadelphia's GI projects include perforated pipes connected to catch basins that require sewer inspection equipment and jet-vac trucks for maintenance. Additionally, vacuum trucks for maintaining pervious pavement are also necessary. This equipment is costly and should be considered when a program is selecting its maintenance entity. For these reasons, consideration of the materials and resources necessary to perform maintenance may dictate whether or not maintenance can be performed in-house.

7 Maintenance Team Development

When developing a maintenance program, consideration should be given to the staffing size and skill sets required to perform the work. In the staffing discussions with the GI programs, each program indicated that they had staff to both oversee activity completion and administration of the maintenance program and staff or contractors to perform the maintenance inspections and

activities. The administrative staff is needed to coordinate activities, issue work orders, and track progress. For GI programs using contractors for maintenance, the administrative staff also occasionally supervised the contractor's work to confirm the correct process and approach to activities.

Based on the GI programs that were interviewed, the in-house staff tended to be a small group ranging from one to six individuals. Although the administrative staffs for the program varied in skill sets, the programs seemed to benefit from in-house staff having an understanding of landscape design, as well as individuals experienced with hiring park or landscaping crews. Table 7 outlines information collected from discussions with GI programs on the details of their administrative staff with reference to the size of the program that the staff oversees.

Table 7. Overview of Current GI Maintenance Program Administrative Staffing Levels

City	Administrative Staff	
	Size	**Skill Sets and Task**
Cincinnati, OH	2 part-time staff	Program staff that provide oversight on tasks and track activities
Kansas City, MO	1 staff	Landscape architect that provides oversight on tasks and tracks activities
Montgomery County, MD	1 staff	Program staff that provide oversight on tasks and track activities
New York City, NY	1 staff for each borough	Horticultural specialists that provide oversight on tasks and track activities. City Park Workers for manual tasks including garbage and sediment removal
Onondaga County, NY	1 staff	Program staff that provide oversight on tasks and track activities
Philadelphia, PA	4 staff	Scientist and engineering staff that inspect SMP's, manage contracts, review designs [for maintainability] at 30% and 70% design, provide on-site oversight on tasks and track implementation activities (i.e. design and construction status
Portland, OR	2 staff	Program staff that provide oversight on tasks and track activities
Seattle, WA	1 staff	Program staff that provide oversight on tasks and track activities

In consideration of defining the crew to perform maintenance, most cities focused on the crews required to maintain their vegetated GI projects. For these projects, several cities sought out individuals or crews with landscaping experience. Some programs specified that they looked for individuals with experience on both manicured beds and wetland type landscape as those skills were most relevant to GI project maintenance.

Table **8** outlines information collected from discussions with GI programs on the details of their maintenance crews.

Table 8. Overview of Current GI Maintenance Crew Staffing Levels for Landscape Efforts

City	In-house Maintenance Crews		Landscape Contractor/Nonprofit Crew Size	
	Size	Skill Sets	Size	Skill Sets
Cincinnati, OH	2 staff	2 part time staff to oversee GI activities with private entities and MSD assets with Parks support. 2 full time Parks staff to assist MSD as requested for inspection and maintenance activities.	No contractor crew	
Kansas City, MO	4 staff	traditional landscape maintenance and utility work	2-4 staff	traditional landscape installation and maintenance
Montgomery County, MD	No in-house crew		3 staff (1 landscape foreman, 2 laborers)	No information available
New York City, NY	5 staff	Gardeners, city park workers and seasonal city park workers	No contractor crew	
Onondaga County, NY	No information available	Use crew for small tasks as supplement to contractor. Can only use according to union job description	Contractor crew used for porous pavement ranges from 2-12 staff Nonprofit crew is 8-9 staff	No information available
Philadelphia, PA	Crews to perform inspections and " light " maintenance (i.e. hand weeding, pruning, trash removal, replacement/cleaning of inlet protection/pretreatment devices)		Landscape contractor (and subsurface contractor) Surface ~12 Subsurface~6	
Portland, OR	No in-house crew		No information available	
Seattle, WA	No in-house crew		Provided through contract services	

8 Maintenance Documentation and Tracking

Once maintenance activities and frequencies are specified and staff is identified, maintenance on GI projects can be performed. To track completed maintenance activities and GI project conditions at each site, each contacted GI program has an established system in place. As maintenance needs are identified in the field, documenting these issues and tracking that maintenance activities are performed to fix these issues can help formally direct maintenance work. This process allows programs the ability to adapt procedures and perform corrective actions for specific problems identified in the field. For the GI programs contacted, these tracking systems also help inform staffing and resource needs for their GI maintenance programs. By tracking GI project conditions and needs and associated activity completion, the system can help identify when to increase staffing or when other resources are needed (i.e. equipment). To help create these feedback mechanisms in the maintenance program, it is important to track the following:

- Completed activities;

- Staff time associated with activity completion;
- GI project conditions found in the field;
- Issues identified in the field that require additional maintenance; and
- Costs associated with the completion of both routine and non-routine maintenance activities.

As these items are tracked through a documentation and tracking system, the information can be used to inform decisions on modifying activity frequency or staffing needs. An ideal goal of maintenance documentation should be to develop a computerized maintenance management system (CMMS) or asset management system that allows for electronic logging and integrates with GIS. One of the surveyed cities recommended making the documentation and tracking process as adaptable as possible to allow for the system to be optimized over time (based on GI implementation locations, types, etc.). It is important to simplify initial efforts for documenting and tracking GI maintenance with the expectation that the system can evolve as more knowledge is gained on ways to improve maintenance and its documentation.

Beyond providing structure and direction for a maintenance program, maintenance activity documentation and tracking can also assist programs with regulatory compliance. Several programs indicated that maintenance for GI was a requirement of their CSO or stormwater management agreements with regulatory agencies. Depending on the regulatory driver and the specific requirements for CSO or stormwater reduction, requirements to report maintenance activities for compliance can vary widely. In preparation for complying with the regulatory requirements for documentation and tracking, GI programs need to be aware of the requirements for performance monitoring and maintenance activity tracking and create their maintenance programs to meet those needs.

Currently, though each GI program has a documenting and tracking method, the systems vary widely in their approaches. As many cities are still in the initial phases of program development, most of the GI programs specifically indicated that they are using an interim tracking database or tool and are in the process of developing a more formal tool or integrating tracking into their current asset management system. Table 9 below highlights the array of documenting techniques and tracking systems currently in place for GI programs.

Table 9. Overview of Current and Expected Maintenance Task Assignment, Activity Logging, and Tracking Systems

City	Activity Coordination and Documentation		Tracking System	
	Current	Expected	Current	Expected
Cincinnati, OH	Print out inspection forms from Microsoft Access database platform to be used in the field and data entry in the office	Provide formal work orders to crews. Incorporation into Collection System Computerized Maintenance Management System (CMMS) (InfoMaster/Cityworks)	Track with customized Microsoft Access database that allows upload of pictures. Work orders are done informally.	Creating a system that has formal work orders and creates feedback to designs.
Kansas City, MO	Contractor created a log and provides quarterly.	Incorporate a checklist into tablets to use in the field.	Tracked through emails.	Incorporate into asset management system (Hansen).
Montgomery County, MD	Work order is issued to contractor and contractor provides daily logs.		Tracked through asset management system (EAM).	
New York City, NY	Use paper sheets to collect information.	Digital entry of data on-site	Tracked in a spreadsheet.	Using a consultant to create a tracking tool.
Onondaga County, NY	Work orders are created when maintenance is required.		Partially incorporated.	Incorporate into asset management system (Maximo).
Philadelphia, PA	Contractor tasks are documented.	Work Order Management System (CityWorks)	Tracked in a database.	Incorporate into asset management system (Cityworks).
Portland, OR	Work orders are created when maintenance is required.		Tracked in a database.	Incorporate into asset management system (Hansen).
Seattle, WA	Work orders are created when maintenance is required.		All GI projects are input into GIS and can create work orders for tracking.	Incorporate into asset management system (Maximo).

9 Maintenance Program Costs

With the pieces of the GI maintenance program more clearly defined, it is necessary to consider long-term maintenance program costs. As described throughout this paper, the programs that were surveyed are in the beginning stages of their maintenance programs. At this stage, program costs are difficult to assess because the programs still have unknown factors. Some programs have initial program cost estimates for performing maintenance on their current levels of GI, but few have confirmed these estimates. These estimates are predicted to significantly change as programs fully understand their maintenance needs and grow their maintenance programs. Based on the discussions on costs with the various GI programs, the cost estimates for maintenance programs are highly dependent on a number of factors including:

- Maintenance entity model used;
- Maintenance program experience;
- Specified level of service for maintenance;
- Site visit frequency;
- Weather conditions;
- Staffing needs;
- Travel time between sites; and
- Estimating the need for all three levels of maintenance (routine, non-routine, and replacement costs).

Table 10 below highlights the current cost estimates that were specified during the discussions with GI programs. Most of the programs did not yet have cost estimates to provide and so were not provided.

Table 10. Examples of Current GI Maintenance Cost Estimates

City	Cost	Notes
Montgomery County, MD	$2355/62 sites/year	Current maintenance estimate
Portland, OR	+/- $3.00/square foot/year for bioretention (first two years) +/- $1.55/square foot/year/ for bioretention (subsequent years)	Current maintenance estimate, Values reported for the 2-year establishment period and after the 2-year establishment period, (assumes no irrigation after 2 years)
Seattle, WA	Landscaping: $2.21 during first 3 years, $1.68 years 4-100.	Current maintenance estimate

10 Conclusion

Based on the conversations with these programs, the implementation of GI and the organizational structure of GI maintenance programs can be influenced by considerations for how the GI projects will be maintained. The success of the GI maintenance program is heavily reliant on: considerations and development of the entities both overseeing and performing maintenance tasks; maintenance tasks performed; the method for tracking maintenance activities; and funding. All of the programs surveyed are in the early stages of the development of both their GI implementation and GI maintenance programs. These programs acknowledge that their programs require the ability to adapt as lessons are learned on construction and maintenance. For any maintenance program, consideration should be given to how the program can change as feedback on areas of improvement is identified.

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