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ALCOSAN's Green Stormwater Infrastructure Guidance Manual

GSI Siting, Selection & Sizing, Cost Estimating, Construction Inspection and Operation & Maintenance

March 2019

Cover photo: *A 585-foot bioswale in Pittsburgh's Hill District, implemented by the Pittsburgh Water and Sewer Authority with ALCOSAN GROW support*

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Acronyms and Abbreviations

AACE	Association for the Advancement of Cost Engineering
AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
ALCOSAN	Allegheny County Sanitary Authority
AMD	Acid Mine Drainage
ASPE	American Society of Professional Estimators
ASTM	American Society for Testing Materials
ATPB	Asphalt-Treated Permeable Base
BMPs	Best Management Practices
CaCl2	Calcium Chloride
CCE	Certified Cost Engineer
CCTV	Closed Circuit Television Video
CEP	Certified Estimating Professional
CMA	Calcium Magnesium Acetate
CPE	Certified Professional Estimator
CtS	Controlling the Source
DEP	Department of Environmental Protection
E&S	Erosion and Sedimentation
EPA	Environmental Protection Agency
FT	Feet
GI	Green Infrastructure
GIS	Geographic Information System
GROW	Green Revitalization of Our Waterways
GSI	Green Stormwater Infrastructure
HASP	Health and Safety Plan
HDPE	High Density Polyethylene
HSG	Hydrologic Soil Group
HVAC	Heating, Ventilation and Air Conditioning
KA	Potassium Acetate
KCl	Potassium Chloride
LID	Low-Impact Development
LIDRA	Low-Impact Development Rapid Assessment
LOI	Letter of Interest
LOS	Level of Service
N/A	Not Applicable
NGICP	National Green Infrastructure Certification Program
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
OF	Overflow
ORD	Office of Research and Development
ORE	Overflow Removal Efficiency
PSI	Pounds per Square Inch
RCS	Regional Collection System
SC	Source Control
UNC	University of North Carolina
USDA	United States Department of Agriculture
WERF	Water Environment Research Foundation

CHAPTER 1

Introduction to GSI

SECTION 1

Introduction to GSI/SC

1.1 Controlling the Source Plan

ALCOSAN is committed to taking a proactive approach to stormwater management. ALCOSAN and its customer municipalities and authorities have completed significant work throughout the service area to understand the scope and challenges of preventing extraneous source flow from entering the Regional Conveyance System. Building on these efforts, ALCOSAN and its Green Stormwater Infrastructure and Source Control (GSI/SC) Program Manager have undertaken a planning-level engineering analysis to create a holistic plan, Controlling the Source (CtS).

The Plan will lay out a consistent framework for evaluating GSI/SC in the ALCOSAN service area and is intended to be a working resource for ALCOSAN, our customer municipalities, and other regional partners to aid in:

1. Identifying cost-effective and high-volume source control projects capable of reducing sewer overflows
2. Developing a framework for coordination of the involved parties
3. Outlining strategies for implementing stormwater management programs and
4. Quantifying the potential impact GSI-SC can have on the ALCOSAN Regional Conveyance System

A draft of the CtS is scheduled to be released in 2019.

1.2 Project Drivers and Goals

While the primary driver for the ALCOSAN Green Revitalization of Our Waterways (GROW) program is reducing the volume of sewer overflows to streams and rivers, GSI projects may involve several other drivers and goals that should be considered when siting, selecting and sizing GSI practices. Practitioners must establish the drivers and goals for a GSI project as early in the process as possible, as they may have significant implications for project performance, site functionality, implementation and life-cycle costs, design complexity, ease of construction and maintenance, ancillary benefits and various other factors.

Project drivers and goals can be the most important factors in the type of GSI selected because the most cost-effective GSI implementation often occurs when GSI strategies are integrated within the context of site or infrastructure improvements that are already planned. In fact, the greatest cost and performance benefits are realized when an interdisciplinary approach is taken to site design or redevelopment so that site improvements are planned and located not only to serve the primary project purpose but also to allow for successful implementation of GSI. The balance of these two drivers (i.e., site programming and appropriate GSI locations) can significantly influence the overall success of GSI implementation.

Typical GSI project design goals include the following:

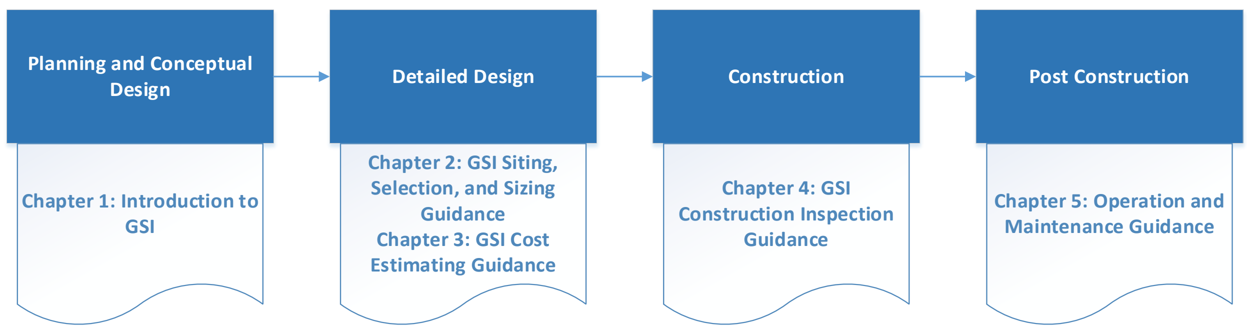
- Runoff reduction through infiltration, evapotranspiration, and/or rainwater harvesting
- Extended detention / slow release
- Water quality improvement
- Combinations of the above

The following list includes typical project drivers and/or opportunities beyond overflow reduction in which GSI can be cost-effectively integrated:

- New or redevelopment, including brownfields
- Drainage improvements
- Accessibility improvements such as ramps, sidewalks, etc.
- Roadway layout improvements
- Roadway or parking lot repaving or reconstruction
- Potential for flood reduction
- Water quality improvements resulting from overflow reduction
- Potable water reduction for landscape irrigation or indoor uses
- Building expansion / renovation or roof replacement
- Utility replacement / rehabilitation
- Street tree or urban forestry programs

1.3 How to Use the Guidance Document

This document is intended to provide guidelines to facilitate successful implementation of green stormwater infrastructure designs, from initial planning stages to post construction maintenance. Figure 1-1 summarizes how to use this document.



Chapter 1 Introduction to GSI introduces GSI facility types and their components.

Chapter 2 GSI Siting, Selection and Sizing Guidance provides key factors to consider when siting, selecting and sizing the most efficient GSI practices.

Chapter 3 GSI Cost Estimating Guidance provides guidance, requirements and resources for developing clear and accurate cost estimates for GSI projects.

Chapter 4 GSI Construction Inspection Guidance provides information to help facilitate successful construction inspections for all phases of GSI construction.

Chapter 5 Operations and Maintenance Guidance provides information on general best practices for GSI operations and maintenance tasks throughout the lifespan of a GSI facility.

SECTION 2

Green Stormwater Infrastructure Facilities

2.1 Overview of GSI Facilities

GSI facilities attempt to mimic the natural water cycle, which helps to mitigate stormwater problems caused by development and urbanization. In alignment with this overall goal, GSI facilities often function to serve three primary objectives:

- Reduce the volume of stormwater runoff
- Reduce the flow rate of stormwater runoff
- Remove pollutants from stormwater runoff

GSI facilities can be designed to meet one or more of these primary objectives while also providing numerous secondary benefits including groundwater recharge, enhanced biodiversity, aesthetic improvement, energy conservation, and improved air quality.

The following sections provide descriptions of common GSI types and example variations listed in Table 2-1, including typical components and primary functions. It is important to note that not all GSI practices are green in the literal sense (i.e. include vegetation); some GSI practices such as infiltration trenches and permeable pavements are more structural in nature yet can still be effective at reducing runoff. In addition, GSI practices are often combined into "treatment trains" to more effectively meet the design objectives and fit efficiently into sites.

GSI facilities can be designed to meet one or more of these primary objectives while also providing numerous secondary benefits.

Table 2-1. GSI Practice Types

GSI Practice	Examples/Variations
Bioretention	Bioretention Basin
	Vegetated Planter
	Vegetated Swale
	Rain Garden
Infiltration Trenches	Tree Trench
	Trench Below Pavement
	Trench Below Vegetation
	Surface Flow Infiltration Trench
Permeable Pavement	Porous Asphalt
	Porous Concrete
	Permeable Block Pavers
	Open Grid Pavers
Other	Green Roof
	Rainwater Harvesting
	Stormwater Wetland

2.2 Bioretention Facilities

For purposes of this guidance document, bioretention facilities are defined as follows:

Bioretention facilities are depressions that contain vegetation in an engineered soil mixture above a gravel drainage bed. They provide storage, infiltration and evaporation of both direct rainfall and runoff captured from surrounding areas.

Bioretention systems can be designed to meet all three primary design objectives via infiltration, evapotranspiration or extended detention. Bioretention attempts to mimic predevelopment hydrologic conditions. Unlike infiltration trenches and permeable pavements, bioretention systems include vegetation and soil, and they treat stormwater by ponding water on the surface prior to filtration and infiltration. Bioretention systems may or may not utilize an underdrain, although they are generally recommended. The bioretention soils should be permeable to allow for infiltration and support vegetation. The vegetation is typically specially adapted native vegetation such as meadow grasses, shrubs and perennials. These systems can be integrated into a variety of locations with a high degree of flexibility, including roadways and other urban sites. Table 2-2 provides a summary of typical bioretention system components, while Figure 2-5 provides a typical schematic of a bioretention facility.

Variations of bioretention and rain garden facilities include:

- Bioretention Basin (Figure 2-1)
  - Excavated surface depression with densely planted vegetation in an engineered soil layer on top of a subsurface storage bed. Runoff is collected from the surface or conveyed from roof leader downspouts to the basin surface.

Figure 2-1. Bioretention Basin
Bioretention basin at East Liberty Presbyterian Church in Pittsburgh, PA with a variety of native plantings (Implemented by East Liberty Development, Inc.)

- Vegetated Planter (Figure 2-2)
  - Designed to be either flow-through or infiltration. Flow-through planters consist of a container or enclosed planting structure with an impervious bottom or they can be placed on an impervious surface such that they do not infiltrate. Runoff is collected from the surface or conveyed from roof leader downspouts to the planter surface. Infiltration planters consist of a container or enclosed planting structure designed for infiltration. Runoff is collected from the surface or conveyed from roof leader downspouts to the planter surface, which must be at an elevation lower than the collection point (e.g. gutter line of street, downspout, etc.).

Figure 2-2. Vegetated Planters
Vegetated Planters adjacent to a building and along a street

- Vegetated Swale (Figure 2-3)
  - Shallow stormwater channel that can be densely planted with a variety of grasses, shrubs and/or trees as in a true vegetated swale or simply planted with turf grass (drainage swales). They are often used along roads or other linear features and function as conveyance systems to attenuate runoff rates, enhance water quality treatment and promote infiltration. Swales are often combined with infiltration trenches to enhance their stormwater storage capacity.

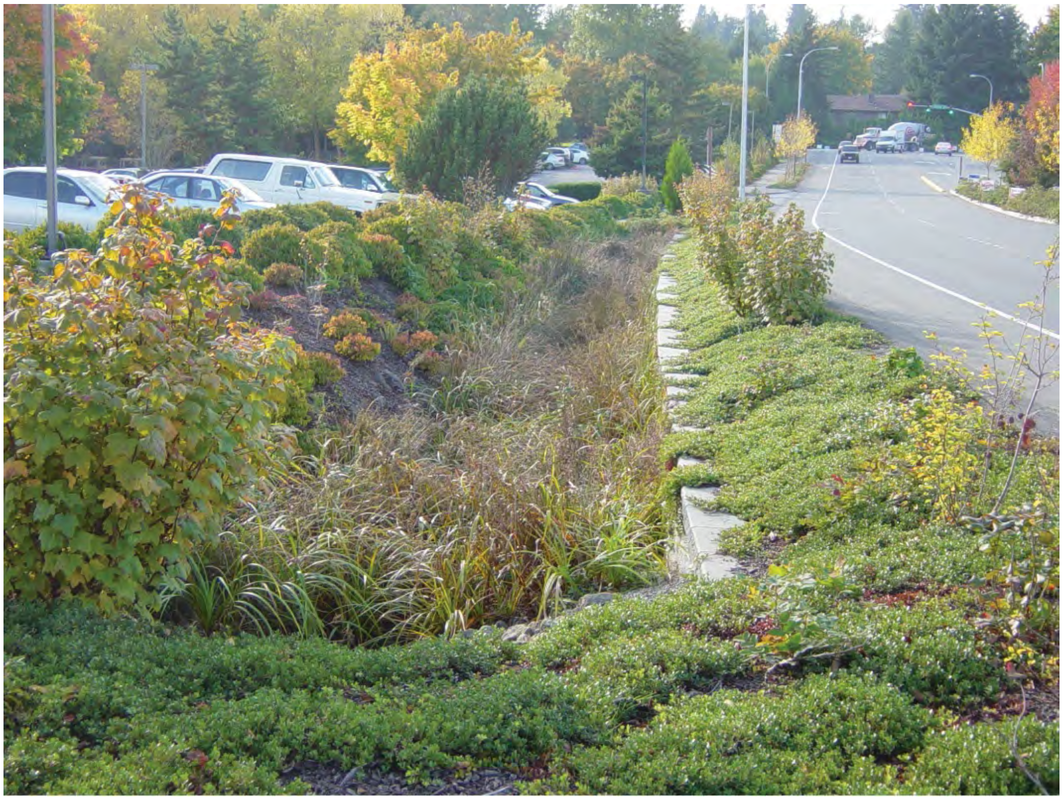


Figure 2-3. Vegetated Swale
Bioswale between a road and parking area

- Rain Garden (Figure 2-4)
  - Type of bioretention with a simpler design and typically smaller footprint that consists of only the engineered soil layer without the subsurface storage bed.

Figure 2-4. Rain Garden
Rain garden in a public park

Typical System Components: Bioretention

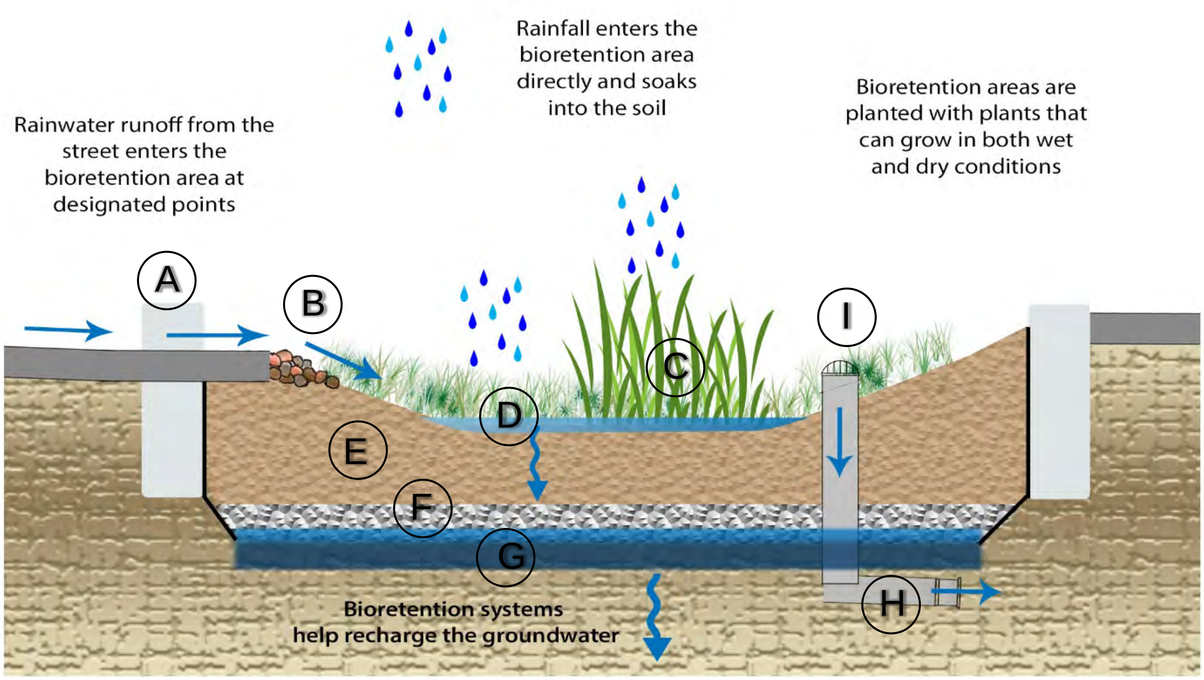


Figure 2-5. Bioretention System Schematic

Table 2-2. Typical System Components: Bioretention

Component Label	Bioretention Components	Description
A	Surface Inlet or Curb Cut	Directs surface runoff into bioretention system
B	Splash Pad, Forebay, Sediment Trap or other Energy Dissipater	Dissipates flow energy to reduce erosion, allows for settling of sediment
Not pictured	Check Dams	Surface berms, dam, or weir composed of various materials to detain runoff in sloped systems, typical height varies with trench depth, but top should be at least 6” below bottom of pavement
C	Vegetation	Drought tolerant, native or adapted vegetation
D	Ponding Depth	Provides above-ground runoff storage via a surface depression
Not pictured	Mulch/Alternative Surface Cover	Reduces soil erosion; provides filtration, organic matter and weed suppression; retains soil moisture. To maintain benefits, choose appropriate mulch type, apply at proper depth and periodically replace. Difficulties of using traditional wood mulch include floating away, chemical treatment, fungus growth, excessive nutrients and replacement costs. Alternatives include creating a ‘living mulch’ with groundcover plants (e.g. creeping thyme) or stone mulch.
E	Bioretention Soil	Planting medium that provides water/nutrients to plants, enhances biological activity and root growth, and provides enhanced storage or stormwater within void space Use very well-drained soil to promote high infiltration rates and to help maintain porosity over time
F	Graded Aggregate Layer	Graded aggregate to provide separation between bioretention soil and gravel drainage bed
G	Gravel Drainage Bed (storage aggregate)	Clean, washed, uniformly graded aggregate below soil layer provides additional runoff storage area
H	Underdrain	Perforated pipe placed in gravel drainage bed to drain system if subgrade infiltration rates are not sufficient to dewater the system in an acceptable period
I	Outlet Device (Riser Structure)	Directs excess runoff flow out of the bioretention facility
Not pictured	Weir	Metal plate, typically, within an outlet device that is utilized to control and maximize the water level within a bioretention facility
Not pictured	Cleanouts	Provide access to underdrain/distribution pipes for inspections and cleaning
Not pictured	Monitoring / Observation Well	Enables access to the subsurface to determine water levels and their fluctuation over time

2.3 Infiltration Trenches

For purposes of this guidance document, infiltration trenches are defined as follows:

Infiltration trenches are channels or depressed areas with side slopes filled with vegetation or gravel that intercept runoff from upslope impervious areas. They provide storage volume and additional time for captured runoff to infiltrate the native soil below.

Infiltration trenches can be located below pavements without direct surface flow, instead receiving stormwater via an inlet and pipe collection system. Infiltration trenches provide capacity to store runoff volume during rainfall and allow captured runoff to infiltrate into the subgrade soil below. Trenches are typically filled with an appropriate, clean, uniformly graded (Figure 2-6) aggregate (e.g. not slag) that provides void spaces to store and filter runoff prior to infiltration. Table 2-3 provides a summary of typical infiltration trench components, while Figure 2-11 provides a typical schematic of an infiltration trench.

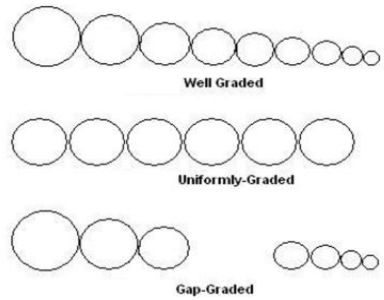


Figure 2-6. Aggregate Classifications.
Source: en.wikipedia.org

Alternative storage media can be used in conjunction with or instead of aggregate. For example, sand-based structural soil can provide structural support under pavements, storage capacity and rooting volume for trees. Various proprietary manufactured storage media units can be used in space-constrained areas where high void percentages are required to maximize runoff storage.

This type of facility provides for removal of common pollutants, as well as reducing runoff volume, attenuating flow, and facilitating groundwater recharge. Infiltration trenches can be combined with other facilities to increase storage / infiltration and can be used in a variety of applications as summarized below.

- Tree Trench (Figure 2-7)
  - Tree trenches combine planting soils and trees with a subsurface storage bed. Tree trenches provide for infiltration, storage and evapotranspiration while providing increased tree canopy.

Figure 2-7. Tree Trench
Tree trench below a sidewalk surface

- Trench Below Pavement (Figure 2-8)
  - Subsurface storage below impervious cover such as parking lots, alleys, sidewalks or streets. Stormwater is typically conveyed to the trench via a subsurface stormwater collection system.

Figure 2-8. Infiltration Trench
Infiltration Trench along curb under the roadway

- Trench Below Vegetation (Figure 2-9)
  - Linear subsurface storage bed located below vegetation. Can be complementary to a vegetated swale. Does not require a surface depression.

Figure 2-9. Infiltration Trench
Infiltration trench in turf grass

- Surface Flow Infiltration Trench (Figure 2-10)
  - Trenches designed to receive flow from the surface via a permeable cover.

Figure 2-10. Surface Flow Infiltration Trench
Infiltration trench with stone surface (source: Maryland Department of Transportation)

Typical System Components: Infiltration Trench

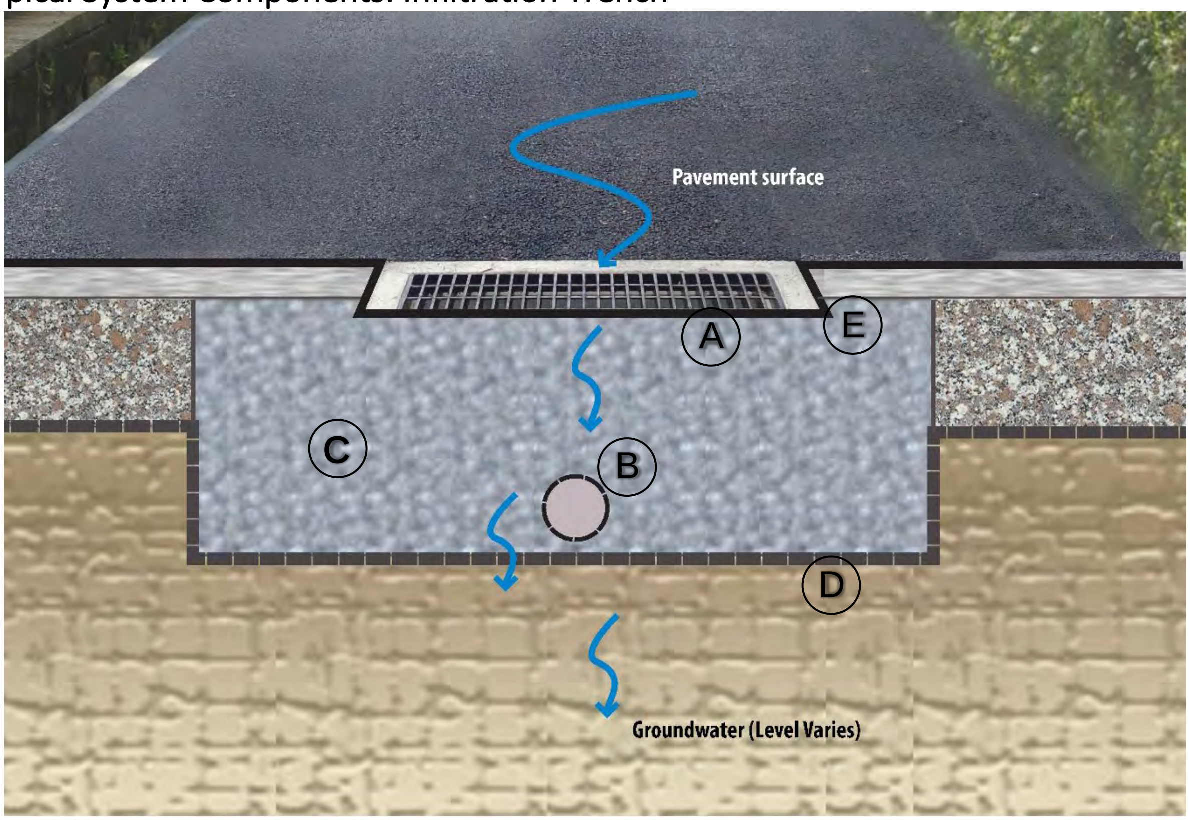


Figure 2-11. Infiltration Trench Schematic
Inlet conveyance to aggregate storage under conventional pavement.

Table 2-3. Typical System Components: Infiltration Trench

Component Label	Infiltration Trench Components	Description
A	Pretreatment	Inlet filter inserts, forebays, sumps or other such devices remove coarse sediment, debris, oil and grease to prevent clogging aggregate storage and trench bottom or sides
Not pictured	Cleanouts	Provide access to underdrain/distribution pipes for inspections and cleaning
B	Underdrain/Distribution Pipes	Perforated pipes placed in aggregate storage bed to distribute runoff throughout bed and to drain system if subgrade infiltration rates are not sufficient to dewater the trench in an acceptable period
Not pictured	Pea Gravel Surface or Riverstone Surface	Top layer trench surface to act as a filter layer for surface runoff entering the trench
C	Coarse Storage Aggregate	Clean, washed, uniformly graded aggregate acts as storage layer (typically yields 40% void space)
Not pictured	Sand Filter	Sand filter layer at bottom of trench
D	Geotextile / Filter Fabric (if applicable)	Prevents soils from clogging aggregate, optional on bottom and sides (or top) of trench
Not pictured	Monitoring Well	Enables access to the subsurface to determine water levels and their fluctuation over time
E	Inlet/Outlet Structures	Inlets/roof drains direct stormwater to infiltration trench; outlet structure directs excess runoff out of trench; outlet structures may be designed for slow release with weirs, orifice caps or other hydraulic controls

2.4 Permeable Pavement

For purposes of this guidance document, permeable pavement sysstems are defined as follows:

Permeable pavement systems are excavated areas filled with gravel and paved over with a porous concrete or asphalt mix. Normally all rainfall will immediately pass through the pavement into the gravel storage layer below it where it can infiltrate at natural rates into the native soil. Block paver systems consist of impervious paver blocks placed on sand or bedding as recommended by manufacturer with a gravel storage layer below. Rainfall is captured in the open spaces between the blocks and conveyed to the storage zone and native soil below.

Permeable pavement is often utilized where a hard yet permeable surface is desired, including parking lots, residential streets, alleys, paths, sidewalks, playgrounds and basketball courts. These facilities reduce runoff volumes, attenuate flows, and aid in the removal of common pollutants. Table 2-4 provides a summary of typical permeable pavement components, while Figure 2-15 provides a typical schematic of a permeable pavement facility.

There are several different types of permeable pavement:

- Porous Asphalt (Figure 2-12)

– Porous asphalt is similar to conventional asphalt, except it is modified to have fewer aggregate fines to allow runoff to pass through the surface.

Figure 2-12. Porous Asphalt Surfaces

- Porous Concrete (Figure 2-13)
  – Porous concrete is similar to conventional concrete, except it is modified to reduce or eliminate fine aggregates and therefore it has a rougher texture with pores for runoff to pass through the surface.

Figure 2-13. Porous Concrete
Precast porous concrete sidewalk and pervious concrete parking bays with conventional asphalt drive aisle.

- Permeable Block Pavers (Figure 2-14)
  – Pavers that are installed with gaps, typically filled with pea gravel or as recommended by manufacturer, that allow stormwater to infiltrate through the spaces between the pavers.

Figure 2-14. Permeable Pavers
Permeable pavers in a parking lane and in a pedestrian plaza

- Open Grid Pavers (Figure 2-15)
  - Similar to block pavers, open grid pavers are designed with larger open areas that are filled with gravel or soil and planted with turf grass that allows infiltration. These are often used in overflow parking areas or fire truck access lanes where infrequent traffic is expected.

Figure 2-15. Open Grid Pavers
Open grid pavers in Philadelphia, PA (source: [Philadelphia Water Department)](Philadelphia Water Department)

Typical System Components: Permeable Pavement

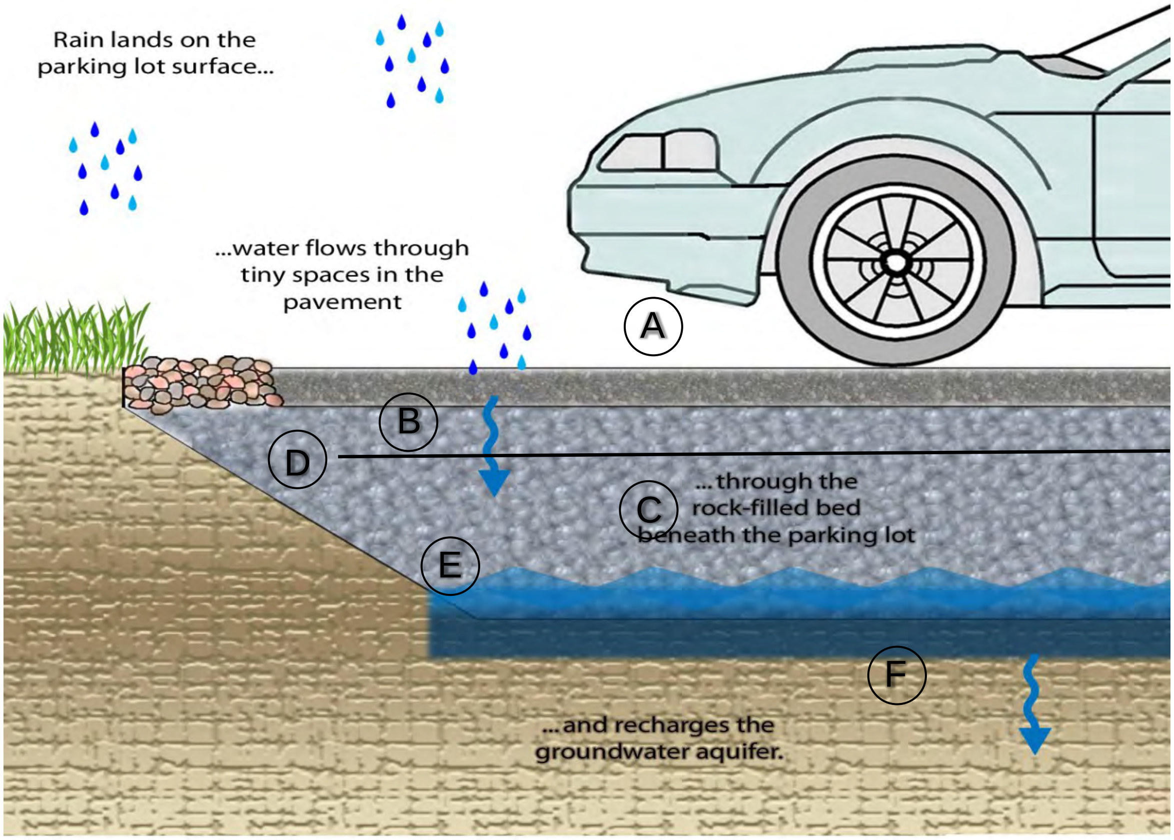


Figure 2-16. Permeable Pavement Facility Schematic

Table 2-4. Typical System Components: Permeable Pavement

Component Label	Permeable Pavement Components	Description
A	Wearing Course	Surface pavement material depending on pavement variation
Not pictured	Bedding Course (pavers only)	Layer of smaller aggregate used to provide a level bed for pavers, also can be used to fill spaces between pavers
B	Base/Choker Course	Clean, washed, open-graded crushed stone; provides level surface for paving between storage aggregate and permeable pavement
C	Storage Aggregates	Provides storage for runoff, comprised of clean, washed, open-graded gravel or crushed stone
Not pictured	Underdrain/Distribution Pipes (if applicable)	Perforated pipes placed in aggregate storage bed to distribute runoff throughout bed and to drain system if subgrade infiltration rates are not sufficient to dewater the trench at an acceptable rate
Not pictured	Cleanouts (if applicable)	Provide access to underdrain/distribution pipes for inspections and cleaning
Not pictured	Monitoring Well	Enables access to the subsurface to determine water levels and their fluctuation over time

Component Label	Permeable Pavement Components	Description
Not pictured	Inlets/Outlet Control Structure	Inlets direct surface runoff to aggregate storage bed; outlet structure directs excess runoff out of the system; outlet structures may be designed with weirs, slow release orifice caps or other hydraulic controls
D	Geogrid	Interlocking plastic reinforcement designed to provide structure and strength under permeable surface
E	Filter Fabric	Prevents soils from clogging aggregate, on bottom and sides of storage bed
F	Subgrade	Existing site soil at bottom of system, where infiltration occurs

2.5 Other GSI Types

In addition to the three main GSI practice types outlined above, there are several additional examples of GSI types, including green roofs, rainwater harvesting and stormwater wetlands. While not the focus of this document, brief descriptions for these other GSI types follow.

Green Roofs

A green roof (or vegetated roof) is a layer of vegetation and media on a flat or pitched roof (up to a 30-degree slope), creating hydrologic characteristics that attempt to mimic a natural pervious surface. A green roof contains multiple layers, consisting of waterproofing, non-soil engineered growth media, fabrics and synthetic components. Green roofs can be optimized to achieve water-quality benefits, peak flow control and volume reduction. Green roofs generally receive direct rainfall, providing source control that prevents the contact of rainfall with pollutants. There are three main types of green roofs: extensive, semi-intensive and intensive. Extensive green roofs are planted with primarily mosses, sedums and succulents. Semi-intensive roofs support perennials, sedums, ornamental grasses and small shrubs. Intensive green roofs support perennials, shrubs, trees or agricultural plantings. The typical media depths for these three types are summarized in Table 2-5.

Table 2-5. Vegetated Roof Types

Vegetated Roof Type	Media Depth (inches)	Function
Extensive	2- 6	Retention and detention of lesser volumes, attenuates runoff rates from smaller storms (<2 inches of rainfall depth)
Semi-Intensive	6 - 9	Retention and detention of intermediate volumes, attenuates runoff rates more than extensive, less than intensive
Intensive	>9	Retention and detention of greater volumes, attenuates runoff rates from larger storms (generally >2 inches of rainfall depth)

[1]Vesuviano G. et al, 2013

Rainwater Harvesting.

Rainwater harvesting is the practice of capturing rainwater from roof surfaces and reusing it for either landscape irrigation or indoor uses such as toilet flushing. Common rainwater harvesting storage techniques include rain barrels and cisterns. In addition to reducing potable water demand, rainwater harvesting systems can help reduce runoff volume and control the peak release rates.

Stormwater Wetlands

Stormwater wetlands are shallow marsh systems planted with emergent vegetation. Wetlands, other than submerged gravel wetlands, maintain a permanent water surface and can be designed to control runoff peak rates and improve water quality. Stormwater wetland types include ponds/wetlands systems, pocket wetlands and submerged gravel wetlands.

2.6 Regional GSI Design References

All GSI practices should be designed in accordance with local standards and regulations. Multiple GSI design resources are available to practitioners at the state and regional levels (Table 2-6).

Table 2-6. Regional GSI Design References

Reference Name	Publishing Agency	Date Published/ Updated	Link
Addressing Green Infrastructure Design Challenges in the Pittsburgh Region Fact Sheet Series	EPA, Environmental Protection Agency	January 2014	Addressing Green Infrastructure Design Challenges in the Pittsburgh Region
Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks	National Recreation and Park Association	2017	Resource Guide for Planning, Designing and Implementing Green Infrastructure in Parks
Green Solutions Fact Sheets	3 Rivers Wet Weather	2016	Green Solutions Bioswales Disconnected Downspout Green Roof Planter Box Permeable Pavement Rain Barrel Rain Garden Vegetated Filter Strip Vegetated Swale
Procedures Manual for Developers Chapter 9: Green Stormwater Infrastructure	Pittsburgh Water and Sewer Authority	January 2018	Procedures Manual for Developers
Pennsylvania Stormwater BMP Manual	Pennsylvania Department of Environmental Protection, Bureau of Watershed Management	December 2006	Pennsylvania Stormwater BMP Manual
Green Stormwater Infrastructure Planning & Design Manual	Philadelphia Water	April 2018	Green Stormwater Infrastructure Planning & Design Manual
Green Streets Design Manual	Philadelphia Water, Philadelphia Streets	2014	City of Philadelphia Green Streets Design Manual
Best Management Practice (BMP) Toolkit	Westmoreland Conservation District.	2015 - 2016	Westmoreland Conservation District BMP Toolkit

2.7 GSI Regulatory Considerations

When considering GSI at the beginning of a project, practitioners are advised to review all regulations that may pose implementation barriers to GSI. For example, some municipalities may require that roof leaders be directly connected to storm or combined sewers. These types of regulations inhibit roof leader disconnection strategies that may be part of rain barrel programs or that would be required for a cistern, planter box or rain garden. Other municipalities may limit the use of permeable pavements (i.e., require conventional pavements) in certain applications. Similarly, road and parking standards may influence GSI selection, placement or design. Such barriers may prove fatal or at least extremely limiting for certain GSI types or they may present opportunities to expand the practice of GSI by permanently eliminating such barriers.

CHAPTER 2

GSI Siting, Selection and Sizing Guidance

SECTION 1

Introduction to Siting, Selecting and Sizing

1.1 Purpose

The intent of this chapter is to provide guidance on the key factors to consider when siting, selecting, and sizing the most effective GSI practices for projects seeking funding under the ALCOSAN Green Revitalization of Our Waters (GROW) program.

Note that this is not a GSI design manual and does not cover all GSI design considerations. Numerous GSI design manuals and resources, at both the state and regional levels, are referenced in Chapter 1, Introduction to GSI.

The process by which green stormwater infrastructure (GSI) practices are sited, selected and sized involves an array of considerations. In fact, it is the interplay among these various considerations that should be fully understood when analyzing sites for GSI implementation. GSI practitioners (typically engineers and landscape architects) are also encouraged to recognize the following with respect to GSI siting, selecting and sizing:

- No two GSI project sites are the same;
- Land use and type play a large role in determining the best GSI for each location;
- Multiple GSI types may be suitable, and necessary, to maximize the volume of stormwater managed for a particular location;
- The most effective GSI practices for a particular project are generally the ones that best balance the various considerations discussed in this document.

In addition, the guidance contained herein is not intended to be prescriptive or inflexible, but rather provide practitioners with a general framework for making informed decisions about common elements encountered as part of GSI projects. There are any number of site-specific characteristics that may not be specifically addressed in this document and must be considered in the design of any GSI practice.

This chapter contains numerous GSI siting, selection, and sizing factors many of which are interrelated and overlapping. While the recommendations included are useful guides for effective GSI decision making, a designer's experience and professional judgment are also critical. Also, not all the discussed factors should be considered equal with respect to their significance on GSI type selection. It is a designer's responsibility to understand the relative importance of these factors for each project location and to differentiate between primary, secondary, or even tertiary factors, as necessary, to make the most informed decision.

1.2 Background

1.2.1 Site Selection and Prioritization

The first step in successful GSI implementation is identifying candidate sites with the most opportunity and the least number of constraints. In terms of the GROW program, ideal sites are those that are most likely to achieve ALCOSAN's goal of maximizing the impact of GSI practices in reducing the volume of overflows to receiving systems. Before specific GSI practices are sited, selected and sized for any project, communities are encouraged to investigate their publicly owned parcels and rights-of-way to identify potential candidates for GSI implementation and then to perform a prioritization analysis to determine the optimal sites.

Site analysis tools such as geographic information system (GIS) mapping are typically used to evaluate both individual sites and larger planning units, such as drainage catchments. Depending on the specific management goals, various physical and environmental features can be mapped to identify areas potentially more or less conducive to GSI (i.e., an opportunities and constraints analysis based in part on clearances from utilities, wetlands, streams, vegetation, buildings, etc.). Other tools that may be useful in determining GSI implementation objectives include hydrologic and hydraulic (H&H) models that are typically used to evaluate large-scale regulatory and planning goals (e.g., ALCOSAN's Regional Collection System H&H model is used to estimate the overflow reduction of proposed projects).

A typical site prioritization approach for GSI implementation involves the following four steps:

1) working with community/program stakeholders to identify key criteria;

2) determining a scoring approach for the various criteria;

3) assigning weights or relative importance to the criteria; and

4) applying the selected criteria and their associated scores and weights to the various potential sites.

Depending on the needs and resources of a community, prioritization criteria can range from simple to rather extensive. Typical criteria can include the following:

- Parcel size and/or amount of available open space (undeveloped, unused, etc.)
- Land use
- Ownership / responsible agency
- Type of street (interstate / principal arterial, minor arterial, major collector, minor collector, local)
- Topography (% slope)
- Size of potential drainage area
- Localized flooding
- Visibility / frequency of use
- Constructability
- Accessibility of site for maintenance
- Soil type and Hydrologic Soil Group (HSG)
- Bedrock and groundwater depths
- Proximity to existing drainage infrastructure
- Soil contamination
- Pollutant loading potential of drainage area
- Planned capital improvements (roadway improvements, utility replacement / rehabilitation, park renovations, etc.)
- Maintenance capacity
- Opportunities for future expansion or elaboration of GSI network

- Opportunities for direct discharge to surface waters
- Overflow Removal Efficiency (ORE) of the location
    - Due to the characteristics of the Regional Collection System, different areas within the ALCOSAN service area produce different amounts of overflow reduction for a given level of source control. The ORE (reduction in overflow volume per unit reduction in inflow) provides a hydraulically informed estimate of overflow impacts of different projects, so that effort and attention can be focused in those geographic areas with the greatest overflow impacts.

GSI Siting

2.1 General GSI Siting Considerations

The first step in constructing a GSI project is identifying the site where the new infrastructure will be located. In this section, a variety of general GSI siting considerations applicable to most if not all GSI practices and applications are briefly discussed. These considerations include maintaining appropriate setbacks between GSI and site features such as buildings, utilities and trees; siting in proximity to existing drainage infrastructure; verifying access for construction, monitoring and maintenance; siting in drainage areas with high pollutant / debris loading potential; integrating with other planned improvements; and avoiding absolute physical constraints to implementation. See Table 2-2 for key design considerations for enhancing suitability.

2.1.1 Setbacks

Setbacks create buffer zones between GSI practices and other site features. Features commonly necessitating setbacks include buildings, utilities, trees and property lines (Table 2-1).

Generally, infiltrating GSI facilities require larger setbacks than non-infiltrating GSI facilities. When setbacks cannot be met, impermeable liners (e.g., high density polyethylene (HDPE) geomembranes) can be installed in GSI to minimize seepage. For example, a flow-through planter could be installed closer than 10 feet to a building foundation if an impermeable liner was used to partially or fully line the planter trench.

During construction, there may also be setback requirements for excavation and staging. Local regulations and safety standards should be consulted to determine required setbacks during such activities.

2.1.1.1 Building Foundations / Structures

When selecting GSI types, practitioners should consider the proximity of GSI footprints to basements, structures and foundations, particularly where there is greater sensitivity to saturated soil conditions or water intrusion. Near building foundations, GSI systems that are non-infiltrating or that do not require excavation (e.g. green roofs and rainwater harvesting systems) are preferred. Subsurface storage and infiltration GSI systems are generally not recommended in close proximity to existing basements, at least not without protection against seepage. Increased setbacks based on site-specific conditions (up to 50 feet or more) should be considered for GSI sited up-gradient of basements to minimize the risk of damage.

2.1.1.2 Utilities

Due to the cost of utility protection and waterproof liners, it is typically more cost effective to provide adequate setbacks to existing utilities (Table 2-1). The setbacks also reduce the risk of damage, both to the utility during GSI installation and to the GSI facility if the utility undergoes repairs. However, when the recommended setback distances are not feasible, there are numerous design modifications that can enable the coexistence of GSI facilities and other utilities. These include the use of impermeable liners, anti-seep collars, and utility wrapping or encasement. In addition, suspended pavement systems, structural soil cells or alternative (modular) storage media can allow for utility gaps in trenches.

Certain GSI types are more adaptable to be sited near existing utilities. Generally, GSI types that contain engineered soils and have a consistent planting palette, such as bioretention and vegetated infiltration basins, are best suited for areas with underlying or adjacent utilities because they are less sensitive to temporary disturbance. Highly structural GSI types such as permeable pavements, planter boxes and infiltration trenches are generally more sensitive to temporary disturbance.

Important considerations for siting GSI near utilities include:

- Type, size, depth, condition and age of utilities
- Suitability of the proposed GSI type
- Sensitivity of GSI elements to disturbance from performing work on the utilities

2.1.1.3 Trees and Vegetation

With careful consideration and sensitive site design, GSI systems can be sited near or adjacent to existing trees and vegetation. The first step in such situations is for a qualified professional to evaluate the health of existing trees and vegetation. Next, the benefits of existing healthy vegetation should be weighed against the benefits of new GSI, as existing vegetated areas are already providing important ecosystem services such as rainwater interception and evapotranspiration.

The proposed GSI should minimize damage to existing vegetation and ideally improve conditions for the vegetation. To minimize damage to existing trees and vegetation, it is important to consider the depth and extent of the root systems. To completely avoid root disturbance, GSI types that require little or no excavation, such as green roofs or above-ground cisterns or planter boxes, could be implemented. Ideally, selected GSI types should enhance existing rooting volume while minimizing root disturbance during installation. Relatively shallow vegetated systems tend to be best suited to minimizing disturbance of existing roots. Vegetated GSI systems that rely at least partially on soils and vegetation can enhance existing vegetation by creating adjacent habitat and space for root growth as well as by providing additional water to the existing vegetation. Such GSI types include bioretention, vegetated swales, vegetated infiltration basins and tree trenches. A setback of 10 feet from tree trunks is recommended (Table 2-1) to apply to mature trees. Alternatively, the horizontal projection of the tree canopy can serve as the guideline for excluding GSI placement to avoid impacts to the roots. It should be noted that GSI can sometimes be placed in closer proximity to trees by employing hand excavation or “soft dig” techniques using air or water and root barriers.

Table 2-1. Recommended Setbacks

Constraining Feature[1]	Minimum Distance between GSI and Constraining Feature (ft)	Distance Type (Horizontal or Vertical)	Notes
Wetlands	10	Horizontal	N/A
Streams	20	Horizontal	N/A
Railroad	15	Horizontal	N/A
Building Foundation / Underground Structures (basements, tunnels, storage tanks, etc.)	10	Horizontal	Note if building has basement.
Utility Lines	3	Horizontal	N/A
Utility Lines	1 - 1.5	Vertical	Depends on utility size, type, age and condition.
Sewer Lines or Sewer Laterals	3	Horizontal	Infiltrating GSI should be prevented from infiltrating within a 1:1 slope from the invert of the sewer (i.e. zone of influence)
Utility Infrastructure (underground vaults, manholes, traffic lights, telephone poles, 'No Parking' signs, parking meters, guy wires etc.)	5	Horizontal	N/A
Fire Hydrant	3.5	Horizontal	N/A

Table 2-1. Recommended Setbacks

Constraining Feature[1]	Minimum Distance between GSI and Constraining Feature (ft)	Distance Type (Horizontal or Vertical)	Notes
Trees / Vegetation	10 ft radius from tree center	Horizontal	Depends on condition of tree, relative benefits of new GSI vs. existing tree preservation. If necessary, use shovel or soft-excavation and avoid tree roots.
ROW Property Lines	3	Horizontal	To protect systems from future construction on adjacent parcels.
Non-ROW Property Lines	5	Horizontal	5 ft minimum. 10 ft preferred.
Infiltration-Limiting Layer (bedrock, high groundwater, etc.)	2	Vertical	Up to 3 ft.
Other Infiltration Facilities (other GSI practices, drain/disposal fields, seepage pits, etc.)	50	Horizontal	N/A
Steep Slopes / Landslide Prone Areas	50 - 200	Horizontal	200 ft from down-gradient slopes greater than 20%. Geotech analysis required if facility affects slope greater than 15%. Moderate to steep slopes (5% - 25%) should be considered a constraint to GSI placement.
Curbs, Curb Ramps, Sidewalks to Remain	2	Horizontal	N/A
Inlets to Remain	2	Horizontal	N/A
Crosswalk	5	Horizontal	Planters/curb extensions may be within or closer than 5 ft. from crosswalks

[1]Practitioners should use engineering judgment for setbacks to constraints not included such as subway entrances, driveways, fences, bus stops etc.

It is also important to consider the debris from existing vegetation and trees, especially leaves, flowers, seeds, pollen and fruit from deciduous plants. Pretreatment including forebays, filter inserts, screens, sumps and settling areas may be necessary for drainage areas with a lot of anticipated debris. For example, permeable pavements underneath or down-gradient of large vegetated areas could prematurely clog without appropriate pretreatment (Figure 2-1).

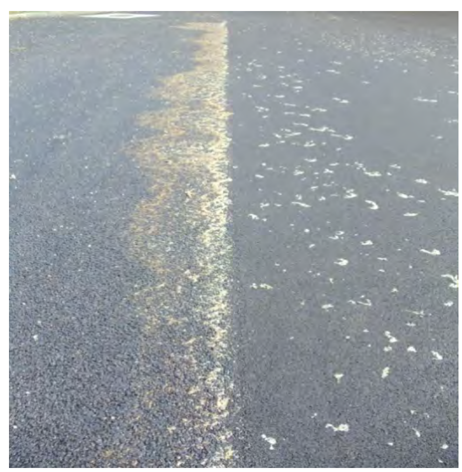


Figure 2-1. Debris on Porous Asphalt

*Example of porous asphalt starting to clog along its interface with conventional asphalt due to vegetation debris; **Sunnycrest Arena** in Syracuse, NY; implemented by Onondaga County*

2.1.2 Proximity of Existing Drainage Infrastructure

The proximity of existing drainage infrastructure should be considered when siting GSI facilities, especially those that typically require underdrains and/or overflow connections, including but not limited to the following practices:

- Bioretention: typically include underdrains and overflow structures
  - Vegetated Swales: may include underdrains; as these are often conveyance practices, they should always drain to a stabilized end-point, such as a plunge pool or level-spreader
- Infiltration Trenches: typically include underdrains, distribution piping and/or below-grade overflow structures
- Permeable Pavements: typically include underdrains and below-grade overflow structures
- Other
  - Green Roofs: typically include gutter systems for overflow
  - Rainwater Harvesting: typically include below-grade overflow connections to collection systems
  - Stormwater Wetlands: may include overflow structures

The following access considerations are important when it comes to siting GSI:

- Construction Access: site entrance/egress, construction equipment, sequencing, and material storage and delivery to the site
- Inspection Access: especially for structures such as cleanouts, manholes and overflow structures
- Monitoring Access: including cleanouts and observation wells for underdrain and distribution piping
- Maintenance Access: including all structures, permeable pavement areas and vegetation

For these GSI types, priority should be given to sites that are closer to available infrastructure to limit the amount of disturbed area and potential utility conflicts associated with installing new underdrain or overflow connections. The depth of existing drainage elements should also be considered since the underdrain of the proposed GSI system may be too high or too low to practically connect. In some areas, a lack of suitable downstream drainage infrastructure may limit GSI project feasibility, and GSI projects that would be completely and permanently dependent on infiltration (i.e., those with no potential underdrain option) should be avoided. With respect to overflow connections, consideration should be given to how GSI projects change the routing and increase the volume of runoff directed toward existing drainage infrastructure during extreme events.

2.1.3 Access for Construction, Inspection, Monitoring & Maintenance

Ideally, GSI practices are located so that access is easy, safe and minimally disruptive to existing site features or uses. For some GSI projects, it may also be important to provide ready access to the public for educational or even recreational uses. Access at some sites can be enhanced in a variety of ways, including mildly sloped and unobstructed paths for maintenance vehicles, strategically placed berms for safe passage over or through surface GSI practices, and location of key structures in highly visible areas.

For GSI facilities within or adjacent to paved areas, practitioners should also consider winter maintenance activities, such as snow plowing and removal, de-icing activities and sanding, and snow storage areas. These activities can negatively affect some GSI practices in a variety of ways, whether by damaging or clogging permeable pavements or damaging soils and vegetation. When such concerns cannot easily be mitigated by appropriate pretreatment practices, designers should consider using infiltration trenches under pavement.

2.1.4 Drainage Area with High Pollutant / Debris Loading Potential

Areas with a high potential for significant pollutant and/or debris loading should be carefully considered when siting GSI practice types. GSI practices that are not conducive to rigorous pretreatment (e.g., permeable pavements) generally should not be used to manage runoff from these areas, while those that deal mostly with rooftop runoff (e.g., green roofs and rainwater harvesting) are typically unaffected by them. In general, GSI types that allow for a robust pretreatment system of settling and filtration (e.g., bioretention and vegetated swales) might be acceptable. However, GSI implementation might be avoided at those areas deemed simply too challenging.

Examples of common areas with high pollutant / debris loading potential include:

- Heavy hydrocarbon loading including fuel storage and refueling areas, vehicle maintenance areas and high-use vehicle parking areas. Infiltration into subgrade soils is typically discouraged in these settings, and options for spill control should be considered.
- Heavy salt and abrasive loading, including roads and other vehicle traffic areas in the winter when de-icing activities take place. Note that high salt loading can reduce soil permeability and GSI designs should take this into consideration.
- Heavy grit and/or solids loading, also including roads and paved areas as well as upland pervious areas that are not well vegetated or stabilized. This also includes construction sites and material stockpiles.

2.1.5 Integration with Other Planned Improvements

GSI is often most cost-effective when integrated with other planned improvements. GSI can be incorporated or piggy-backed into a variety of improvements related to new or redevelopment, drainage, accessibility (ramps, sidewalks, etc.), roadway layout, roadway or parking lot repaving or reconstruction, building expansion / renovation, or utility replacement / rehabilitation. The type of improvement proposed for a project can have a significant impact on the type of GSI selected.

Practitioners are encouraged to consider which GSI types could best be integrated with planned improvements such as infrastructure rehabilitation (e.g., infiltration trenches), streetscape improvements (e.g., tree trenches and curb extensions), park renovations (e.g., permeable pavement and bioretention), and so on. There may be multiple GSI types that are suitable.

2.1.6 Absolute Constraints to GSI

Certain site conditions may preclude implementation of GSI for various reasons. When performing a planning-level analysis, it is helpful to eliminate sites or areas of sites that have such absolute constraints that render GSI unfeasible. Practitioners are strongly encouraged to review local regulations for provisions that affect GSI placement, especially any provisions for infiltration or erosion control.

Absolute Constraints Include:

- Wetlands
- Streams
- Railroads
- Landslide-prone areas
- Surface water
- Very steep slopes (greater than 25%)
- Superfund or fuel/storage tank parcels

Table 2-2. Summary of GSI Suitability and Key Design Considerations for Enhancing Suitability by Siting Factors

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Siting Factors			
GSI Practice	**High Pollutant / Debris Loading Potential**	**Integration w/ Other Planned Improvements**	**Localized Flooding / Floodplain**
Bioretention: Bioretention Basin, Vegetated Planter, Rain Garden	• Provide robust and easily maintainable pretreatment components such as forebays, splash pads, etc.; when space-limited, use structures with screens, sumps, filter inserts, baffles, lamella plates, etc. • Consider high-flow filter media or other types of enhanced soil media or amendments • Specify hardy plant species (e.g. salt tolerant)	• Integrate with drainage improvements, site redevelopment, accessibility improvements (ramps, sidewalks, etc.) and roadway layout improvements	• Use curb extensions to help mitigate nuisance flooding at street corners • To help mitigate localized flooding, design for additional storage capacity • Specify biodegradable erosion control matting
Bioretention: Vegetated Swales	• Use robust and easily maintainable pretreatment components (forebays, splash pads, filter strips, etc.) • Consider high-flow filter media or other types of enhanced soil media or amendments • Specify hardy plant species (e.g. salt tolerant); plant system densely when serving as pretreatment for other GSI practices (maintaining access for maintenance / cleaning)	• Integrate with drainage improvements, site redevelopment and roadway layout improvements	• Locate within or adjacent to flood-prone areas to provide relief via storage and/or conveyance • Specify biodegradable erosion control matting • Increase storage / conveyance capacity
Infiltration Trenches: Tree Trench, Trench Below Pavement, Trench Below Vegetation, Surface Flow Infiltration Trench	• Provide robust and easily maintainable pretreatment structures with screens, sumps, filter inserts, baffles, lamella plates, etc.; swales and filter strips can also provide pretreatment	• Integrate with utility replacement / rehabilitation, pavement reconstruction, drainage improvements, and accessibility improvements (ramps, sidewalks, etc.)	• Locate within or adjacent to flood-prone areas to provide relief and limit surface flooding • To help mitigate localized flooding, design for additional storage capacity • Provide robust and easily maintainable pretreatment; provide mechanism to clean/restore after flood event
Permeable Pavement: Porous Asphalt, Porous Concrete,	• For high sediment loading potential, avoid using permeable pavement, as it could lead to clogging	• Integrate with pavement reconstruction, site redevelopment and accessibility	• Avoid using permeable pavement in flood-prone areas, as it could lead to clogging

Table 2-2. Summary of GSI Suitability and Key Design Considerations for Enhancing Suitability by Siting Factors

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Siting Factors			
GSI Practice	High Pollutant / Debris Loading Potential	Integration w/ Other Planned Improvements	Localized Flooding / Floodplain
Permeable Block Pavers, Open Grid Pavers	• If feasible, provide robust and easily maintainable pretreatment for runoff from adjacent areas and pipe directly into subsurface storage system	improvements (ramps, sidewalks, etc.)	• To help mitigate localized flooding, design for additional storage capacity • Include inlets for backup drainage (generallly considered a good practice for all permeable pavement installations)
Other: Green Roofs	N/A	• Integrate with building expansion / renovation, roof replacement	• To help mitigate localized flooding, design for additional storage capacity
Other: Rainwater Harvesting	• Provide robust and easily maintainable pretreatment structures with screens, sumps, filters, etc. • Consider the use of first flush diverters • When harvesting for reuse, more complex treatment may be required (disinfection, filtration, etc.)	• Integrate with site redevelopment, building expansion / renovation	• Elevate or otherwise protect cistern if in flood-prone area • If possible, size / operate cistern to reduce localized flooding
Other: Stormwater Wetlands	• Use robust and easily maintainable pretreatment components (forebays, swales, filter strips, etc.) • Consider the use of an impermeable liner to prevent groundwater contamination when heavy contaminant loading is expected • Consider the use of an iron enhanced sand filter for additional nutrient removal • If desired, specify plant species and/or other features that deter birds and geese from staying or nesting	• Integrate with site redevelopment	• Locate within or adjacent to flood-prone areas to provide relief • To help mitigate localized flooding, design for additional storage capacity (up to 100-year storm)

2.2 GSI Selection Considerations by Site Type

This section provides general guidance for effectively siting and selecting GSI at a variety of publicly owned sites (including municipally owned facilities, streets and alleys, parks and playgrounds, schools, public housing, vacant lots and commercial / business districts), assuming typical characteristics and configurations. However, it should be noted that specific characteristics attributed to a site type could vary greatly between individual sites. For example, parks can vary from relatively large areas with significant open space to tight urban pocket parks that are mostly paved over. Practitioners must evaluate each site for its unique opportunities and constraints for GSI implementation. (For additional guidance on a variety of specific site and physical feasibility factors independent of site type, see Section 3.)

Factors that will likely guide GSI siting and selection at publicly owned sites include the following:

- Usage – type, frequency, seasonality, etc.
- Safety – people and/or vehicles
- Community context – surrounding land uses, visibility, aesthetics, etc.
- Pollutant loading potential – unstable soils, heavily vegetated areas, intense uses
- Constructability
- Accessibility – maintenance, wheelchair users, etc.
- Education / demonstration potential
- Maintenance capabilities – budget, experience, and/or resources of responsible agency
- Potential for connection to water bodies or other GSI
- Potential to capture and manage runoff from upstream sources

The following sections provide brief discussions on the common challenges and opportunities for GSI implementation at the various types of publicly owned sites. Table 2-3 provides additional guidance on the feasibility of the various GSI types and considerations for enhancing their feasibility.

2.2.1 Municipally Owned Facilities

Municipally owned facilities generally have a high feasibility for GSI implementation. Municipally owned facilities can vary greatly from highly visible and used administration offices and libraries (Figure 2-2) to less visible, more industrial sites like maintenance areas, storage yards and police or fire stations. These sites typically contain relatively large areas that can be utilized for locating GSI practices.

In addition to managing stormwater generated on site, GSI practices implemented at municipally owned facilities often can manage significant volumes of stormwater runoff from adjacent impervious areas. Municipally owned sites can provide unique opportunities to demonstrate different GSI technologies and variations (e.g., different types of permeable pavements). Such demonstrations can provide useful and practical information that yields more streamlined and cost-effective GSI projects in the future. In some cases, these sites have limited accessibility to the public, which can allow for easier maintenance and increased safety both during construction and the lifespan of the implemented GSI.

Typical GSI implementation challenges at municipally owned facilities include the following:

- Dual use considerations (balancing recreational needs with GSI space needs)
- Multiple and sometimes unpredictable site use desire paths
- Proximity of existing buildings
- Presence of internal roof drains
- Potentially high visibility / usage

- Potentially high sediment loads at municipal maintenance / storage yards, therefore potentially increased maintenance requirements
- Future development / expansion plans

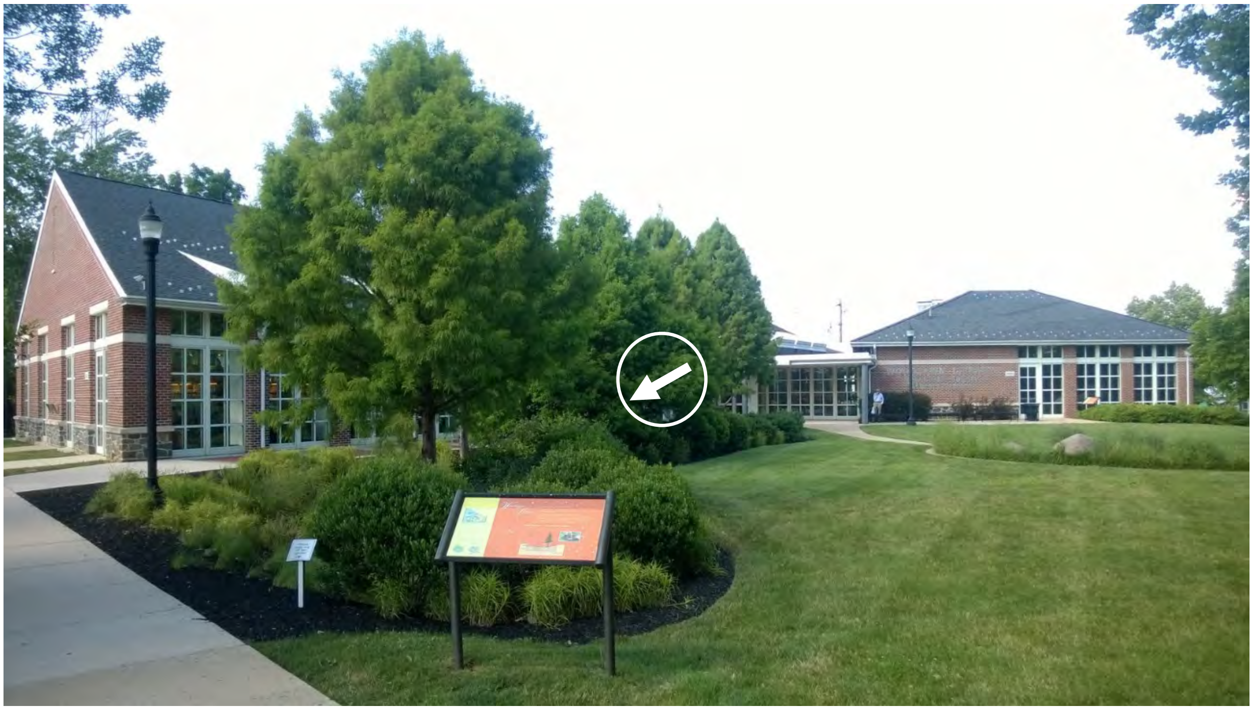


Figure 2-2. Bioretention Facility at Public Library
Example of a bioretention facility with educational signage (indicated by arrow) at the Woodlawn Library in Wilmington, DE; implemented by the City of Wilmington

2.2.2 Streets and Alleys (Rights-of-Way)

The feasibility of GSI implementation in streets and alleys can greatly vary depending on a variety of factors. Rights-of-Way are one of the largest sources of stormwater runoff, therefore providing one of the best opportunities for potential management. Anticipated traffic loads and frequencies, maintenance needs and available space all contribute to the selection of the best GSI practice for streets and alleys.

Although they potentially include many constraints and challenges (see list below), streets and alleys also provide a variety of opportunities for high-performance and cost-effective GSI implementation. Landscaping and vegetation (street trees, curb extensions and sidewalk planters) can be located in available spaces such as medians, no parking zones, grass strips and roadway swales, thereby enhancing urban aesthetics and increasing tree canopy (Figure 2-3). Green streets or green alleys can be optimized by capturing stormwater runoff from not only the right-of-way but also from adjacent impervious areas to maximize stormwater capture.

GSI practices in streets and alleys can potentially be implemented at lower overall costs when they are incorporated or piggy-backed onto repaving or pavement reconstruction activities, as well as utility replacement or rehabilitation (note that cost savings are usually achieved by thoughtfully integrating GSI early in the project). GSI in streets can also effectively align with accessibility improvements (e.g., new curb ramps or sidewalks), reductions in street widths (i.e., road diets), planned streetscape improvements, nuisance flood mitigation and traffic calming efforts.

GSI practices in streets are sometimes selected and designed either as part of an overall strategy to reduce localized flooding at the neighborhood level or sited at or near flood-prone locations (including floodplains). Though not generally well suited for peak rate control for extreme storms, GSI types such as bioretention and infiltration trenches can be more easily (and cost-effectively) modified than others to maximize storage capacity for peak rate control for such events.

Typical GSI implementation challenges at streets and alleys are numerous and include the following:

- Utilities (surface, subsurface and overhead)
- Type of street, average daily traffic and loads
- Turning radii
- Limited space, especially in streets (The minimum roadway width should be based on local regulations for various types of corridors.)
- Sight clearances (for vegetative practices)
- Constructability
- PennDOT or other standards for roadway stability, compaction, etc.
- Signs, mailboxes, benches, etc.
- Accessibility (e.g. minimum sidewalk widths – typically 5 feet)
- Street slopes
- Bus stops, loading zones, etc.
- Bike lanes
- Parking demand
- Nuisance street flooding / undersized drainage infrastructure
- Proximity of existing drainage infrastructure (especially for alleys and mid-block GSI practices)
- Upstream sources of debris / sediment

Figure 2-3. ROW Curb Extension

Example of a vegetated curb extension (indicated by arrow) in the public right-of-way in front of Sedgwick Station located in Philadelphia, PA and implemented by the Philadelphia Water Department

2.2.3 Parks and Playgrounds

Parks and playgrounds generally have a high feasibility for implementing a variety of GSI types. While these parcels may not have a lot of impervious cover within them, they often have relatively large areas of open space and therefore the potential to manage significant volumes of stormwater runoff from adjacent areas. Implementing GSI at parks can provide multiple other benefits such as increased tree canopy / urban forestry, a natural source of irrigation for valued green spaces, aesthetically improved public spaces that are adapted to desired community uses (Figure 2-4), and enhanced buffers for existing natural resources. Additionally, parks often occupy undeveloped land, which generally permits greater soil infiltration rates.

Successfully implementing GSI at parks and playgrounds often involves a balancing act between existing recreational needs and the space required for GSI practices. Typical GSI implementation challenges at parks and playgrounds include the following:

- Accessibility / safety
- Dual use considerations (balancing recreational needs with GSI space needs)
- Potentially high sediment, trash and debris loads
- Multiple and sometimes unpredictable desire paths

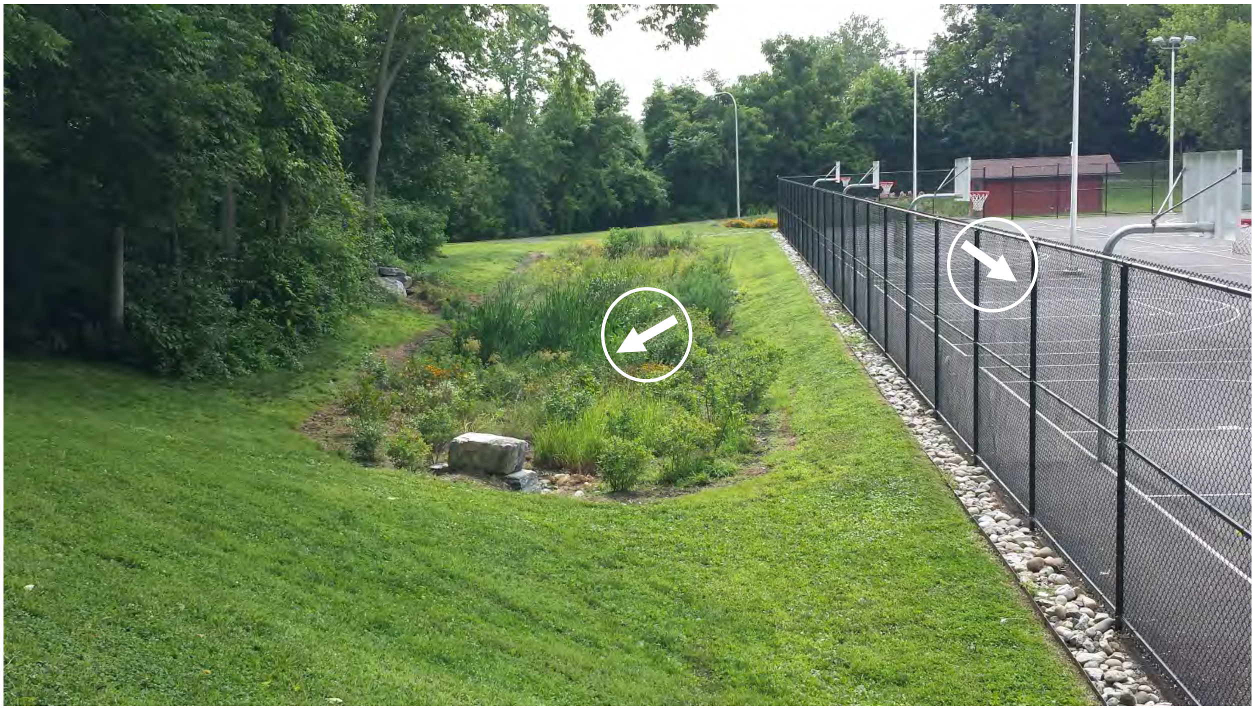


Figure 2-4. Bioretention and Porous Pavement in Public Park
*Example of bioretention and porous asphalt basketball courts (indicated by arrows) at **Brandon Park** in Lancaster, PA and implemented by the City of Lancaster*

2.2.4 Schools

Public schools are typically situated on larger parcels with a considerable portion of their land area occupied by impervious play surfaces, parking, rooftops and other areas (Figure 2-5). Because of this, many GSI types can often be feasibly and cost-effectively implemented at schools. In addition to managing stormwater generated on site, GSI practices at schools can also manage significant volumes of stormwater runoff from adjacent impervious areas. These types of sites can also provide unique opportunities to educate students and the public about GSI implementation and to demonstrate different GSI technologies and variations. Such demonstrations can often provide useful and practical information that yields more streamlined and cost-effective GSI projects in the future.

Typical GSI implementation challenges at schools include the following:

- Accessibility / safety
- Construction and maintenance activities must be scheduled around school hours
- Dual use considerations (balancing recreational needs with GSI space needs)
- Multiple and sometimes unpredictable desire paths
- Proximity of existing buildings
- Presence of internal roof drains
- Potentially high visibility / usage
- Potentially high sediment loads at municipal maintenance / storage yards

Figure 2-5. Bioretention on School Property

*Example of bioretention (indicated by arrow) at **Seymour Academy** located in Syracuse, NY and implemented by Onondaga County*

2.2.5 Public Housing

Public housing sites generally offer many of the same opportunities for GSI implementation as schools and municipally owned facilities, though they also have several unique constraints and challenges that should be considered (see below). Perhaps more so than other site types, public housing sites generally lend themselves to GSI types, variations and components that should have minimal maintenance needs.

Typical GSI implementation challenges at public housing sites include the following:

- Accessibility / safety
- Maintenance
- Vandalism / theft
- Proximity of buildings
- Presence of internal roof drains

2.2.6 Vacant Lots

The feasibility of implementing GSI on vacant lots can vary from moderate to high depending on a variety of constraints and challenges (see below). However, vacant lots offer a unique opportunity to potentially achieve multiple goals, including:

- Reduce stormwater runoff and combined sewer overflows
- Reduce the amount of vacant properties and therefore the cost burden of maintaining unused spaces
- Help mitigate the negative effects of vacant and abandoned properties (e.g. crime and vandalism)
- Potentially reduce nuisance flooding in residential areas
- Create public amenities that contribute to neighborhood revitalization
- Create shade and reduce urban heat island effect
- Air quality improvements

- Erosion prevention

By focusing on vacant lands that are not as desirable for development or other community uses, municipalities can transform urban blight into productive and educational green spaces (Figure 2-6). The success of such transformations is largely dependent on gaining community endorsement and engagement. When most successful, neighbors and community leaders should have a tangible stake in their success and therefore develop a powerful sense of pride and ownership in the community gardens or pocket parks created in vacant lots. Several GSI practices are easily integrated with such amenities, and therefore are more likely to be adequately maintained and remain effective from a performance perspective.

Typical GSI implementation challenges at vacant lots include the following:

- Site and drainage area size (Vacant lots usually do not have much impervious cover, therefore managing adjacent impervious area is important.)
- Community endorsement / engagement
- Potential for historic foundations, debris, abandoned utilities, contamination, compaction, poor soil quality
- Accessibility, specifically for construction and maintenance
- Property ownership issues

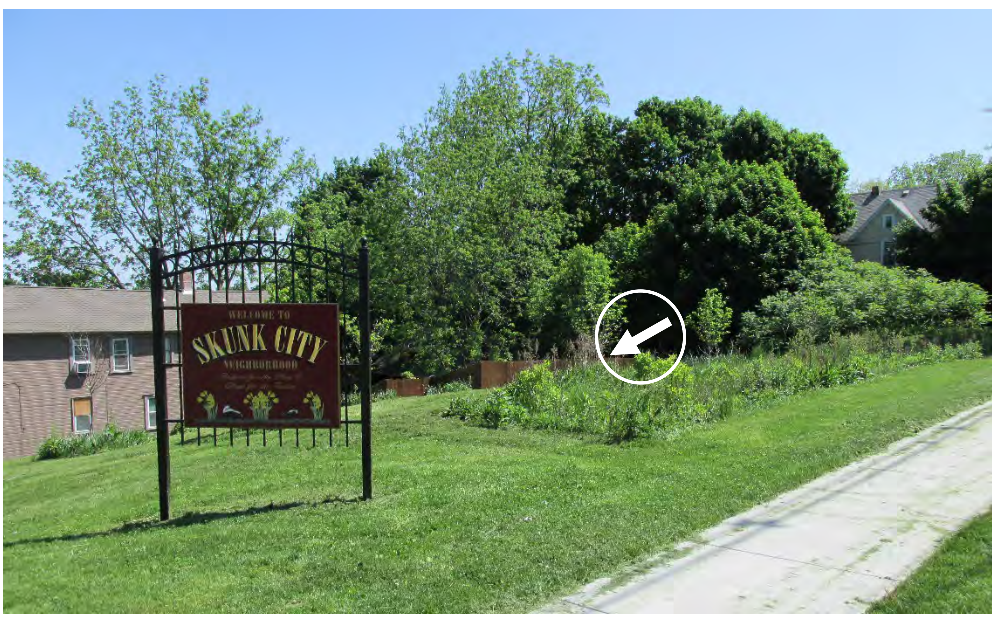


Figure 2-6. Bioretention Area in Vacant Lot

Example of bioretention (indicated by arrow) in a vacant lot in Syracuse, NY and implemented by Onondaga County

2.2.7 Commercial/Business Districts

Commercial/business districts often include large public areas, such as parking lots and other paved surfaces, that can provide multiple opportunities for GSI implementation. Parking lots are often much less constrained (e.g., fewer utilities) and flatter than streets and alleys and therefore may offer better opportunities to maximize capture of both direct rainfall and runoff from adjacent impervious areas. Permeable pavement and/or infiltration trenches can be cost-effectively integrated with repaving or pavement reconstruction efforts. Bioretention or vegetated swales can be incorporated into islands (Figure 2-7), no parking zones or in paved areas slated for removal (based on a reduced need for parking). Tree trenches can be located between parking stalls or along the perimeter of parking lots, thereby increasing tree canopy and promoting evapotranspiration. Greening parking lots can also be done in conjunction with a reevaluation of their configuration and capacity, in some cases improving circulation, yielding a greater number of parking stalls or reducing the amount of impervious cover.

Typical GSI implementation challenges at commercial/business districts include the following:

- Utilities (surface, subsurface and overhead)
- These areas are generally private land
- Maintenance responsibility/access
- Creating the proper grading to direct runoff toward GSI

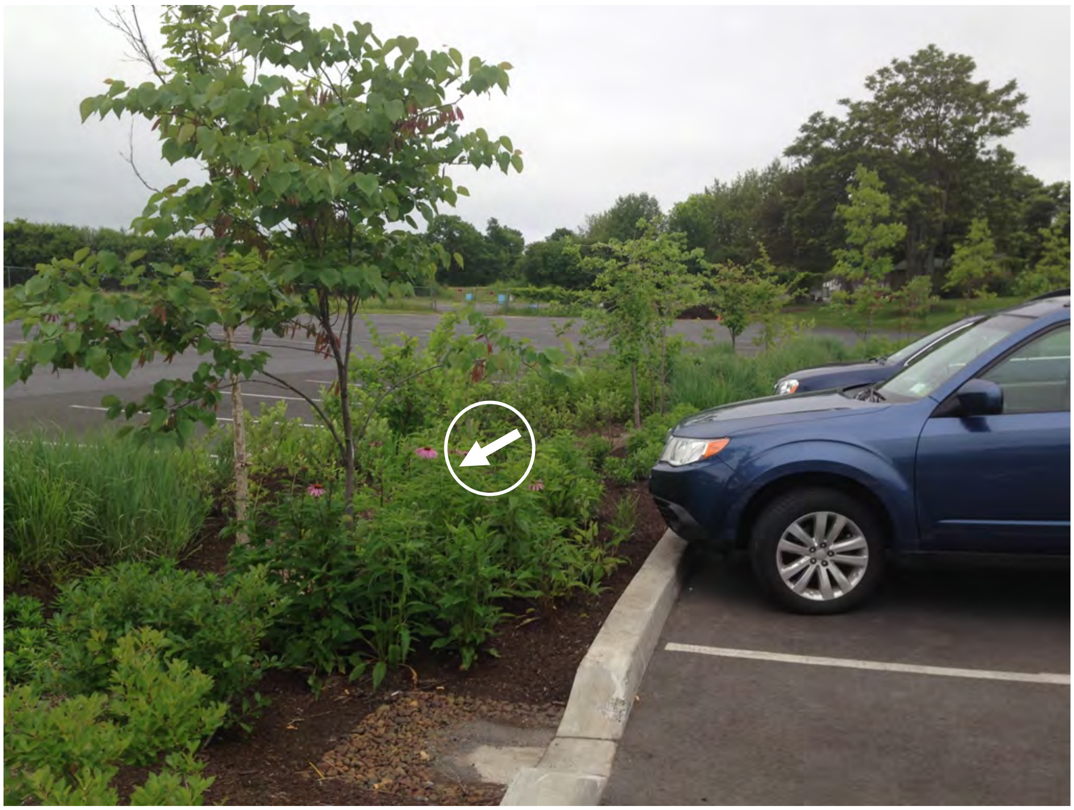


Figure 2-7. Bioretention in Commercial Parking Lot

Bioretention (indicated by arrow) in a parking lot island at the Rosamond Gifford Zoo in Syracuse, NY; implemented by Onondaga County

Table 2-3. Summary of GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Type

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Type							
GSI Practice	Municipally Owned Facilities	Streets and Alleys (Rights-of-Way)	Parks and Playgrounds	Schools	Public Housing	Vacant Lots	Commercial / Business District
Bioretention: Bioretention Basin, Vegetated Planter, Rain Garden	• Enhance but do not disrupt existing site uses by locating in corners, edges, unused green spaces, parking lot islands or next to downspouts • Design for greater visual appeal with a more robust planting palette and interesting drainage features (e.g. stone spillways/channels) • Place by entrances to maximize visual appeal and create opportunities for managing street runoff	• Locate in grass strips, sidewalks with adequate width, medians, road shoulders or no parking zones (generally not suitable for alleys) • Consider use of more robust/reinforced curb design adjacent to streets • Design for appropriate turning radii, sight clearances and pedestrian accessibility • Include features that discourage vandalism or theft (e.g. lockable lids) • Consider more robust pretreatment components if litter / debris is a concern at the site • Use salt-tolerant plants	• Enhance but do not disrupt existing site uses by locating in corners, edges, unused green spaces or parking lot islands • Be aware of desire paths; include components such as vegetative or physical barriers that discourage foot / bike traffic through GSI practice • Place by entrances to maximize visual appeal and create opportunities for managing street runoff	• Enhance but do not disrupt existing site uses by locating in corners, edges, unused green spaces, parking lot islands or next to downspouts • Be aware of desire paths; include components such as vegetative or physical barriers that discourage foot / bike traffic through GSI practice • Consider opportunities for integration with school curriculum (signage, observation platforms, etc.)	• Locate in corners, edges, unused green spaces, parking lot islands or next to downspouts • Keep planting palettes relatively minimal and include features that discourage vandalism or theft (e.g. lockable lids) • Consider more robust pretreatment components if litter / debris is a concern at the site	• Seek endorsement from community groups on designs, planting palettes, layouts, etc.; investigate opportunities to integrate with community gardens • Investigate opportunities to capture runoff from adjacent buildings and streets • Consider stone borders or other type of visual indicator that delineates swale boundaries for maintenance purposes	• Locate in no parking zones or parking lot islands/corners • Consider use of more robust/reinforced curb design when adjacent to streets • Design for appropriate turning radii, sight clearances and pedestrian accessibility
Bioretention: Vegetated Swales	• Locate in existing pervious areas that are adjacent to or downhill from impervious surfaces, such as parking, walkways, buildings, and streets • Use Bioswales or Vegetated Swales with Subsurface Storage for sites with higher visibility / public usage • For maintenance / storage yards with potentially high sediment loads, design robust pretreatment and specify hardy plant species; consider using only as pretreatment for other GSI practices	• Locate in grass strips, medians, or road shoulders (generally not suitable for alleys) • If appropriate, design as pretreatment/conveyance for other GSI practices or to be used in combination with Infiltration Trenches • Include safe and accessible crossings for pedestrians, potentially in combination with check dams for sloped streets • Use salt-tolerant plants	• Locate in existing pervious areas that are adjacent to or downhill from impervious surfaces, such as parking, walkways, playgrounds, and streets • Consider stone borders or other type of visual indicator that delineates swale boundaries for maintenance purposes • Locate to avoid inputs of springs, irrigation systems, chlorinated wash-water, or other dry weather flows	• Locate in existing pervious areas that are adjacent to or downhill from impervious surfaces, such as parking, walkways, playgrounds, buildings, and streets • Keep side slopes milder than 3H:1V for maintenance and safety considerations; flatter slopes are encouraged where adequate space is available • Design for relatively shallow flow depths	• Locate in existing pervious areas that are adjacent to or downhill from impervious surfaces, such as parking, walkways, buildings, and streets • Include safe and accessible crossings for pedestrians • Design for relatively shallow flow depths	• Seek endorsement from community groups on designs, planting palettes, layout, etc. • Investigate opportunities to capture runoff from adjacent buildings and streets • Consider stone borders or other type of visual indicator that delineates swale boundaries for maintenance purposes	• Locate in linear parking lot islands/edges • If appropriate, design as pretreatment/conveyance for other GSI practices or to be used in combination with Infiltration Trenches • Include safe and accessible crossings for pedestrians, potentially in combination with check dams for sloped sites

Table 2-3. Summary of GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Type

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Type							
GSI Practice	**Municipally Owned Facilities**	**Streets and Alleys (Rights-of-Way)**	**Parks and Playgrounds**	**Schools**	**Public Housing**	**Vacant Lots**	**Commercial / Business District**
Infiltration Trenches: Tree Trench, Trench Below Pavement, Trench Below Vegetation, Surface Flow Infiltration Trench	• Locate in existing pervious areas that are adjacent to impervious surfaces, such as parking, walkways, plazas, buildings and streets • Use impermeable liners as needed to protect adjacent buildings • Consider converting unnecessary impervious areas to vegetated infiltration trenches	• Cost effectively locate in existing grass strips adjacent to impervious areas • Design for appropriate sight clearances when tree trenches are employed; also ensure that appropriate tree species, height and spacing are specified; select species with appropriate form/branching that will not conflict with vehicular or pedestrian circulation • Expand under both pervious and impervious areas as needed for stormwater capture; often used in combination with bioretention • Use salt-tolerant trees and plants	• Locate in existing pervious areas that are adjacent to impervious surfaces, such as parking, walkways, playgrounds and streets • Consider using tree trenches to increase canopy and shade, especially next to parking stalls and walkways; choose species with appropriate form/branching that will not conflict with vehicular or pedestrian circulation • In dense urban parks and playgrounds, consider integrating trenches under pavement	• Locate in existing pervious areas that are adjacent to impervious surfaces, such as parking, walkways, playgrounds, buildings and streets • In dense urban schools, consider integrating trenches under pavement • Use impermeable liners as needed to protect adjacent school buildings	• Locate under pervious areas that are adjacent to impervious surfaces, such as parking, walkways, plazas, buildings and streets • Use impermeable liners as needed to protect adjacent buildings • Consider permeable epoxied stone for surface flow infiltration trench surface or else locate them at the edges of the site (away from buildings)	• Anticipate historic foundations, building materials and/or abandoned utilities • Investigate opportunities to capture runoff from adjacent buildings and streets	• Cost effectively locate in existing grass strips adjacent to parking areas • For tree trenches, protect trees from vehicular damage by using bollards, wheel stops, curbs, etc. • Expand under both pervious and impervious areas as needed for stormwater capture; often used in combination with bioretention
Permeable Pavement: Porous Asphalt, Porous Concrete, Permeable Block Pavers, Open Grid Pavers	• Locate in parking lots, walkways or plazas • Investigate opportunities to capture runoff from adjacent areas (roofs, parking lots, streets, etc.) and pipe directly into subsurface storage system • Investigate opportunities to demonstrate multiple types of permeable pavements	• Ensure that the selected permeable pavement type is appropriate for the anticipated vehicular use, loading and frequency • Investigate and account for potentially negative impacts of anticipated winter maintenance activities (plowing, sanding, etc.)	• Investigate opportunities to integrate into play surfaces (e.g. porous asphalt basketball courts), as well as parking lots and plazas • Ensure that installations are accessible for maintenance • Be aware of potentially high sediment loads (i.e. clogging); pretreat or divert runoff from adjacent pervious areas or simply avoid installing at certain locations (e.g. narrow paths next to vegetation)	• Investigate opportunities to integrate into play surfaces (e.g. porous asphalt basketball courts), as well as parking lots • For certain play surfaces, consider specifying softer flexible permeable pavements with recycled rubber • Ensure that installations are accessible for maintenance	• ● Locate in parking lots, walkways or plazas ● Investigate opportunities to capture runoff from adjacent areas (roofs, parking lots, streets, etc.) and pipe directly into subsurface storage system ● Ensure that installations are accessible for maintenance	• N/A	• ● Ensure that the selected permeable pavement type is appropriate for the anticipated vehicular use, loading and frequency ● Consider using permeable pavement only in parking stalls (not driving aisles) ● Investigate and account for potentially negative impacts of anticipated winter maintenance activities (plowing, sanding, etc.)

Table 2-3. Summary of GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Type

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Type							
GSI Practice	Municipally Owned Facilities	Streets and Alleys (Rights-of-Way)	Parks and Playgrounds	Schools	Public Housing	Vacant Lots	Commercial / Business District
Other: Green Roofs	• Consider access and visibility when selecting appropriate roof areas • Consider including observation platforms and/or educational signage • Ensure that roofs can support the anticipated loads	N/A	N/A	• Consider access and visibility when selecting appropriate roof areas • Consider including observation platforms and/or educational signage	• Consider access and visibility when selecting appropriate roof areas • Ensure that roof slopes are adequate for Green Roof installation	N/A	N/A
Other: Rainwater Harvesting	• Consider using customized or artistic rain barrels with greater aesthetic appeal • Consider locating rain barrels at downspouts and/or larger capacity cisterns for buried roof drains • Reuse captured rainwater for landscape irrigation or internal graywater uses (for rehabilitation projects)	N/A	• Consider locating rain barrels at downspouts of small buildings (bathrooms, pavilions, gazebos) • Reuse captured rainwater for landscape irrigation • Direct excess runoff to other GSI practices, such as bioretention/rain gardens or vegetated swales	• Consider locating rain barrels at downspouts and/or larger capacity cisterns for buried roof drains • Reuse captured rainwater for landscape irrigation or internal graywater uses (for rehabilitation projects) • Consider opportunities for integration with school curriculum (signage, interactive elements, easily operable valves, etc.)	• Consider locating rain barrels at downspouts of buildings • Reuse captured rainwater for landscape irrigation	N/A	N/A
Other: Stormwater Wetlands	• Locate in low corners of sites, away from highly used / trafficked areas • Include a safety shelf (aquatic bench) with shrubs and tall grasses around the perimeter • Include observation platforms, walkways and/or educational signage	• Ensure there is sufficient drainage area to make wetlands viable; investigate opportunities to capture runoff from adjacent buildings, parking areas and streets • Use fencing, raised curbs, traffic delineators, reflectors, paint or other type of indicator / barrier as appropriate	• Locate in low corners of sites; do not locate within natural wetland areas • Include a safety shelf (aquatic bench) with shrubs and tall grasses around the perimeter • Include observation platforms, walkways and/or educational signage	• Locate in low corners of sites, away from playgrounds / fields • Include a safety shelf (aquatic bench) with shrubs and tall grasses around the perimeter • Include observation platforms, walkways and/or educational signage	• Locate in low corners of sites, away from highly used / trafficked areas • Include a safety shelf (aquatic bench) with shrubs and tall grasses around the perimeter • If desired, specify plant species and/or other features that deter birds and geese from staying or nesting	• Seek endorsement from community groups on designs, planting palettes, configurations, etc. • Ensure there is sufficient drainage area to make wetlands viable; investigate opportunities to capture runoff from adjacent buildings, parking areas and streets • Include a safety shelf (aquatic bench) with shrubs and tall grasses around the perimeter	• Locate in medians or parking lot islands/corners • Investigate opportunities to capture runoff from adjacent buildings and streets • Use fencing, raised curbs, traffic delineators, reflectors, paint or other type of indicator / barrier as appropriate

SECTION 3

GSI Type Selection Factors

3.1 General Considerations

When considering site and physical feasibility factors influencing GSI type selection discussed in Sections 3.2 and 3.3, practitioners are encouraged to explore several other factors that are more regional or programmatic in nature. Factors that include project replicability, local experiences and perceptions, fast-track potential, local maintenance capacity, and local availability of materials may not all be applicable in some communities. However, in communities where they are, they may have significant impacts on GSI type selection, and practitioners should consider them carefully during the planning stages of their projects.

- Replicability: While every location presents unique challenges and specific design considerations, some GSI types are more suited to easily repeatable design configurations than others and, therefore, might fit better into large-scale GSI implementation programs, especially those with limited timeframes. Replicability is ultimately a function of design simplicity and standardization. In general, vegetated swales, tree trenches, permeable pavement and green roofs are conducive to replication, though most GSI types can be designed with standardized configurations for similar project applications. Such standardization can often yield efficiencies in the design, permitting, bidding and construction phases of GSI implementation.

- Local Experiences and Perceptions: Some GSI types may have a better local track record than others based on monitoring data, implementation experience, perception, contractor competency, maintenance effectiveness, etc. Although not always technically justified, this is a factor that might still play an important role in GSI type selection. In some communities, practitioners may encounter barriers of perception with respect to selecting GSI such as permeable pavements.

- In the first two years of the ALCOSAN GROW program, a variety of GSI types have been implemented, with the most common types being bioretention, permeable pavements and, to a lesser extent, vegetated swales and infiltration trenches. Practitioners are encouraged to investigate what types of GSI practices have been constructed locally (including those implemented by the private sector), how these practices are performing and being maintained, how they are perceived by stakeholders, and their overall success as implemented projects.

- Fast-Track Potential: Rapid deployment of GSI is often a critical component of large-scale GSI implementation programs, especially during the early stages of such programs. Therefore, at a programmatic level, the potential for various GSI types to be fast-tracked with respect to both design and construction should be considered. Examples of GSI types with high fast-track potential, include vegetated swales, curb extensions and vegetated infiltration trenches.

  Similar to replicability, a GSI project's fast-track potential is a function of its design simplicity, size, and location (i.e. site type). Examples of GSI projects with high fast-track potential include a small vegetated curb extension implemented at a street corner as part of a curb ramp reconstruction and a vegetated swale implemented in a parking lot island. An example of a GSI project with low fast-track potential is a permeable pavement playground at a school.

- Local Availability of Materials: Some GSI types (e.g., permeable pavements) consist of materials that may not be readily available in all communities. Importing such materials from other areas may prove expensive or impractical and, therefore, practitioners are encouraged to take such considerations into account when selecting GSI types. The more common GSI implementation becomes in the ALCOSAN service area, the less this factor will come into play.

3.2 Site Factors

The effect of site layout on GSI type selection is highly variable and for many sites, strongly influenced by site function and land use. The function of school sites, for example, is to provide adequate access for students and faculty, as well as recreational and potentially outdoor classroom areas for students. Not only can GSI add a recreational component to a school site, it can also provide an educational opportunity and be designed so that its function is easily understood by any observer. Stormwater management is often not a main consideration when laying out a school site, especially in highly constrained urban areas. However, with its flexibility to include micro-scale practices and break up site drainage areas, GSI practices can be successfully integrated to almost any site layout configuration. This section will briefly discuss GSI considerations for the following key site factors:

- Space constraints
- Availability of sunlight
- Public safety
- Public visibility and high-use sites

A summary of GSI practice considerations for these key site factors is presented at the end of this section in Table 3-1.

3.2.1 Space Constraints

The size of a site, as well as its usable space, can have a significant effect on GSI type selection. Larger sites are commonly more suitable for incorporating open or landscaped areas, which could be well suited for GSI types such as bioretention/rain gardens, vegetated infiltration trenches or stormwater wetlands. Smaller, more constrained sites have correspondingly smaller available spaces for GSI practices and often the only feasible GSI practices are storage/infiltration trenches beneath standard or permeable pavement and tree trenches. In general, GSI types that have a high dual-use potential (i.e. allow for a use beyond stormwater storage/treatment) are ideally suited to space-limited sites. Green roofs and rainwater harvesting are other good options for building sites with limited at-grade space available for GSI implementation.

The following design variations have high suitability for sites with space constraints:

- Flow-through and infiltration planters, rain gardens and curb extensions
  - To minimize footprint, consider use of high flow filter media or other types of enhanced soil media or amendments
  - Use of raised curbs, seat walls or decorative fencing may also help to maximize the GSI footprint without traditional side slope grading
- Green roofs
- Infiltration trenches, often below parking or other pavement areas
  - Use of deep stone columns for additional storage and/or enhanced infiltration may help to minimize the GSI footprint
  - Use of alternative storage media with higher capacity may help to achieve storage goals in very constrained spaces; examples include plastic modular storage units, plastic arches, pipes and concrete chambers
- Permeable pavements (Figure 3-1)
  - Design for dual-use by using porous asphalt for areas like playgrounds or basketball courts
- Use rainwater harvesting cisterns (above or below ground, depending on the space limitation)

Practitioners should also consider below-grade space constraints and the impacts they might have on both available GSI footprint and underdrain/overflow connectivity. Below-grade utilities such as electric and gas lines may need special consideration as GSI practices are not typically allowed to be co-located above or below these constraints. Routing and connection of underdrain and/or overflow piping should also be considered for any potential utility crossings to help avoid any vertical conflicts and provide the required amount of offset or buffer. Excavation techniques such as hand digging or "soft dig" techniques (vacuum excavation using air or water) may also help to protect nearby utilities and tree roots.

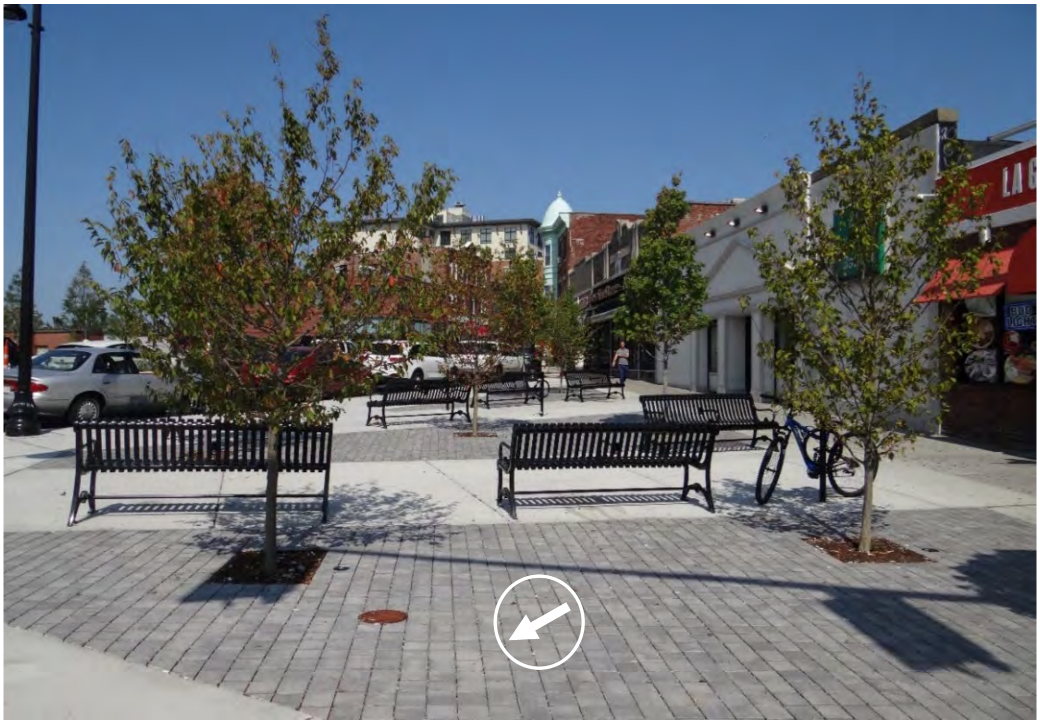


Figure 3-1. GSI on Constrained, Urban Site

At this highly constrained urban site at Central Square in Boston, MA, permeable pavers, infiltration trenches and sand-based structural soils (indicated by arrow) combine to maximize stormwater capture and enhance tree rooting volume; implemented by the Boston Water and Sewer Commission

3.2.2 Availability of Sunlight

The availability of sunlight should be considered when integrating vegetated GSI types into sites with variable light and shade conditions. Practitioners are advised to investigate whether vegetated GSI types will not only survive but also thrive given sunlight availability, and whether it is more prudent to use non-vegetated GSI types in less than ideal conditions. Limited sunlight does not necessarily preclude the use of vegetated GSI practices but is an important consideration when selecting plant species to help establish successful landscaping and minimize the need for re-planting.

The following design variations are recommended for shaded and low-light sites:

- Minimize vegetated areas by adjusting GSI practice selection or using non-vegetative landscape features such as stone, concrete or pavers
- Specifying shade-loving or shade-tolerant plant species

3.2.3 Public Safety

Public health and safety, particularly with respect to pedestrian accessibility, should be a high priority at every site and is particularly important for high-use sites such as parks and schools. One of the main responsibilities of a designer is to ensure that GSI does not have an undue negative effect on accessibility, safety, walkability and so on. For example, designers should ensure that GSI systems are laid out so they still allow for a minimum width of 5 feet for pedestrian walkways. Ideally, the selected GSI types and configuration will have a positive effect on public safety considerations, resulting in improved conditions for pedestrians. In general, improving transportation conditions via effectively integrated GSI types will improve pedestrian conditions.

When selecting GSI types with depressions, slopes, trip hazards and standing water, the following considerations should be kept in mind:

- Bioretention and rain gardens should be graded appropriately with respect to public safety (typically no steeper than 3:1, horizontal to vertical), and should be fenced or surrounded by shrubs or other landscape features if steeper slopes are used.
- Areas with permanent or temporary ponding depths greater than 12 inches should include overflow structures to prevent overtopping or flooding over pedestrian sidewalks or other foot traffic areas.
- The use of bollards may be considered for bioretention or other surface GSI types as both a visual barrier as well as physical protection from vehicular traffic.

Some GSI types like vegetated curb extensions can significantly enhance public safety. Vegetated curb extensions, or bump-outs, are designed to extend the curb line and can therefore reduce the length of crosswalks and pedestrian crossings. Thus, this GSI practice not only captures roadway runoff, it also can provide significant traffic calming and public safety benefits.

The following landscape design recommendations should be considered for vegetated GSI practices at highly visible sites:

- Develop a layered and intermingled planting scheme that provides a variety of landscape functions, including structural species, ground cover species and filler species to help out-compete weeds
- Use of seasonal-themed plant species helps to incorporate visual interest by weaving color and texture into the landscape design
- Avoid the use of monocultures and invasive species
- Use native plants and establish dense plant coverage at the time of planting (e.g. 18 inches on center). Use plugs or container plants rather than seeds.
- Integration of observational platforms and/or educational signage can help further draw attention to key GSI practice features
- Consider options to make the functionality apparent both during and outside of storm events (e.g., decorative cobble channels, trench drain covers, pavement markings, etc.)

3.2.4 Public Visibility / High Use Sites

Aesthetics are an important factor to take into consideration, particularly when placing GSI facilities in public settings with high visibility. GSI types that entail above-ground aesthetic considerations are bioretention/rain gardens, vegetated swales, vegetated infiltration basins, planter boxes, vegetated curb extensions and green roofs (on visible roof areas). Aesthetic decisions may range from the physical shape and form of the GSI practice to the landscape design and plant selection. While it may be appropriate for stormwater wetlands and vegetated infiltration basins to have a naturalized look, rain gardens and planter boxes in conventional urban settings may require a more manicured appearance. Therefore, expectations regarding vegetation aesthetics, planting palettes and anticipated maintenance regimes should be considered from the start of the GSI design process.

Public visibility of GSI types ultimately depends on the site and larger context that surrounds the GSI practice (Figure 3-2). In general, above-ground GSI types such as bioretention/rain gardens, vegetated infiltration trenches, vegetated curb extensions and certain types of permeable pavements all rank as highly visible to the community. Infiltration trenches and green roofs on non-visible roofs rank relatively low in terms of public visibility, which, at times, may be a desirable characteristic. The landscape design recommendations in Table 3-1 should be considered for vegetated GSI practices at highly visible sites.

Figure 3-2. Bioswale in Highly-Visible Site

Bioswale (indicated by arrow) along a highly visible street adjacent to ***Leavenworth Park*** *located in Syracuse, NY and implemented by Onondaga County*

Some GSI types are also more readily understood and accepted by the public than others. For example, rain gardens and planters are increasingly accepted and enjoyed by community members with limited concern. Green roofs are also becoming more mainstream. On the other hand, stormwater wetlands typically encounter higher resistance, with communities expressing concerns about standing water, flooding, drowning, and mosquitoes and/or other vectors. Most concerns related to GSI types can be addressed early in the process by conducting public meetings to discuss proposed alternatives, providing educational information and answering/addressing the community's questions and concerns, as well as managing their expectations. Transparent GSI designs allow observers to readily understand and interpret the function of the GSI.

Table 3-1. GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Selection Factors

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Selection Factors				
GSI Practice	**Space Constraints**	**Limited Availability of Sunlight**	**Highly Visible Sites**	**High Use Sites**
Bioretention: Bioretention Basin, Vegetated Planter, Rain Garden	• Use raised curbs, seat walls or decorative fencing to maximize GSI footprint, help protect GSI, and promote pedestrian safety • Extend subsurface storage under adjacent pavement areas if necessary • Consider high flow filter media or other types of engineered soil media or amendments	• Specify shade-loving or shade-tolerant plant species • Consider landscape features such as stone, concrete and pavers	• Develop an aesthetically rich, layered planting scheme with visual and seasonal interest • Use robust and easily maintainable pretreatment structures • Include observation platforms, walkways and/or educational signage • Ensure robust O&M protocols are in place	• Understand anticipated vehicular and pedestrian circulation patterns and desire paths and configure site layout accordingly • Use permeable epoxied stone borders, channels, and/or energy dissipaters and specify lockable lids on structures • Use fencing, raised curbs, traffic delineators, reflectors, paint or other type of indicator / barrier as appropriate
Bioretention: Vegetated Swales	• Specify less intensive excavation techniques to protect tree roots (hand excavation or "soft dig" techniques using air or water) • Ensure adequate pedestrian access; create bridges over GSI practices as appropriate • If intended as conveyance to another GSI practice, consider the use of a pipe for additional capacity for target storm events	• Specify shade-loving or shade-tolerant plant species • Minimize vegetated area by using cobble channels	• Use robust and easily maintainable pretreatment components (forebays, splash pads, filter strips, etc.) • Use aesthetically pleasing and locally sourced materials for weirs and check dams (e.g. limestone blocks); consider a more aesthetically-complex, layered plant palette • Shield drainage structures (overflow risers, cleanouts, flared-end sections, etc.) with stone and/or vegetation • Ensure robust O&M protocols are in place	• Use permeable epoxied stone borders, channels, and/or energy dissipaters and specify lockable lids on structures • Include safe and accessible crossings for pedestrians; ensure that swale does not conflict with existing vehicular or pedestrian circulation patterns • Use fencing, raised curbs, traffic delineators, reflectors, paint or other type of indicator / barrier as appropriate
Infiltration Trenches: Tree Trench, Trench Below Pavement, Trench Below Vegetation, Surface Flow Infiltration Trench	• Consider using deep stone columns for additional storage and to promote infiltration into more permeable soil layers • Consider the use of suspended pavement systems (structural soil cells) or sand-based structural soil to provide adequate rooting volume • Use alternative (higher voids) storage media to maximize capacity	• Avoid the use of vegetated infiltration trenches	• Develop an aesthetically rich, layered planting scheme with visual and seasonal interest for vegetated infiltration trench • For tree trenches, specify trees with characteristics that are well suited to the aesthetics and use of the site • Ensure robust O&M protocols are in place	• For tree trenches, use bollards or similar barriers to protect trees from vehicles; choose species with appropriate form/branching that will not conflict with vehicular or pedestrian circulation • Discourage foot traffic on vegetated infiltration trenches • Consider permeable epoxied stone for surface flow infiltration trench surface
Permeable Pavement: Porous Asphalt, Porous Concrete, Permeable Block Pavers, Open Grid Pavers	• Consider porous asphalt for playgrounds or play surfaces (e.g. basketball courts); design for dual use • Use impermeable liners next to buildings; use anti-seep collars to protect against seepage • Use alternative (higher voids) storage media to maximize capacity	N/A	• Use attractive pavers that integrate well with the look and use of the site • Avoid use of porous concrete, which can have very inconsistent appearance and texture (if selected, consider precast porous concrete) • Ensure robust O&M protocols are in place	• Understand anticipated traffic flows and select / configure permeable pavement accordingly • Design for anticipated traffic loads / frequencies • Avoid porous asphalt where frequent wheel turning is anticipated
Other: Green Roofs	N/A	• Consider the use of a blue roof • Specify shade-loving or tolerant plant species	• Include observation platforms and/or educational signage • Enhance visual appeal by implementing sloping green roofs and/or introducing topography • Ensure robust O&M protocols are in place	• Ensure safe access to the roof (elevator, stairs, etc.) • Incorporate railings and green screens to provide protection from falls • Incorporate stable, slip resistant walkways using pavers, concrete slabs, gravel, etc.
Other: Rainwater Harvesting	• Consider the use of cisterns when surface space is limited; specify appropriate size, configuration, location (inside, underground, etc.) • Consider the use of rain barrels when subsurface space is limited; specify appropriate size/configuration • If possible, integrate into other existing or proposed site features (benches, stairs, etc.)	• Ensure there is adequate demand for harvested rainwater (i.e. landscape irrigation demand may be low at these sites)	• Include educational signage • Consider using customized or artistic elements with greater aesthetic appeal • If desired, shield components using vegetation, fencing, etc. or select types that better blend in with site features • Ensure robust O&M protocols are in place	• Ensure that placement does not impact site accessibility • Specify lockable lids and secure cisterns • Ensure that overflows are appropriately directed away from high use areas

Table 3-1. GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Selection Factors

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Site Selection Factors				
GSI Practice	**Space Constraints**	**Limited Availability of Sunlight**	**Highly Visible Sites**	**High Use Sites**
Other: Stormwater Wetlands	• Consider the use of retaining walls to maximize wetland area and/or to provide support for adjacent structures • Ensure adequate pedestrian access; create bridges over GSI practices as appropriate • Consider the use of a diversion structure so that the available wetland area is capable of adequately treating the contributing flow and bypassing excess flow	• Specify shade-loving or shade-tolerant plant species	• Use robust and easily maintainable pretreatment structures • Include observation platforms, walkways and/or educational signage • Avoid the use of monocultures and non-native invasive species, such as cattails, common reed and multiflora rose • Ensure robust O&M protocols are in place	• Post multilingual "No Swimming" signs • Include a safety shelf (aquatic bench) with shrubs and tall grasses around the perimeter • Place outlets away from areas of heavy public use; specify screens on outlets • If desired, specify plant species and/or other features that deter birds and geese from staying or nesting

3.3 Physical Feasibility Factors

Physical feasibility factors, specifically natural / legacy site conditions, while critical from a design and siting perspective, are generally less differentiating or limiting when it comes to GSI practice type selection. However, there are still a variety of considerations that fall under this category that a designer should assess when selecting the most appropriate GSI types for any site. Physical feasibility factors can be classified as either subsurface (soil type and permeability, geology type/depth, depth of bedrock and seasonally high groundwater table, presence/depth of limiting soil layers, and contaminated soils) or surface factors (steeper slopes). This section will briefly explore how these various factors affect specific GSI practice selection and potential design modifications to accommodate these conditions. A GSI practice selection matrix for physical feasibility factors is presented at the end of this section in Table 3-2.

3.3.1 Soil Permeability / Compaction / Clay

For subsurface factors, it is important for practitioners to consider the typical functions of the GSI types and their respective sensitivity to such conditions. For example, certain GSI types, such as green roofs and rainwater harvesting systems, require little or no excavation and are, therefore, insensitive to soil permeability, shallow seasonal high groundwater and other subsurface factors. However, other GSI types, such infiltration trenches and permeable pavements, typically require more excavation depth for maximum effectiveness and, as such, are much more sensitive to limiting subsurface conditions like shallow bedrock.

- Low soil permeability conditions (typically less than 0.25-inch per hour) can affect some GSI practices, especially practices that typically rely on exfiltration to the in-situ soils such as infiltration trenches, bioretention/rain gardens and permeable pavements. Low permeability or poor infiltration capacity may be due to underlying soil types (e.g., clays or fine silts) or compacted soil conditions.
- Soil compaction may also be a significant consideration for GSI practices in urban areas. The designer should also consider the impacts of construction activities on post-construction soil conditions.
  - Underlying soils may be restored (at least partially) from compaction by using scarification, deep plowing or roto-tilling.
  - Construction equipment should be located outside of the GSI practice footprint when possible to avoid compacting the practice bottom and sidewalls. Use of lightweight, wide-tracked equipment is also preferable when possible.
  - Contractors are frequently insensitive to the issues of compaction and should be instructed to prevent compaction prior to the start of construction.
- Clay soils or other fine soil types like silt and silty clay may further limit subsurface soil infiltration capacity.
  - In the ALCOSAN service area, outcrops of swelling clay (i.e., clay that is susceptible to large volume changes due to its moisture retaining capability) may be present, though they are generally rare. If such clay is suspected at a site, a geotechnical investigation is strongly recommended for verification. If swelling clay occurs near building foundations or pavements, it is recommended to locate GSI sufficiently away from these structures to prevent any damage. Impermeable liners should also be used as appropriate.

Suitable design modifications for these conditions include designing the practice for slow release or filtration instead of infiltration by using underdrains, outlet control structures or micro-siphons. Soil amendments such as compost, sand or other engineered media may also be considered to enhance underlying soil conditions.

Planning-level soil information is available from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey, including general surface soil compositions, soil properties and hydrologic soil group (HSG) types. Typically, soils classified as HSG A or B are most suitable for infiltration design conditions, while HSG C or D soils may require design modifications to be effective and may not be suitable for some infiltration designs. (Note that the majority of the ALCOSAN service area is classified as urban soils and therefore may not have an assigned HSG.) For design purposes, more detailed geotechnical data, including soil borings and infiltration testing, are strongly recommended.

3.3.2 Depth to Bedrock / Seasonal High-Water Table / Depth of Limiting Soil

The following subsurface physical feasibility factors may significantly limit the available depth or footprint of excavated GSI types:

- Shallow bedrock presence (e.g., less than 7 feet below ground surface) at a site may present a significant challenge for excavated GSI types such as bioretention, infiltration trenches and some permeable pavements. A minimum distance of 2 feet between the GSI facility invert and the top of the bedrock layer is typically recommended for infiltration systems.
- Seasonally high groundwater table depth may also limit the depth of some GSI types. For GSI practice inverts less than 2 feet above the seasonally high groundwater table, the designer should consider use of an impermeable liner or other measures to prevent groundwater contamination. An anti-flotation evaluation may also need to be considered in some cases to protect outlet and other structures from the buoyant forces of a high groundwater table. For stormwater wetlands, intercepting the groundwater table may be beneficial to help maintain submerged conditions.
- Limiting soils layers, including hard-pan clays, confining layers and other impermeable soil types may also limit GSI practice selection for types which rely on infiltration and may make construction excavation activities more difficult.

For excavated GSI types in close vertical proximity to these subsurface conditions, practitioners should try to build up the practice when feasible to ensure adequate separation from bedrock and groundwater. The GSI practice layout may need to be optimized by spreading subsurface storage out as wide as possible to reduce the required subsurface depth. Use of an alternative media with increased void space may also help to meet sizing goals while utilizing a smaller depth or more compact footprint.

3.3.3 Contaminated Soils

As with other subsurface factors, the depth, extent and/or type of contaminated soils at a site will likely influence the type of GSI selected, especially if such soils will not be removed or remediated. If GSI types requiring excavation or appreciable disturbance of potentially contaminated soils cannot be avoided, it is generally preferable to consider those types that can still be effective without infiltration. For example, vegetated curb extensions, vegetated swales, planters, stormwater wetlands and tree trenches can all improve water quality through filtration, reduce peak rate (to varying degrees), and provide some volume reduction by relying on evapotranspiration.

The use of an impermeable liner at sites with contaminated soils should be evaluated for all GSI types to minimize infiltration. As appropriate, GSI types such as bioretention, infiltration trenches, permeable pavements and vegetated swales should be designed for filtration and slow release (e.g., using underdrains) instead of infiltration under these conditions. Contaminated soils can also significantly increase the cost of GSI implementation as the excavated materials may be considered waste that requires special handling and/or disposal requirements. Even non-hazardous contaminated soils may require Pennsylvania Department of Environmental Protection (DEP) review and approval for disposal at a regulated landfill.

3.3.4 Mining Related Areas

When siting BMPs, place as far as possible from mining-related areas. Mining-related areas may cause acid mine drainage (AMD) and may discharge pollutants including suspended solids, dissolved solids, iron, manganese and other metals. For treatment of polluted mine runoff, a combination of BMPs can be used depending on the pollutants of concern including oil-water separators, wet ponds, constructed wetlands and proprietary filter devices. AMD may also require chemical/physical treatment to raise the pH of the discharge. For more information on abandoned mines, please see the Coal Mines and Coal Mining Related Facilities Fact Sheet or contact the Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation.

3.3.5 Steeper Slopes

The presence of steeper slopes may be a significant factor in the selection of most GSI types, including bioretention, permeable pavements and stormwater wetlands. These GSI types are typically considered to be sensitive to slope and may require design modifications such as check dams, berms or baffles between cells to accommodate sites with steeper slopes (e.g., greater than 5%). In most cases, the bottom surfaces of GSI facilities such as bioretention and infiltration trenches should be flat to promote infiltration and/or filtration, so large elevation drops across a GSI facility may also require similar design modifications to optimize the design (Figure 3-3).

GSI types such as vegetated swales, rain gardens and infiltration trenches are typically better suited to sloping sites because they represent thinner, more linear systems that can be efficiently aligned along a contour without excessive disturbance. Steeper sites may also require GSI design variations with smaller footprints and a stepped configuration (e.g., stepped rain gardens instead of a larger bioretention facility).

Facility side slopes steeper than 3:1 (horizontal to vertical) have an increased risk for slope erosion and should be adequately stabilized using vegetation, erosion control matting or hard armoring. Energy dissipation at inflow points using a rock apron or armored splashpad may also be necessary if peak inflows exhibit erosive velocities.

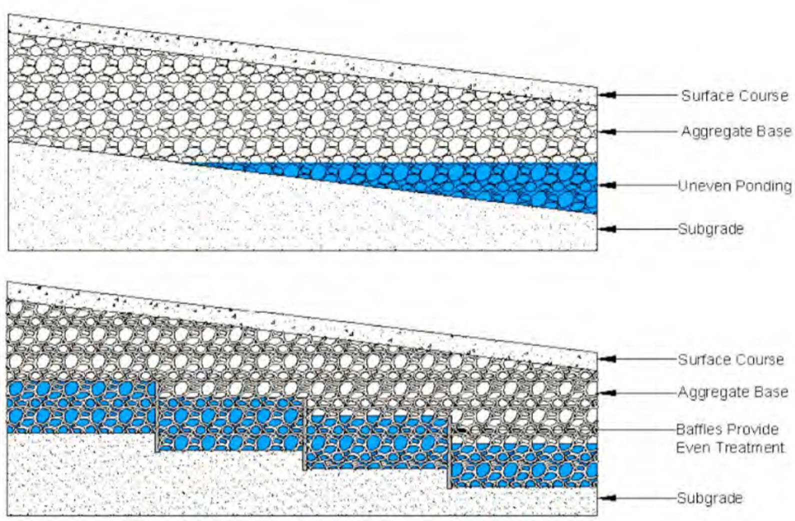


Figure 3-3. Baffles on Steep Slope
Baffles used in a sloping permeable pavement application increase the storage efficiency (Source: EPA Green Infrastructure Technical Assistance Program Addressing Green Infrastructure Design Challenges in the Pittsburgh Region: Steep Slopes, January 2014)

Table 3-2. GSI Suitability and Key Design Considerations for Enhancing Suitability by Physical Feasibility Factors

Key: Typical Suitability Rating	High	Medium	Low

GSI Suitability and Key Design Considerations for Enhancing Suitability by Physical Feasibility Factors				
GSI Practice	Low Permeability / Clay Soils	Shallow Bedrock / Groundwater	Contaminated Soils	Steeper Slopes
Bioretention: Bioretention Basin, Vegetated Planter, Rain Garden	• Allow for infiltration but design for slow release using underdrains and/or micro-siphons • Protect soil from compaction or restore it via scarification or deep plowing • Consider deep stone columns to penetrate confining layers and to promote infiltration into more permeable soil layers • Amend soil w/ compost, sand, etc.	• If feasible, build up practice to ensure adequate separation from bedrock/groundwater • Keep media as shallow and spread out as possible (extend subsurface storage media beyond surface footprint if necessary); min. soil thickness of 18" • Use alternative (higher voids) storage media to maximize capacity	• Use impermeable liner • Design for slow release (underdrain) • Consider issues related to contaminated spoils from excavations (costs, approvals, disposal facility, etc.)	• Use check dams / berms between level or mildly sloped cells • Stabilize slopes, use diversion berms and provide energy dissipation at inflows • Limit surface depth to 24" when adjacent to sidewalks; limit total depth to 6'
Bioretention: Vegetated Swales	• Design for conveyance and/or pretreatment for other GSI practices • Protect soil from compaction or restore it via scarification or deep plowing • Consider deep stone columns to penetrate confining layers and to promote infiltration into more permeable soil layers • Amend soil w/ compost, sand, etc.	• Design for conveyance and/or pretreatment for other GSI practices • If using subsurface storage, keep it relatively shallow and spread out (beyond the swale limits if necessary)	• Use impermeable liner • If using subsurface storage, design for slow release (underdrain) • Consider issues related to contaminated spoils from excavations (costs, approvals, disposal facility, etc.)	• Use check dams / berms • Plant a dense, robust and layered system with hardy species to prevent erosion • Stabilize slopes and provide energy dissipation at inflows; use erosion control matting as appropriate
Infiltration Trenches: Tree Trench, Trench Below Pavement, Trench Below Vegetation, Surface Flow Infiltration Trench	• Allow for infiltration but design for slow release using underdrains and/or micro-siphons • Protect soil from compaction or restore it via scarification or deep plowing • Consider deep stone columns for additional storage and to promote infiltration into more permeable soil layers	• If feasible, build up practice to ensure adequate separation from bedrock/groundwater • If separation to bedrock/groundwater is less than 2', consider impermeable liner • For trenches under pavement, keep storage media as shallow as possible, while accounting for anticipated load and frost depth	• Use impermeable liner • Design for slow release (controlled underdrain) • Consider issues related to contaminated spoils from excavations (costs, approvals, disposal facility, etc.)	• Use check dams / baffles between level or mildly sloped trench segments • Limit total depth to 6' • Reduce cost by using approved fill material above storage elevation instead of gravel
Permeable Pavement: Porous Asphalt, Porous Concrete, Permeable Block Pavers, Open Grid Pavers	• Allow for infiltration but design for slow release using underdrains and/or micro-siphons • Protect soil from compaction or restore it via scarification or deep plowing • Amend soil w/ compost, sand, etc.	• If feasible, build up practice to ensure adequate separation from bedrock/groundwater • Keep storage media as shallow as possible, while accounting for anticipated traffic loads and frost depth • If separation to bedrock/groundwater is less than 2', consider impermeable liner	• Use impermeable liner • Design for slow release (underdrain) • Consider issues related to contaminated spoils from excavations (costs, approvals, disposal facility, etc.)	• Use check dams / baffles between level or mildly sloped trench segments • Limit total depth to 6' • Limit slope to approximately 5%
Other: Green Roofs	N/A	N/A	N/A	N/A
Other: Rainwater Harvesting	N/A	• When above-ground storage is infeasible, keep subsurface storage relatively shallow and spread out	N/A	N/A
Other: Stormwater Wetlands	N/A	• If feasible, build up practice to ensure adequate separation from bedrock • Unless there are water quality concerns, shallow groundwater can be favorable (use impermeable liner when water quality is a concern)	• Use impermeable liner • Consider issues related to contaminated spoils from excavations (costs, approvals, disposal facility, etc.)	• Use check dams / berms between cells • Stabilize slopes, use diversion berms and provide energy dissipation at inflows

GSI Sizing Considerations

4.1 General GSI Sizing Considerations

Storage calculations should be performed for each individual GSI system. In general, GSI systems in the combined sewer area should be sized with a static storage volume that can manage 1 to 2 inches of runoff from the contributing impervious drainage area. Pervious area may also be considered for design purposes, though impervious area should be the focus for sizing GSI systems.

Practitioners are encouraged to consider the following with respect to GSI sizing:

- Storage provided above the elevation of the overflow invert should not be included in the static storage capacity
- Maximum permissible dewatering time for GSI systems is typically 72 hours; for surface systems, it is recommended that ponding areas completely drain in less than 24 hours
- Calculations should include release rates for slow-release systems, which may be subject to limits according to local regulations
- GSI features should generally have a minimum width of 3 feet, for cost-efficiency of excavation and other construction costs
- When considering GSI areas and depths, factor in loading ratios (see section 4.3 for further discussion)
- GSI footprints should account for pretreatment forebays or other sediment control measures

The following void percentages are recommended to be used in storage calculations (Table 4-1):

Table 4-1. Recommended Void Percentages for Storage Calculations

Storage Material	Void Space
Gravel / Open graded aggregate / Stone	35-45%
Soil	15-25%
Sand	25-35%
Pipes embedded in GSI	90-94%
Modular storage	product specific

The total depth of GSI practices can have significant implications with respect to costs and stormwater benefits. Deep systems (e.g. greater than 4 feet or as otherwise defined depending on jurisdiction) require sheeting and shoring, which can drive up project costs and complicate construction. A tiered or stepped approach may be considered to reduce excavation and make GSI more cost-effective (see section 3.3.5 for further discussion).

Design depths of GSI components can vary based on numerous factors, including type of GSI, required storage volume, loading ratio, inclusion of trees, frost penetration depth, inverts of connecting drainage pipes, bedrock / groundwater depth, and considerations related to vehicular loading, freeboard and pipe bedding. Table 4-2 provides typical design depths for various GSI types and components. Note that these values can vary greatly based on the primary storage component of the practices, whether primarily surface (e.g. wetlands), subsurface (e.g. infiltration trenches), or both surface and subsurface (e.g. bioretention).

Table 4-2. GSI Component Storage Depths

GSI Type	GSI Component	Depth (inches)
GSI Practices with Surface Storage	Ponding	3 - 12[1,2]
GSI Practices with Vegetation	Engineered/Bioretention Soil	18 – 36
GSI Practices with Subsurface Storage Under Pavement	Aggregate	12 - 24[2]
GSI Practices with Subsurface Storage Under Vegetation	Aggregate	6 - 24[2]
GSI Practices with Subsurface Storage	Sand Filter (if applicable)	6 - 8

[1]Stormwater wetlands can have surface depths up to 6 feet.

[2]Depths include freeboard, which is typically 6 inches minimum.

For more detailed GSI sizing guidance, practitioners should consult the various design manuals that are available at the state and regional levels in Chapter 1, Introduction to GSI. While these manuals can serve as useful resources for GSI designs, they should be cross-checked with all other local standards and regulations.

4.2 Maximize Drainage Area

GSI sited near topographic low points will generally receive the greatest potential drainage area. Due to economies of scale, systems with larger drainage areas tend to be more cost effective per volume of stormwater runoff managed. Drainage area evaluations should be performed early in the design process to appropriately size and site GSI.

Adjacent impervious areas should be evaluated to determine if they could be feasibly redirected to GSI practices via new inlets (immediately uphill from existing inlets) and storm pipes, intercepting existing drainage infrastructure, or by closing existing inlets. Downspouts (also known as roof leaders) can be disconnected to become part of the drainage area that will be managed by GSI practices or can be disconnected to nearby pervious areas. Parking lots and driveways often drain partially or entirely to the right-of-way and therefore can be managed by public GSI.

Practitioners should note that property ownership may affect the ability to obtain credit for management of runoff. For example, some municipalities may elect to avoid managing runoff from private properties due to the lack of control over future land uses. In such cases, it is best to maximize the publicly owned drainage area.

Control devices such as weirs and orifices can be used to release excess runoff flows from large drainage areas in a controlled manner. Another strategy is to combine various GSI types to achieve multiple objectives, including flood control. For example, runoff may be conveyed to smaller vegetated GSI systems such as vegetated swales and bioretention for runoff volume and water quality control while allowing excess flows to be directed to a larger surface or subsurface storage facility where capacity can be maximized to provide peak rate attenuation for extreme storm events.

4.3 Loading Ratio

The ratio of impervious drainage area to the corresponding GSI system footprint, or impervious loading ratio, is an important factor in sizing GSI systems. Designing GSI practices with acceptable loading ratios can significantly improve their chances for long-term effectiveness. On the other hand, overloading GSI practices can lead to premature clogging and even failure.

The desired loading ratio depends on the mechanism and type of GSI (Table 4-3). The loading ratios in Table 2-2 assume stabilized drainage areas and typical pretreatment. A system can be designed with a higher loading ratio with the inclusion of more robust pretreatment and/or diversion structures. In general, infiltrating GSI systems should have a lower loading ratio than slow-release systems to minimize the potential for groundwater mounding or clogging of the subgrade soils. Vegetated GSI types that receive runoff at the surface (e.g. bioretention) can generally have a higher loading ratio than GSI types that receive runoff in subsurface storage components (e.g. infiltration trenches). The reason for this higher loading ratio is that the soils in surface-receiving GSI can more readily absorb sediment, plants help maintain soil permeability, and these systems are usually easier (i.e. more accessible) to maintain. When a system is a combination of surface- and subsurface-receiving GSI, both the surface and subsurface loading ratios should be calculated separately to ensure appropriate GSI footprint sizing.

Table 4-3. Recommended Loading Ratios

GSI Mechanism[1]	Surface Receiving Runoff	Recommended Loading Ratios of Impervious Drainage Area to GSI Area[2]
Infiltration / Runoff Reduction	Subsurface	5:1 - 12:1
	Surface (Vegetated)	10:1 - 20:1[3]
Slow Release	Subsurface	10:1 - 20:1
	Surface (Vegetated)	15:1 - 25:1[3]

[1]To protect against surface clogging, the loading ratio for permeable pavement should be kept at 3:1 or as recommended by manufacturers. However, the storage / infiltration system underneath permeable pavements can have higher loading ratios, provided the contributing drainage area is drained by inlets with pretreatment.

[2]Ratios are for stabilized drainage areas. Practitioners should consider the amount of sediment loading expected, factoring in ground cover and land use. Practitioners should consult a geotechnical engineer for special cases (e.g. carbonate soils, karst geography, landslide-prone areas, fractures, faults, other geologic features). Higher loading ratios necessitate more robust pretreatment.

[3]Loading ratios for surface systems could be increased by using high flow media.

CHAPTER 3

Cost Estimating Guidance Document

SECTION 1

Introduction to Cost Estimating

The purpose of this chapter is to provide applicants seeking GROW funding for GSI projects with guidance, requirements and useful resources to develop clear and accurate cost estimates for their GROW applications to ALCOSAN. The document has been divided into two main sections:

- Section 1 provides general discussion on the differences between GSI cost estimating and traditional infrastructure estimating, typical planning-level costs for GSI, cost eligibility for GROW funding, several strategies for making GSI projects more cost-effective, typical cost considerations for establishing vegetated GSI practices, and a list of cost estimating resources.
- Section 2 provides more specific information related to cost estimating for GROW projects, including estimator qualifications, levels of project completion, required cost information and recommended contingencies and risk factors.

1.1 GSI Cost Estimating vs. Traditional Infrastructure Cost Estimating

Cost estimating for GSI can be different in several ways from estimating traditional infrastructure. It is important for GSI cost estimators to recognize and try to accurately account for the potential differences.

For example, it may be necessary to consider some or all the following factors for typical GSI projects:

- A contracting community that is inexperienced with procuring and installing certain GSI elements
- Availability of specialized GSI materials
- Need for atypical construction sequencing with appropriate weather conditions, and the associated schedule implications
- That many GSI projects are retrofits of existing sites in urban environments, which entail an additional element of risk and uncertainty
- Relative lack of both GSI cost-estimating resources and planning-level costs
- Uncertainties regarding which items are directly related to GSI implementation and performance and which items are not
- The extra importance of erosion and sedimentation controls
- The potential need for additional warranty and post-construction activities (e.g., during the plant establishment period for bioretention facilities)

1.2 Typical GSI Planning-Level Costs

This section provides planning-level cost information that can be used when evaluating and comparing various GSI options in the ALCOSAN service area. The costs provided here are based on recently built GSI projects in Pennsylvania cities such as Pittsburgh, Lancaster and Philadelphia, as well as Syracuse, New York. For GSI operations and maintenance (O&M) costs, see the ALCOSAN GROW “GSI Operations and Maintenance Guidance” document (Chapter 5).

When developing cost estimates, applicants should consider whether the GSI project is a stand-alone (i.e. retrofit) project or integrated into a redevelopment or reconstruction project. For redevelopment/reconstruction projects, the GSI cost portion can be considered differential (i.e., additional) to the conventional construction cost. For example, if an alley is being reconstructed and permeable pavement is incorporated, the marginal GSI cost is the difference between the cost of conventional pavement that would have been installed and that of the permeable pavement. For retrofits of existing sites, where GSI represents all or a majority of the proposed work, the GSI cost may be equal to the overall construction cost. In general, GSI is more cost-effective when it is part of an integrated project rather than a stand-alone or retrofit project.

Table 1-1 provides typical planning-level capital costs per impervious acre managed based on the type of GSI implementation, whether stand-alone or integrated. The reported costs in Table 1-1 were based on multiple constructed GSI projects (of varying types) in the various cities listed above and were adjusted to be representative of the Pittsburgh region in December 2017. As these are capital costs, they include "soft costs" like project administration fieldwork, engineering and landscape architecture, which typically make up 20-35% of the total. For finer-level analyses, these typical costs should be adjusted as appropriate based on localized information such as project size, constraints and project setting.

Table 1-1. Planning-level Baseline GSI Capital Costs for Public Projects (assumed to represent a typical site and constraint level)

Type of GSI Implementation	Typical Planning-Level Capital Cost ($/impervious acre managed)
Stand-alone (retrofit)	$370,000
Integrated (redevelopment)	$260,000

Cost Implications of Physical Constraints to GSI

As part of a planning analysis for GSI implementation, ALCOSAN developed a list of relative constraints to GSI implementation. Specifically, these were physical characteristics that do not necessarily preclude GSI implementation but may impact the effectiveness, cost and/or limit the types of GSI possible. The potential cost implications of these relative constraints were considered (Table 1-2) and estimated for typical GSI applications (Figure 1-1). While site-specific cost estimates should be developed when feasible, scaling estimated costs using these constraints may be appropriate for planning-level estimates.

Table 1-2. Planning-Level Estimates of Cost Impacts Associated with Various Relative Constraints to GSI Implementation (cost increases that might be expected compared to a location without that constraint)

<table>
<tr><th>Relative Constraints</th><th>Potential Cost Implications</th><th>Constraint Subcategory</th><th>Approximate Cost Increase</th></tr>
<tr><td>Utility Pipe Corridors</td><td>Cost of liner and/or protecting/working around utilities</td><td>-</td><td>18% - 25%</td></tr>
<tr><td rowspan="3">Slopes</td><td rowspan="3">Extra excavation/fill, baffles, sheeting and shoring</td><td>5 to 9.99%</td><td>5% - 7%</td></tr>
<tr><td>10 to 14.99%</td><td>15% - 21%</td></tr>
<tr><td>15 to 24.99%</td><td>25% - 35%</td></tr>
<tr><td rowspan="5">Hydrologic Soil Group (HSG)</td><td rowspan="5">Increased excavation costs for urban soils, need for underdrains, soil amendments</td><td>B/D</td><td>8% - 11%</td></tr>
<tr><td>C</td><td>3% - 4%</td></tr>
<tr><td>C/D</td><td>8% - 11%</td></tr>
<tr><td>D</td><td>10% - 14%</td></tr>
<tr><td>Urban Fill</td><td>5% - 7%</td></tr>
</table>

Table 1-2. Planning-Level Estimates of Cost Impacts Associated with Various Relative Constraints to GSI Implementation (cost increases that might be expected compared to a location without that constraint)

Relative Constraints	Potential Cost Implications	Constraint Subcategory	Approximate Cost Increase
Depth to Bedrock	Shallow bedrock could increase excavation costs and/or liner costs	1.1 to 2.6 feet	15% - 21%
		2.6 to 5.0 feet	5% - 7%
		5.0 to 5.7 feet	3% - 4%
Depth to Water Table (annual minimum)	Shallow water table could increase excavation costs and/or liner costs	Less than 0.49 feet	25% - 35%
		0.5 to 1.35 feet	20% - 28%
		1.36 to 1.9 feet	15% - 21%
		1.91 to 2.26 feet	13% - 18%
		2.27 to 2.59 feet	10% - 14%
FEMA 100-year Floodplains	Cost impact more on the O&M/restoration side	-	15% - 21%
Forest Land Cover	Tree removal/replacement and/or protection	-	13% - 18%
Brownfield Parcels, Parcels with Abandoned Mines, Cemeteries	Cost of liner and/or soil disposal	-	15% - 21%
Streets/Roadway	Increased demo and/or pavement/curb restoration costs	-	8% - 11%

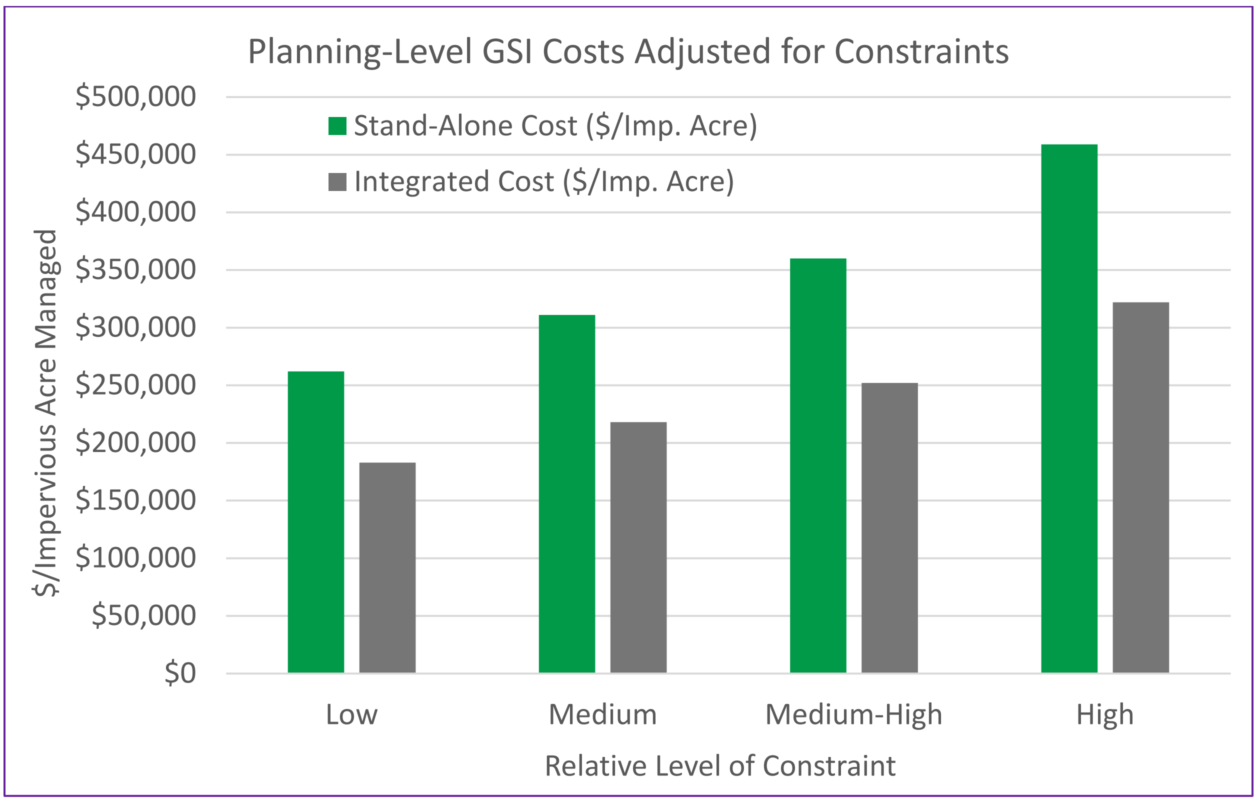


Figure 1-1. Planning-Level GSI Costs

Planning-level GSI costs based on the relative level of constraint considering the combination of constraints in Table 1-2.

1.3 GROW Program GSI Cost Eligibility

Only those GSI project elements that directly contribute to reducing sewer overflows or inflow to the Regional Collection System (RCS) are eligible for funding under the GROW program. Specifically, eligible items include those that pertain to the design and/or construction of the functional (i.e., from a stormwater management perspective) portions of GSI projects on public properties within the ALCOSAN service area (Figure 1-2). Conversely, items are considered ineligible if any of the following are applicable:

1. They are not directly related to design or construction (e.g., municipal administration),
2. They are related to GSI projects implemented on private properties, and
3. They do not contribute to the primary function of GSI practices, which is to reduce sewer overflows by reducing or eliminating stormwater inputs to combined sewers tributary to overflow points. An example of a typical project-related item that does not contribute to the primary function of GSI practices is a new sidewalk that is not above an infiltration trench or necessitated by the implementation of any GSI components.

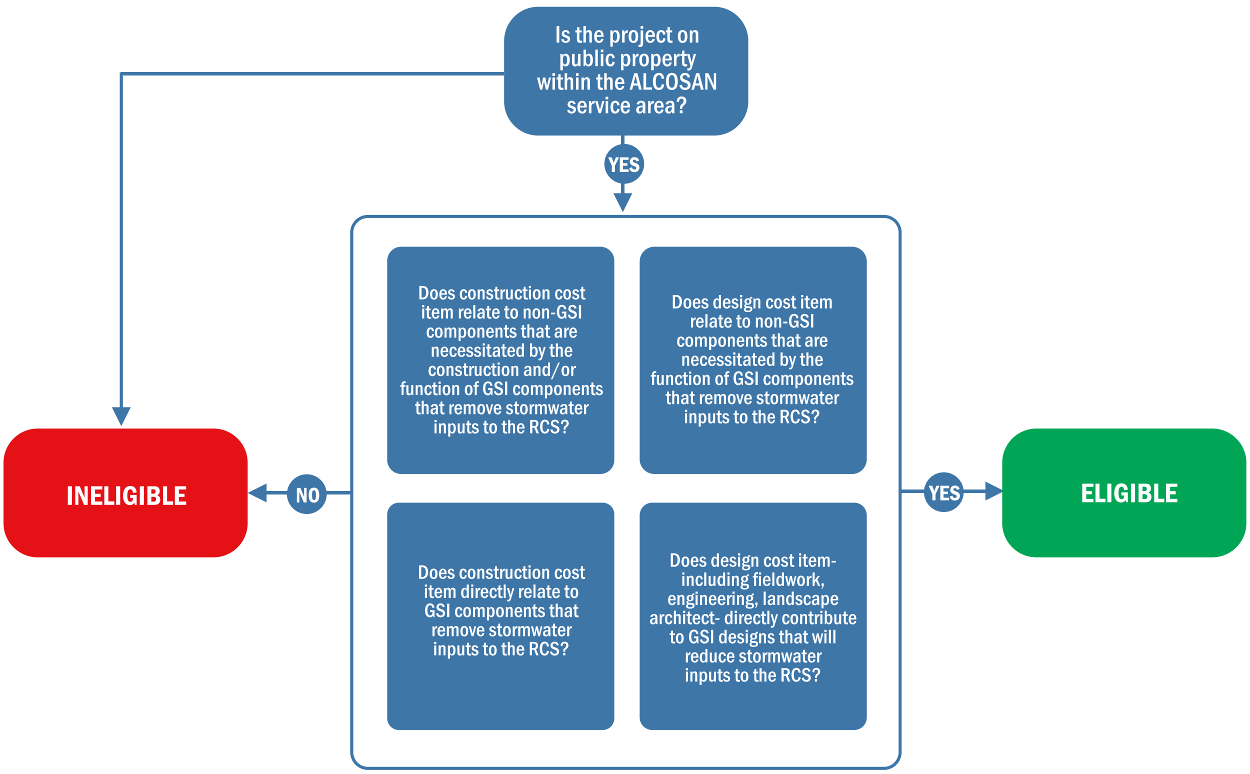


Figure 1-2. GROW Program Item Eligibility

Specific examples of eligible items include, but are not limited to, surveying, geotechnical investigations and landscape architecture. Specific examples of ineligible items include, but are not limited to, flow monitoring, municipal administration and public relations. When developing cost estimates for GROW applications, applicants should clearly and accurately identify whether each project element is eligible or ineligible and provide sufficient detail for review.

1.3.1 Eligible Design Costs

Eligible design costs are for those design or design-related elements, or soft costs, necessary to implement GSI within municipality- or municipal sewer authority-owned properties to reduce the amount of runoff entering sewers tributary to overflows. Any design or design-related costs that do not directly contribute to the function of a GSI project are not eligible for GROW funding and should be itemized within the ineligible costs section of the cost estimate. GROW funding is ultimately awarded based on the total eligible design and construction cost, with the total including funds contributed by all parties.

The following items represent design or design-related costs that are considered eligible for funding. Items that are required to be reported in the GROW Cost Estimate Template (Appendix 3-A) are marked with an asterisk (*).

- Fieldwork*
  - Surveying and Base Plan Development including topography, subsurface and surface utilities, trees and other site features, and wetland delineations associated with proposed GSI project location
  - Geotechnical Investigations including infiltration tests, borings, laboratory soil tests, etc., as necessary to confirm feasibility of or design considerations for GSI project
  - Mitigation efforts related to contaminated soils
- Engineering*
  - Alternative development and evaluation (can be no greater than 10% of engineering cost)
  - Conceptual GSI design (can be no greater than 10% of engineering cost)
  - Drainage area delineation / mapping
  - H&H modeling / drainage and performance calculations
  - Detailed GSI design including siting, sizing, selection, layout, etc. for all levels of design completion (e.g., 30%, 60%, 90% and 100%)
  - Traffic analysis / engineering (as needed based on GSI location/configuration)
  - Computer-aided drafting (plans, details, profiles, sections, etc.)
  - Specification development
  - Cost estimating
  - Construction engineering - reviewing contractor submittals and shop drawings, reviewing change orders and RFIs, attending construction meetings, inspections, punch list evaluations, start-up evaluations, etc. (Note: construction inspections services are also potentially eligible, but they are listed under construction costs.)
- Landscape Architecture* including GSI project layout, configuration and development of planting plans/schedules/details
- Utility / Stakeholder Coordination
- Project Management including design review meetings with client, invoicing, project status reporting, etc.

Once again, the above design or design-related costs are potentially eligible for GROW funding if they are directly related to the function of GSI practices. Applicants are expected to provide adequate detail and cost accuracy consistent with the specified percentage of design and/or construction completion. In addition, applicants are encouraged to provide sufficiently detailed backup information for those design costs that are potentially related to GSI practices (e.g., traffic engineering), but may not be obvious.

The design contingency (%) is required to be reported in the cost estimate. Upon input of this contingency, the template automatically calculates the design contingency cost as a percentage of the design subtotal and then adds it to this subtotal to get the total design cost. (Note that the total design cost is to be entered in Section 3.4a of the GROW application.) Contingency is further discussed in Section 2.3.

1.3.2 Eligible Construction Costs

Eligible construction costs are for those construction elements necessary to construct GSI within municipality- or municipal sewer authority-owned properties. Table 1-3 lists examples of eligible construction costs for all GSI types under the GROW program. If there is no cost to report for a required item, then place a zero ("0") in the quantity column. As with design costs, applicants are encouraged to provide sufficiently detailed backup information for those construction costs that are potentially related to GSI practices (e.g., curb modifications), but may not be obvious.

Table 1-3. Examples of GSI Construction Items Eligible for GROW Funding

Item	Description
Mobilization*	Organizing and arriving on site for the beginning of the construction phase and then vacating and cleaning up the site after the construction phase is complete
Public Notification/ Traffic Control/ Cleanup*	Notifying the public of construction schedules, road/sidewalk closures, parking impacts and other potential impacts; installing traffic and safety signs/fencing, controlling the flow of traffic and cleaning the site regularly
Erosion and Sedimentation Controls*	Installing and maintaining proper erosion and sediment (E&S) controls during construction, including inlet protection, tree protection fence, silt fence, compost filter sock, stabilized construction entrance, erosion control blanket, etc.
Temporary Bypass*	Installing temporary drainage channels to allow uphill runoff to bypass construction sites, or installing bypassing equipment for allowing sewer flows to bypass existing sewer segments or manholes where GSI flow outlet or overflow connections are being installed
Site Restoration*	Restoring the site around the GSI that had to be disturbed during GSI construction; this may include streets, sidewalks, curbs, ramps, railings, vegetation and trees
Construction Inspection Services*	Resident inspectors; monitoring contract compliance, quality and progress of constructing GSI practices
Existing Utility Protection / Relocation	Protecting utilities with plastic sleeves, concrete encasement, etc., or relocating utilities (horizontally and/or vertically), including surface utilities such as light poles, to make way for GSI or GSI-related improvements (e.g. conveyance piping) is acceptable; redirecting or installing utilities to power or operate any component of the site that is not directly associated with the GSI function is not eligible
Roadwork, Sidewalk and/ or Curb Modifications	Only modifications needed to convey water to GSI are eligible, though curbs needed to contain GSI are also eligible
Site Clearing, Demolition and Excavation	All aspects, including tree removal, saw cutting, dewatering, shoring, disposal/hauling, backfill, etc. are eligible
Re-grading	Modifying slope or elevations of GSI footprints or drainage areas in support of directing stormwater flows to GSI

Table 1-3. Examples of GSI Construction Items Eligible for GROW Funding

Item	Description
Underdrain, Conveyance, Distribution and Outlet Pipes	Can be further itemized by size, material, solid vs. perforated, and fittings; connections to existing pipes are eligible provided they are required for GSI performance
Inlets, Catch Basins, Manholes, Cleanouts, Monitoring Wells, and Outlet/ Overflow Structures	Can be further itemized by size, material, grate type, inclusion of internal weirs (for outlet/overflow structures) or traps/hoods/slow-release orifices, sediment sumps, extensions and fittings; connections/modifications to existing structures are eligible provided they are required for GSI performance
Aggregate	Differentiated by type and size
Downspout Disconnection	Eligible if directed to GSI, either directly or indirectly
*Required to be reported in the GROW Cost Estimate Template.	

It should be noted that all the construction work associated with the project may be subject to the Pennsylvania Prevailing Wage Act, as determined by the Pennsylvania Department of Labor and Industry. Estimates for construction costs should reflect best professional judgment on the use of prevailing wages.

In addition to the items in Table 1-3, other example construction items eligible for GROW funding that may be more applicable for bioretention, rain gardens and vegetated swales include:

- Splash pads, rip rap, cobbles or other flow velocity/energy dissipaters
- Internal check dams or weirs
- Engineered soils, including high flow filter media
- Soil additives or amendments
- Coarse sand, if applicable
- Plants (shrubs, ground cover, perennials, grasses, etc.; plugs or containers)
- Trees (bare root or ball and burlap)
- Meadow seed mix
- Mulch
- Erosion control matting
- End-walls / flared-end sections
- Filter inserts for catch basins and overflow structures
- Raised curb, cheek walls, bollard and chain, permanent fencing, traffic delineators, etc., as required to protect GSI, as well as site users
- Geotextiles (woven and non-woven) and liners

Example construction items eligible for GROW funds that may be more applicable for permeable pavement installations include:

- Permeable asphalt surface course and asphalt treated permeable base course, if applicable

- Permeable concrete
- Permeable unit pavers or blocks
- Fill/bedding stone for pavers or choker course for permeable asphalt / concrete
- Pretreatment structures or filter inserts for catch basins and overflow structures
- Geotextiles (woven and non-woven) and liners
- Pavement markings, sign posts and other associated traffic or parking-related components necessitated by the permeable pavement construction

Example construction items eligible for GROW funds that may be more applicable for infiltration trenches include:

- Coarse sand filter layer at bottom of trench, if applicable
- Geotextiles (woven and non-woven), liners and geogrids
- Pretreatment structures or filter inserts for catch basins and overflow structures
- Modular storage units
- Sand-based structural soil (for tree infiltration trenches)
- Anti-seep collars to discourage seepage from the trench (also important for other GSI types)

The construction contingency (%) is required to be reported in the cost estimate. Upon input of this contingency, the template automatically calculates the construction contingency cost as a percentage of the construction subtotal and then adds it to this subtotal to get the total construction cost. (Note that the total construction cost is entered in Section 3.4b of the GROW application.) Contingency is further discussed in Section 2.3.

1.3.3 Ineligible Costs

ALCOSAN requires applicants to account for the full cost of GSI projects (or other GROW funded projects) by submitting costs of items that do not directly contribute to reducing sewer overflows and are therefore ineligible for funding. Applicants must account for all ineligible project costs by clearly identifying, itemizing, and totaling them in the GROW Cost Estimate Template. Note that funding is awarded based on total eligible design and construction costs, with the total including funds contributed by all parties.

Project costs are considered ineligible if they are not directly part of the design or construction of GSI (or other GROW funded project) within municipality- or municipal sewer authority-owned properties or right-of-way. Examples of ineligible costs are listed below. Items that are mandatory to report are identified with an asterisk.

- Design costs (fieldwork, engineering and/or landscape architecture for all site improvements not directly related to GSI function)*
- Legal and administrative duties*
- Bonds and insurance*
- Flow monitoring*
- Permits (including costs for preparing applications and permit fees)*
- Non-source reduction construction elements (lighting, decorative fencing, furniture, site photos, etc.)*

- Work on private property (including work on privately-owned storm drainage pipes)*
- Start-up / maintenance costs*
- Public relations, workshops and outreach communications (including sketches, graphical renderings or photo simulations)
- Lobbying
- Litigation and/or legal fees
- Fees for securing other financing
- Interest on borrowed funds
- Land or easement acquisition
- Downspout disconnection on non-municipality- or municipal sewer authority-owned properties
- Bidding and award costs
- Redirecting or installing utilities to power or operate any component of the site that is not directly associated with the GSI function
- Contractor change orders related to design errors
- Pavement milling/re-paving or reconstruction unrelated to GSI
- Pedestrian crosswalks, pavement markings and other similar improvements unrelated to GSI
- Parking lot wheel stops or guard rails unrelated to GSI
- Installing dedicated pedestrian walkway pavers or paths through GSI, as well as observation decks
- Signage (educational/interpretive signage for GSI practices may be considered on a case-by-case basis)

The above items are provided as examples of efforts or items that are typically unrelated to the ability of GSI practices to function as designed and reduce inflow or sewer overflows. If an applicant believes that any of the above items or other items not listed are in fact directly related to GSI performance, then they are encouraged to provide sufficiently detailed backup information.

Note that there is no contingency added to the ineligible cost. The total ineligible cost is entered in Section 3.4c of the GROW application.

1.4 GSI Cost Reduction Strategies

For the GROW program, there is an applicant match/cost share requirement. GROW awards cover 15% to 85% of the total eligible project costs and applicants must describe the other sources of funding in the application.

GROW funding percentages are based on the project’s cost per gallon of sewer overflow reduction. If a project is not capable of cost-efficiently reducing sewer overflow but does cost-efficiently remove flow from the RCS, it may still be considered for funding. GSI costs remain a significant barrier to widespread implementation; however, there are various ways to reduce capital costs and plan effectively for long-term O&M.

The effectiveness of source reduction on a per gallon basis varies significantly depending on the location of the project within the ALCOSAN system. This variability has been estimated by the overflow reduction efficiencies (OREs) developed for the full ALCOSAN service area. All else being equal, a GSI project in the highest ORE area would be less than half the cost in terms of overflow reduction than the same project in the lowest ORE area (Table 1-4). While municipalities cannot control the OREs within their jurisdictions, they can target the highest ORE areas available to them.

Table 1-4. OREs can Significantly Affect the Efficiency of Projects on a Cost per Overflow Volume Reduced Basis

Site Description	Impervious Area Captured (ac)	Estimated Construction Cost per Impervious Acre	GSI Capture Depth (in.)	Runoff Capture (%)*	Runoff Capture (gal/yr)*	Estimated Overflow Reduction Efficiency (ORE)	Estimated CSO Reduction (gal/yr)	Cost Efficiency ($/gal/yr overflow reduction)
Example Park Project #1	1.0	$260,000	1.00	92%	792,000	42%	330,000	$0.79
Example Park Project #2	1.0	$260,000	1.00	92%	792,000	98%	780,000	$0.33

*Based on typical year rainfall of 37.24 inches and annual impervious runoff coefficient of 85%.

GSI type (e.g., bioretention, permeable pavement), performance requirements and sizing are important considerations that are often analyzed from a cost perspective. Communities frequently examine cost-efficiency metrics such as the cost per square foot of green infrastructure, the cost per gallon of storage provided, cost per acre of impervious area managed, or the cost per pound of pollutant removed. However, many local and site-specific factors — such as land value, space limitations, existing utilities and environmental conditions including slope and soils — can heavily influence costs and make them more variable, as previously discussed in Section 1.2.

Costs can be minimized by addressing O&M during the planning and design of GSI.

Location in the urban environment and aesthetic goals are significant determining factors for capital costs. Highly-manicured GSI in high-profile locations warrants more careful design, installation and maintenance as compared to systems that will not play a prominent role in public space. Other site-specific factors affect O&M costs as well. However, these costs can be minimized by addressing O&M during the planning and design of GSI. For example, maintenance costs for permeable pavements can be reduced by not placing them in areas with high leaf litter or where higher sediment loads would be expected. Additional information on factors affecting O&M costs are discussed in the GROW GSI Operations and Maintenance Guidance document.

Applicants should consider the following strategies to reduce GSI costs:

- **Integrate with other infrastructure projects/planned improvements**
- **Think programmatically, rather than on an individual project basis**
- **Seek economies of scale**

Applicants should consider the following strategies to reduce GSI costs:

- Integrate with other infrastructure projects/planned improvements
  - Communities can potentially realize cost savings of 20% to 50% or more by strategically integrating GSI with other planned infrastructure improvements, such as road reconstruction, site redevelopment, rehabilitation of existing utilities and roof replacements. In these cases, the

net cost of the GSI is the incremental cost beyond the cost of the conventional planned improvements.

  – Bring in GSI designers to review planned infrastructure improvements and help identify low-cost enhancements that may provide GSI performance

- Think programmatically, rather than on an individual project basis
  – Consider organizing GSI into repeatable program types that have similar contracting and implementation mechanisms. Foster inter-departmental coordination and evaluate ways to streamline planning, design, permitting and procurement. For example, standard GSI details can be developed and on-call contracts utilized where appropriate.
  – Ensure that all agencies similarly understand GSI priorities and opportunities and are on-board with modifying design standards to include GSI components or functions.
- Seek economies of scale: economies of scale can often be achieved through practices that hold a greater volume or manage larger drainage areas, by bundling projects or through neighborhood-scale projects.
  – Increasing storage capacity can often be done relatively inexpensively because a significant portion of GSI costs typically involves mobilization, traffic control, surface restoration, inlet/outlet structures, etc. that may not significantly change if the system gets deeper to provide additional storage (Figure 1-3). Since some storage will go unused during smaller storms, increasing storage capacity can result in diminishing returns in terms of annual runoff capture, overflow reduction, etc. However, increased capacity can provide other benefits such as flood reduction, climate change resiliency, and may also prolong the working life of GSI and/or reduce maintenance frequency. Therefore, sizing criteria should be carefully considered based on an individual community's goals.

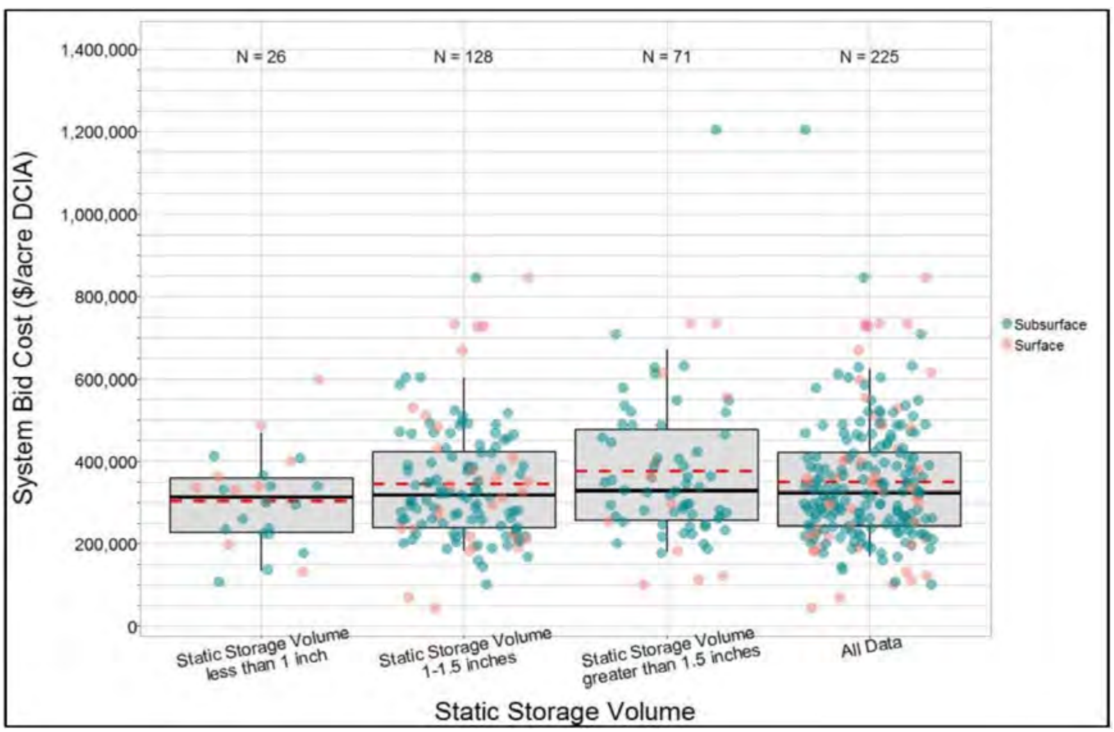


Figure 1-3. GSI Unit Bid Costs by Storage Volume

An analysis of 225 GSI projects in Philadelphia showed relatively small cost differences between projects with widely variable storage capacities (Note: DCIA is Directly Connected Impervious Area) (source: Philadelphia Combined Sewer Overflow Long Term Control Plan Update, Appendix A, September 2009).

– Developing larger projects that manage more impervious area can result in cost savings through reduced unit prices and increased competition. Although there is scatter in the data based on system type and site-specific conditions, Figure 1-4 shows typical costs in Philadelphia trending from over $600,000 per impervious acre for the smallest systems to about $200,000/acre for larger projects.

Figure 1-4. GSI Unit Bid Costs by Managed Impervious Area and System Type
(source: Philadelphia Combined Sewer Overflow Long Term Control Plan Update, Appendix A, September 2009).

– Grouping smaller GSI projects together into bundles for bidding and construction can also result in cost savings through reduced material costs, design costs and increased competition. For example, Philadelphia Water reported that bids for bundles of GSI projects managing about 1 impervious acre or less averaged approximately $400,000 per acre, those managing 2 acres or more averaged about $300,000 per acre, and the largest bundles approached costs of only $220,000/acre (Figure 1-5).

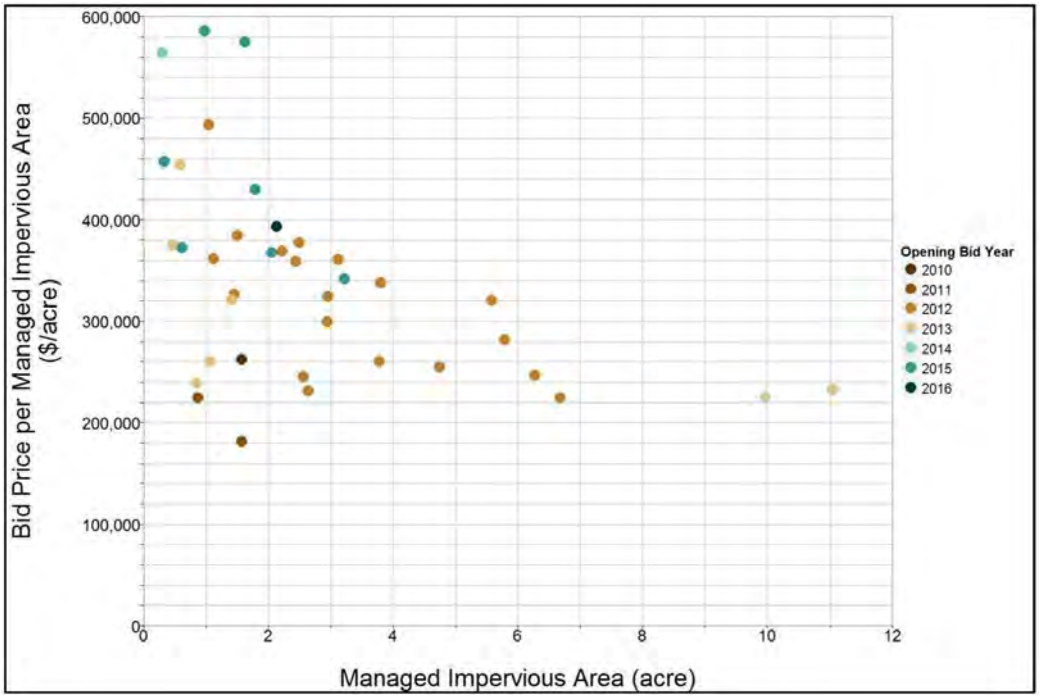


Figure 1-5. GSI Unit Bid Costs by Managed Impervious Area and Bid Year

Unit costs for larger GSI bid packages in Philadelphia tend to be significantly less (source: Philadelphia Combined Sewer Overflow Long Term Control Plan Update, Appendix A, September 2009).

- Economies of scale plays a role with maintenance as well. Maintenance costs can be reduced when the number of practices reaches critical mass. For instance, cost efficiencies can be achieved when there are enough practices in the ground to have a dedicated service crew, to fully utilize a specific piece of equipment, or to create competition to achieve better contract pricing. Municipalities can also consider partnering with other municipalities to achieve these economies of scale, for example, sharing a piece of specialized maintenance equipment (e.g., a vacuum sweeper for permeable pavement).

1.5 GSI Establishment Costs

The establishment period for GSI can generally be considered the period approximately one to three growing seasons after installation when roots and ground coverage have not yet fully developed. With any vegetated GSI system, practitioners should consider that the costs of maintenance during the vegetation establishment period are typically higher than routine maintenance costs after establishment (Figure 1-6). (See the “GSI Operations and Maintenance Guidance” chapter for cost information related to post-establishment maintenance.)

During the establishment period, additional maintenance may be required above typical maintenance activities. This additional maintenance may include a higher frequency of inspections, watering, weeding, soil stabilization, erosion repairs, mulching and replacing dead or diseased plants. Typical establishment costs range from $2 to $3 per square foot, depending on the complexity and density of the planting palette, the nature and size of the contributing drainage area and numerous other factors. To reduce the impacts of vehicles or pedestrian traffic, barricades can be placed during the establishment period. For some vegetated GSI systems, it may also be prudent to keep them offline during this period by covering inlets or blocking curb cuts with sand bags or other means. Note that these activities may apply if the GSI system itself is vegetated or if the GSI is affected by landscaped areas tributary to it, especially if those are not fully established or were disturbed during construction.

Figure 1-6. Bioretention Vegetation over Time

As the vegetation in this bioretention system matures, opportunities for weeds and erosion and the subsequent need for maintenance is reduced.

As a stand-alone item, maintenance during the establishment period is not eligible for GROW funding. However, establishment maintenance can be more cost effective if it is done by the contractor and included in the construction contract. It is often beneficial to system performance to include the initial maintenance period in the construction bid so that the maintenance is performed as needed by a contractor and plant warranties (including replanting when necessary) can be effectively imposed. Landscaping activities unrelated to GSI are not be eligible for funding.

1.6 References for other Cost Estimating Sources

1.6.1 References for Cost Estimating Methodologies

There are numerous construction cost estimating resources available to the design community. This section lists some of the more common and/or useful documents for estimating costs for a variety of project types, including GSI.

RSMeans from Gordian publishes several cost books for construction unit pricing for materials, labor and productivity, as well as city cost indexes. Depending on the nature of the project, the following RSMeans cost books may be useful for GSI project pricing:

- Heavy Construction Costs Book (most current version)
- Green Building Costs Book (most current version)
- Site Work & Landscape Costs Book (most current version)

The Association for the Advancement of Cost Engineering (AACE) provides a useful reference for defining estimate classes as they pertain to relative project definition maturity or design stage. The estimate classes range from Class 5 (concept/screening level) to Class 1 (detailed construction design for bid). These estimate classes provide helpful information corresponding to the project definition for deliverables, end usage and estimating methodology, as well as expected accuracy ranges. The designer should check the AACE website for the latest revisions of the following resources:

- AACE International Recommended Practice No. 18R-97, Cost Estimate Classification System – As Applied in Engineering, Procurement, and Construction for the Process Industries (Revised March 1, 2016)
- AACE International Recommended Practice No. 40R-08, Contingency Estimating – General Principles

1.6.2 References for Planning-level GSI Costs

This section lists several useful resources for determining or confirming planning-level cost estimates for common GSI technologies and project types. In addition to utilizing these resources, applicants are encouraged to research actual construction costs for GSI projects in their communities, as well as local market conditions. National GSI cost resources include:

- Cost-Effectiveness Study of Urban Stormwater BMPs in the James River Basin
- Methodology for Developing Cost Estimates for Opti-Tool
- EPA's LID webpage
- EPA's 2013 Article: Case Studies Analyzing the Economic Benefits of Low Impact Development and Green Infrastructure Programs
- EPA's Office of Research & Development (ORD) cost estimation tool for the National Stormwater Calculator
- New England Environmental Finance Center
- UNC Environmental Finance Center's Catalog of Finance Publications on Green Infrastructure Approaches to Stormwater Management (spreadsheet that provides a catalog of 46 publications with GSI cost relevance)
- Houle, et al. Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management
- University of New Hampshire Stormwater Center's Forging the Link: Linking the Economic Benefits of LID and Community Decisions
- Center for Neighborhood Technology's Green Values Stormwater Tool Box, which includes the Green Values Calculator
- Water Environment Research Foundation (WERF): User's Guide to the BMP and LID Whole Life Cost Models, Version 2.0
- Low Impact Development Center
- ECONorthwest's The Economics of Low-Impact Development: A Literature Review
- Drexel University's Low Impact Development Rapid Assessment (LIDRA Model)
- Summer 2016 World Water Article
- December 2015 Stormwater Report Article
- Onondaga County, NY Save the Rain website

More local and regional resources that may prove useful include the following:

- 3 Rivers Wet Weather RainWays website, which includes retrofit and new construction cost information for a variety of common GSI types (based on GSI footprint)
- Capital Region Water's City Beautiful H2O Program - specifically Appendix B, Basis of Cost Opinions
- Philadelphia Water Department's Green City, Clean Waters - Pilot Program Final Report, specifically Section 4.0 Construction Cost
- City of Columbus, Ohio's Green Infrastructure Design Guidelines
- Milwaukee Regional Green Infrastructure Plan, Milwaukee Metropolitan Sewerage District
- ALCOSAN, 2015. *Starting at the Source: How our region can work together for clean water.*
- PWSA, 2016. The Green First Plan: A City-Wide Green Infrastructure Assessment, Draft Report, 11/10/16.

GSI Cost Estimating Standards and Methodology

This section summarizes the GSI cost estimating standards, methodology and contingencies and risk factors for supporting GROW applications and streamlining ALCOSAN reviews of the applications. Section 2.1 discusses various cost estimating standards, including acceptable professional qualifications for cost estimators, present value cost estimates versus life cycle cost estimates, the importance of cost itemization, and defining levels of project completion. Section 2.2 discusses the specific cost estimating methodology for GROW applications, including required cost information and inputs for the GROW Cost Estimate Template (Appendix 3-A). Section 2.3 includes recommendations for accounting for contingencies and risk factors during both design and construction of GSI projects.

2.1 Cost Estimating Standards

2.1.1 Cost Estimator Qualifications

Cost estimates for GROW projects should be prepared by or under the direction of a Professional Engineer (i.e., responsible engineer) licensed in the Commonwealth of Pennsylvania. The responsible engineer should have at least 5 years of experience in cost estimating, specifically for GSI projects. Other acceptable qualifications include:

- AACE International accreditation of Certified Cost Engineer (CCE)
- AACE International accreditation of Certified Estimating Professional (CEP)
- American Society of Professional Estimators (ASPE) Certified Professional Estimator (CPE)

2.1.2 Present Value vs. Life Cycle Cost Estimate

There are two basic cost estimating approaches for typical GSI projects:

- Present value cost estimates, which typically only consider initial capital costs and typically include both design and construction costs.
- Life cycle cost estimates, which consider all aspects of a project including planning, design, permitting, construction, O&M over the lifetime of the GSI practice, and replacement/rehabilitation costs (if applicable).

GROW project awards are evaluated based on present value cost analysis metrics and applicants are required to provide these metrics in the application. However, applicants are encouraged to consider life cycle costs as a useful tool for selecting between different project alternatives, such as GSI types, combinations, configurations, locations, and/or sizes at a particular site.

2.1.3 Level of Project Completion

To be eligible for GROW funding, GSI projects must have advanced to at least the 60% design level. For such projects, applicants can submit applications for various levels of project completion, such as 60/70/90/100% design development, on-going construction or completed construction (if reimbursement projects are eligible). However, applicants are expected to provide the appropriate level of costing detail and contingencies for the specific phase of the project being submitted.

Appropriate example unit costs for various project completion levels are as follows:

- 60-90% design: Material unit costs for all design items, such as cost per linear foot of silt fence, cost per overflow outlet structure; or cost per linear foot of pipe.

  Note that anticipated construction costs should be fairly refined at this stage of the design and should generally be close to the final design pricing.

- 90-100% design and on-going or completed construction: Often the same line items as pre-90% design levels, but also includes any additional and/or refined pricing from manufacturers or contractors.
  - Contractor bid pricing may be available at or around this stage.

See Section 2.3 for additional information on appropriate contingencies and risk factors.

2.2 Cost Estimating Methodology

This section discusses the methodology and information required to prepare a GSI project cost estimate as part of a GROW application. At a minimum, the cost estimate should include eligible design costs, eligible construction costs, and ineligible costs in an itemized format. Sections 2.2.1 and 2.2.2 summarize the required project information for cost estimates.

Both the methodology and information described below are necessary for ALCOSAN to efficiently evaluate which items are eligible for GROW funding and to determine that the submitted costs are reasonable. Delays caused by the need for ALCOSAN to request clarifying information or making assumptions can be avoided by following these guidelines.

2.2.1 Required Cost Information

Applicants are generally required to submit a cost estimate in the GROW Cost Estimate Template (Appendix 3-A). However, cost estimates developed in a similar format are acceptable, provided they clearly itemize costs and provide estimated quantities and unit costs for each line item. Detailed invoices of reimbursement work can serve as supplemental information but do not replace the need for a cost summary in the format of the GROW Cost Estimate Template. At a minimum, each cost estimate must contain the following information:

1. Include the GROW ID, municipality/ authority, project name, name of individual preparing the cost estimate, and project type.
2. Specify the level of project completion. For projects currently in design, specify the level of design completion. (Note: the minimum level of design completion is 60% for GROW eligibility.) For projects currently in construction, estimate the level of construction completion or specify if the construction is complete.
3. Specify the following project design information: impervious drainage area, GSI capture depth, and estimated overflow reduction efficiency (ORE).
4. Eligible design costs, eligible construction costs and ineligible costs must be clearly identified.
5. Estimates must be itemized with the quantity, units, unit costs and total cost clearly identified for each item. The total cost for each item must be the product of the quantity and unit cost.
6. The items required to be included should be clearly identified within the cost estimate. These required items are listed in Sections 1.3.1, 1.3.2, and 1.3.3 and in the GROW Cost Estimate Template, as discussed further below.
7. Specify the source of the unit costs provided.
8. Any contingencies should be included separately for design and construction.

9. It is highly recommended that when a cost element has a lump sum cost of $25,000 or more, that applicants further itemize the element or provide back-up documentation. Acceptable documentation may be comparisons to other example costs of similar items in past projects.

2.2.2 ALCOSAN GROW Program Cost Estimating Template (GROW Cost Estimate Template)

Applicants are encouraged to use the GROW Cost Estimate Template (Appendix 3-A). The template is an Excel spreadsheet loaded with instructions, calculations and an itemized structure with input prompts to help guide the user towards completeness and compatibility with the GROW requirements. (Note that the spreadsheet is provided with the invitation to apply to GROW.)

The template contains three worksheet tabs. The first tab (“Instructions”) is the list of instructions for filling out the template. The second tab (“Runoff & OF Reduction”) is a worksheet for estimating both the annual stormwater runoff capture and the annual overflow reduction. The third tab (“Cost Estimate Form”) is the actual cost estimate worksheet. The required project information for these worksheets is summarized in Table 2-1.

Table 2-1. GROW Cost Estimate Template - Required Project Information

Cost Estimate Information	Description
GROW ID*	This GROW ID is the same as on the first page of the application. ALCOSAN assigns a unique GROW ID # to each project during the LOI stage.
Municipality/ Authority*	Provide the name of the governmental entity that is seeking the funding and will be responsible for implementing the project.
Project Name*	Provide the project name in Section 2.1 of the GROW application.
Individual Preparing Cost Estimate**	The person responsible must have a Pennsylvania Professional Engineering License, or other acceptable qualifications (see Section 2.1.1)
Project Type**	Specify the type of source reduction project, whether GSI, inflow/infiltration control, sewer separation, system optimization or direct stream inflow removal
Level of Completion**	Specify the level of completion of the project. Typical milestones include 60%, 90%, or 100% design, and construction ongoing or complete. Projects submitted prior to 60% design completion will not be considered eligible for GROW funding.
Impervious Drainage Area***	Provide the size of the impervious area, in acres, that will be captured by the project.
GSI Capture Depth***	Provide the depth of runoff, in inches, from the contributory impervious area that will be captured by the project. Typical minimum depth of capture is 1 inch.
Estimated Overflow Reduction Efficiency (ORE)***	Due to the characteristics of the RCS, different areas within the ALCOSAN service area produce different amounts of overflow reduction for a given level of source control. The ORE (reduction in overflow volume per unit reduction in inflow) provides a hydraulically informed estimate of overflow impacts of different projects. ALCOSAN will provide the ORE to applicants based on each project’s location.

* This information is required to be input in all three tabs.

** This information is required to be input in the OF Reduction and Cost Estimate Form tabs.

*** This information is required to be input only in the OF Reduction tab.

The purpose of the Runoff & OF Reduction tab is to calculate the estimated annual volumes of both runoff capture and overflow reduction based on the inputs of contributory impervious drainage area, GSI capture depth and ORE. The resultant volumes, as well as the impervious drainage area, are then automatically referenced in the Cost Estimate Form tab to yield project cost efficiencies, which will be used by ALCOSAN to evaluate potential funding amounts for each project. Though cost efficiency is not the only category by which projects are evaluated, it is an important metric and, in general, projects that are more cost-effective are more likely to receive greater amounts of funding.

The Cost Estimate Form is separated into four sections: Project Information (discussed above), Design Costs, Construction Costs and Project Costs Ineligible for GROW Funding (i.e. ineligible costs). These sections are explained further in Sections 1.3.1, 1.3.2, and 1.3.3, respectively. The items that are required to be reported in each section have been pre-populated (and indicated with an asterisk). Extra items can be added in the green highlighted rows within each section by copying and pasting rows or inserting new rows and copying the formulas in the correct columns. For each added item, the applicant is to provide the quantity, unit and unit cost. (Each required item has been pre-populated with a quantity of “1” and units of “lump sum”. If a required item does not have a cost associated with it, then the user should input zero (“0”) in the quantity column.)

The applicant is also required to provide the source of each cost identified in the Cost Estimate Form. For design costs, sources will typically be based on contracted, budgeted or invoiced amounts. For construction costs, typical sources include bid/as-built costs, industry-accepted references (e.g., RSMeans), manufacturer or vendor costs, costs from other completed projects of a similar nature, or costs based on designer estimates/calculations. With respect to ineligible costs, the source will be dependent on the type of cost, whether related to labor (i.e., design), construction or one of the other categories listed in Section 2.2.5 (e.g., permits).

Once the above information has been input into the Cost Estimate Form**,** the worksheet automatically calculates the total cost for each line by multiplying the quantity by the unit cost in that line. The worksheet also automatically adds all the line item totals to calculate the subtotal of the section. Design and construction contingency is then calculated for their respective sections based on an input percentage of their respective subtotals. These contingencies are then added to the subtotals to calculate the section totals. Further discussion about contingencies is provided in Section 2.3.

The total design cost is added to the total construction cost to yield the total eligible project cost. As stated above, the worksheet then divides this total cost by the values in the Runoff & OF Reduction tab to yield total eligible cost / impervious drainage area ($/ac), runoff cost efficiency ($/gal/year), and OF cost efficiency ($/gal/year).

2.3 Contingencies and Risk Factors

Adding contingencies to cost estimates is a way to account for uncertainties in a project based on the information available when the cost estimate is developed. It is not intended to account for any known future events that can affect the project. Any known future conditions should already be accounted for in the design, construction or ineligible cost sections.

Applicants are to provide separate contingencies for design and construction. Design contingencies can cover design changes due to unanticipated factors, such as changing client preferences, community input and other planned improvements. The magnitude of design contingency is partially determined by the level of technical complexity of the project and to the stage of design for which the cost estimate was developed. Design contingencies normally decrease as the design becomes more refined.

Construction contingencies are a reserve for construction cost increases due to overcoming adverse conditions or unexpected events such as extreme weather events, subsurface conditions, and vandalism, that were unforeseen at the time of the contract bidding and award. Construction contingencies can also account for unanticipated conflicts that can arise (e.g., unmapped or abandoned utilities), especially in historic urban environments. Table 2-2 summarizes the recommended contingencies for various stages of design and construction completion.

Table 2-2. Recommended Design and Construction Contingency Percentages

Project Phase	Design Contingency (% of Design Subtotal)	Construction Contingency (% of Construction Subtotal)
Detailed Design (60-90%)	5-10%	20-30%
Detailed Design (90-100%)	0-5%	10-20%
Construction (0-30%)	0-2%	0-10%
Construction (30-100%)	0%	0%

The contingencies summarized above should be considered recommended typical percentages. If an applicant wishes to use higher contingencies, then they should provide supporting analysis or reasoning with their GROW application. For example, a risk analysis can be useful if considerable uncertainties are identified. Cost risk analysis can establish the areas of high cost uncertainty and the probability that the estimated project cost will or will not exceed the estimated cost. Computer programs are commercially available for an in-depth risk assessment approach instead of a simple percentage designation. If a cost risk assessment was used, applicants should provide a summary of the analysis with the cost estimate.

Appendix 3-A
ALCOSAN GROW Program Project Application Cost Estimate Template

Appendix 3-A
ALCOSAN GROW Program Project Application Cost Estimate Template

ALCOSAN GROW Program Cost Estimate Template Instructions

GROW ID:	2018-01-###
Municipality/Authority:	Example Municipality
Project Name:	Example GSI Project

Instructions for "Cost Estimate Form" worksheet

1. Applicants are requested to fill in green-shaded items throughout the Template, starting with the GROW ID, Municipality/Authority, and Project Name items in this worksheet.
2. Applicants shall complete the **Runoff & OF Reduction** worksheet first.
3. Applicants shall fill in Individual Preparing Cost Estimate, Project Type, Level of Completion, Impervious Drainage Area, GSI Capture Depth, and Estimated Overflow Reduction Efficiency (ORE). The ORE will be provided by ALCOSAN.
4. Applicants shall complete the **Cost Estimate Form** worksheet.
5. Applicant to add as many rows as necessary for itemizing design, construction & ineligible cost elements specific to their project.
6. Applicants are expected to enter the Item Description, Quantity, Units, Unit Cost, and Source for each line that they have an itemized cost for related to the proposed project.
7. Items denoted with an asterisk (*) are required to be reported. If no cost associated with project, enter zero (0) as quantity.
8. Applicants are expected to provide adequate detail for the elements of the project consistent with the level of design associated with the project, as identified in the application Section 4.2.
9. Applicants are to provide values for design and construction contingencies as deemed appropriate based on the level of design. ALCOSAN will not assume a default value for design or construction contingencies. Projects that have ongoing construction or have been completed are expected to report zero (0%) for all contingencies.
10. Applicants are able to provide sub-categories within Design, Construction, and Ineligible Costs as desired, but Applicants are responsible for accurately accounting for the Total Design, Construction and Ineligible Costs
11. Applicants are requested to ensure all referencing is accurate at time of submission. ALCOSAN reviewers will base cost on the *quantity*unit price* reported.
12. Cost estimates are to be prepared by a Professional Engineer licensed in the Commonwealth of Pennsylvania, or a similarly qualified representative.
13. ALCOSAN will review estimates for consistency with the GROW Program Guidelines in determining the eligibility of project elements and the total project cost eligible for GROW grant award.

ALCOSAN GROW Program - 2018 Funding Cycle
Runoff and Overflow (OF) Reduction Estimator

Project Information

GROW ID:	2018-01-###	*Municipality/Authority:*	Example Municipality
Project Name:	Example GSI Project		
Individual Preparing Cost Estimate:	Project Engineer		
Project Type:	GSI	*Level of Completion:*	60% Design
Impervious Drainage Area (ac):	1	*GSI Capture Depth (runoff from impervious area; in):*	1.25
Estimated Overflow Reduction Efficiency (ORE):	91%		

Global Inputs

Typical Year Rainfall (in):	37.24
Annual Impervious Runoff Coefficient:	85%
Runoff Capture (%):	96%

Volume Estimator

Runoff Volume (gal/yr)	860,000
Runoff Capture (gal/yr)	822,000
Estimated Overflow Reduction (gal/yr)	750,000

ALCOSAN GROW Program - 2018 Funding Cycle
Project Application Cost Estimate

Project Information

GROW ID:	2018-01-###	*Municipality/Authority:*	Example Municipality
Project Name:	Example GSI Project		
Individual Preparing Cost Estimate:	Project Engineer		
Project Type:	GSI	*Level of Completion:*	60% Design

(*) Indicates items that are required to be reported. If no cost associated with project, enter zero (0) as quantity.

Design Costs

Item	Quantity	Units	Unit Cost	Cost	Source
[Applicant Identified Design Item #1]				$ -	
Fieldwork*	1	Lump Sum		$ -	
Engineering*	1	Lump Sum		$ -	
Landscape Architecture*	1	Lump Sum		$ -	
			Design Subtotal	$ -	
			Design Contingency* 0%	$ -	
			TOTAL DESIGN COST (Enter in 3.4a of GROW Application)	$ -	

Construction Costs

Item	Quantity	Units	Unit Cost	Cost	Source
[Applicant Identified Construction Item #1]				$ -	
[Applicant Identified Construction Item #2]				$ -	
Mobilization*	1	Lump Sum		$ -	
Public Notification/Traffic Control/Cleanup*	1	Lump Sum		$ -	
Erosion & Sedimentation Controls*	1	Lump Sum		$ -	
Temporary Bypassing*	1	Lump Sum		$ -	
Site Restoration*	1	Lump Sum		$ -	
Construction Inspection Services*	1	Lump Sum		$ -	
			Construction Subtotal	$ -	
			Construction Contingency* 0%	$ -	
			TOTAL CONSTRUCTION COST (Enter in 3.4b of GROW Application)	$ -	
			TOTAL ELIGIBLE COST	$ -	
			TOTAL ELIGIBLE COST / IMPERVIOUS DRAINAGE AREA ($/ac)	$ -	
			RUNOFF COST EFFICIENCY ($/gal/yr)	$ -	
			OF COST EFFICIENCY ($/gal/yr)	$ -	

Project Costs Ineligible for GROW Funding

Item	Quantity	Units	Unit Cost	Cost	Source
[Applicant Identified Ineligible Item #1]				$ -	
[Applicant Identified Ineligible Item #2]				$ -	
Design*	1	Lump Sum		$ -	
Legal & Administrative*	1	Lump Sum		$ -	
Bonds & Insurance*	1	Lump Sum		$ -	
Flow Monitoring*	1	Lump Sum		$ -	
Permits*	1	Lump Sum		$ -	
Non-Source Reduction Construction Elements (Lighting, Fencing, Furniture, Site Photos, etc.)*	1	Lump Sum		$ -	
Work on Private Property*	1	Lump Sum		$ -	
Start-up / Maintenance Costs (if separate from construction contract or beyond establishment period)*	1	Lump Sum		$ -	
			TOTAL INELIGIBLE COST (Enter in 3.4c of GROW Application)	$ -	

CHAPTER 4

GSI Construction Inspection Guidance Document

SECTION 1

Introduction to GSI Construction Inspection

Successful implementation of green stormwater infrastructure (GSI) projects requires a multi-disciplinary and knowledgeable team at the outset of the project and throughout design and construction. GSI projects are particularly susceptible to issues related to construction techniques as these facilities rely on natural systems, both soils and vegetation, to manage stormwater through the processes of infiltration and evapotranspiration. Therefore, it is critical that construction incorporate techniques that maintain soil permeability, support healthy vegetation and protect infiltration surfaces from sedimentation and compaction.

This document is intended to serve as a practical, concise and user-friendly guide to facilitate construction inspections of green stormwater infrastructure projects within the ALCOSAN service area. This chapter covers bioretention systems, infiltration trenches and permeable pavements, and variations thereof. This chapter is intended to inform individuals involved in all phases of GSI construction, including municipal staff, designers, developers, contractors and maintenance personnel.

The chapter is focused on construction inspections related to GSI performance. It is not a comprehensive guide to construction inspections related to safety, traffic control, permit conformance, public relations or other non-GSI related construction activities.

Section 1 introduces the chapter as well as provides information on the typical construction considerations for each type of GSI technologies. Section 2 provides detailed information related to the critical construction practices for GSI installations, as well as step-by-step guidance in conducting GSI construction inspections. The construction inspection checklists provided in Appendix 4-A are intended to be used by construction inspectors in conjunction with the detailed construction inspection guidelines provided in Section 2.2.

1.1 Construction Inspection Overview

The construction process and the roles related to the construction, inspection and monitoring of GSI facilities should be clearly defined at the outset of project implementation. The respective roles of the contractor, design professional and municipal representatives will vary throughout the construction process, so it is critical to understand those roles prior to and during construction. For most GSI implementation projects, the construction process and primary roles and responsibilities typically follow the general steps summarized below:

Table 1-1. Construction Inspection Process Roles and Responsibilities

Construction Process Step	Primary Responsibility	Mandatory Participation	Optional Participation	Purpose/Notes
Pre-Construction Meeting	Municipal representative and/or design professional	Contractor	ALCOSAN; other partnering organizations	Review roles and responsibilities; project scope and schedule; communication protocol, etc. Ensure any pre-construction monitoring equipment is removed
Milestone-Based Construction Inspections	Municipal representative and/or design professional	Contractor	ALCOSAN; other partnering organizations	Regularly inspect construction progress and critical milestones to observe if construction techniques meet requirements of plans and specifications

Table 1-1. Construction Inspection Process Roles and Responsibilities

Construction Process Step	Primary Responsibility	Mandatory Participation	Optional Participation	Purpose/Notes
Final Inspection	Municipal representative and/or design professional	Contractor	ALCOSAN; other partnering organizations	Final inspection at end of construction to check that GSI facilities have been constructed according to design intent and best practices (include performance testing as required by specifications)
Post-Construction Submissions/ Certifications	Municipal representative and/or design professional	Contractor	ALCOSAN; other partnering organizations	Submit as-builts including planting plans and material testing certification; Check monitoring equipment is installed according to plans

While municipal representatives, design professionals and other partnering organizations provide oversight and design guidance during construction, it is ultimately the responsibility of the general contractor and subcontractors to construct the GSI facilities according to the contract documents.

Contractors are responsible for being fully acquainted with all contract documents including but not limited to the following:

- Construction plans and details
- Construction specifications as well as any testing and documentation required by specifications
- Manufactured product data, including manufacturer's installation guidelines
- Site construction, traffic control, safety and environmental permit requirements

1.2 GSI Facility Types: Typical Construction Considerations

While there are numerous GSI facility types and variations, this chapter will focus on bioretention, infiltration trenches and permeable pavement systems. There are many construction considerations that are common among all GSI facilities, but some variations exist based on desired system function and performance goals. Successful GSI construction primarily depends on ensuring that procedures and methods associated with construction activities preserve and protect the natural systems required for effective facility performance, while preventing impacts to GSI system components and materials. Additionally, elevations of pipes, weirs, overflows and final grades generally require greater precision than standard construction practices. The following sections provide an overview of construction considerations specific to three common GSI system types.

1.2.1 Bioretention Facilities

Bioretention facilities depend on proper infiltration into soils, gravel being clean, properly sorted and protected from clogging, and healthy vegetation to be successful.

For any facility variation utilizing infiltration, it is crucial that the infiltration area is not compacted or contaminated with sediment or fines during the construction process. Care should be taken during construction to ensure that heavy machinery is not used within the infiltration footprint and that no construction equipment is running on the subgrade once the excavation is within a foot of the finished bottom elevation. Appropriate erosion and sediment (E&S) controls must also be used to protect the area.

For designs with gravel drainage beds, clean, washed, uniformly graded aggregate is typically used as specified, and some alternate aggregate types, such as slag, are not acceptable for installation. Contamination of the clean aggregate can occur during on-site storage and installation or following installation, which may cause system clogging issues post construction. Clean aggregate must be stored properly to ensure that it is protected from fines and sediments, and once placed, the aggregate should be adequately protected from sediment using approved E&S controls.

Engineered soils, also called bioretention soils, are critical to bioretention system function and vegetation success. On-site soils and improperly imported fill are generally not suitable for use in bioretention systems as they typically contain a substantial seed bank which can often lead to a weed flush and competition with the preferred plants. Engineered soils should have relatively high infiltration rates, and inspectors should ensure that the material installed meets the bioretention soil specification and that the soils are stored and installed correctly. Once soils are placed, they should be protected from erosion until planted and fully stabilized. During plant establishment, bioretention systems should be closed to surface runoff, and erosion control blankets should be used to prevent erosion and sedimentation of surface soils.

During planting, it is critical that healthy plants that are appropriate for the specific site layout and conditions are properly installed within the seasonal time frame specified (usually spring and fall). Care should be taken during construction to follow all planting guidelines and a plan should be in place for watering, weeding and plant replacement during the warranty and establishment periods (usually one to two years).

1.2.2 Infiltration Trenches

Infiltration trenches utilize site soils to infiltrate stormwater runoff, therefore it is crucial that the trench bottom and sides are not compacted or fouled with sediment or fines during construction. Care should be taken during construction to ensure that heavy machinery is not used within the infiltration footprint and that appropriate erosion and sediment controls are in place to protect infiltration zones from sedimentation.

During excavation, the infiltration trench subgrade must be unfrozen, firm and stable with no standing water, mud or other deleterious materials. If needed, temporary dewatering and drainage systems must be appropriately placed prior to beginning excavation work. Trench bottoms are typically designed to be level to allow for distributed and even infiltration of runoff, but trenches may be installed on slopes with stepped level beds.

A separation layer of geotextile or a clean sand filter layer should be installed between the uncompacted subgrade and the aggregate storage layer to prevent migration of fine particles into the storage layer. Typically, geotextile is placed on the sides of the trench while the bottom separation is provided by geotextile or a sand filter layer. The top of the storage trench may be covered with geotextile when surface infiltration is not included in the design (e.g., trenches under conventional pavement). Geotextiles and sand filter layers should remain free from sediment for the duration of construction.

Storage aggregates are to be clean, washed, uniformly graded crushed stone that meet all requirements of the design specification. Proper handling and storage of the aggregate is critical to prevent sediment contamination prior to and during placement in the trench. Aggregates should be placed from the outside of the infiltration zone in lifts (or as specified) and should be compacted according to the application and specifications. Once the storage aggregate has been placed in the trench, it should be adequately protected from sediment using approved E&S controls until surrounding areas are completely stabilized.

Infiltration trenches may also utilize manufactured storage media units in areas where space is limited, and higher void ratios are required. It is critical in these cases to follow the manufacturer’s installation recommendations and guidelines and to utilize any technical support provided by the manufacturer or the manufacturer's representative during construction to ensure the system is installed correctly.

Surface treatments over infiltration trenches vary by site and application. When a trench is overlain by conventional pavements, it is critical to ensure that the storage layer is covered with nonwoven geotextile prior to backfill and paving operations. When trenches are designed to allow surface infiltration, a graded aggregate filter layer may be required between the storage reservoir and surface aggregates (pea gravel or riverstone) or planting soils.

1.2.3 Permeable Pavement

Success of a permeable pavement installation primarily depends on using a properly specified permeable mix, clean and properly graded storage and bedding aggregates, and protection of permeable pavements and the infiltration zones from sedimentation and compaction.

Both porous asphalt and pervious concrete mix designs require appropriate testing to ensure that the pavement mix meets the requirements of the specification for strength and permeability. Common asphalt tests include a Drain Down Test (ASTM D 6390), Moisture Susceptibility Test (AASHTO T 283), and Air Voids Test (AASHTO T 269/ASTM D 3203). Typically, concrete is tested following installation of a test panel, and cores are extracted and tested for thickness (ASTM C 42), void structure (ASTM C 138), and for core unit density (ASTM C 140). Poured in place paving mixtures typically should not be placed if conditions are wet or if the ambient temperature, measured in the shade, is below 55 degrees Fahrenheit.

Because permeable pavement typically utilizes infiltration, it is crucial that the infiltration area subgrade is not compacted or contaminated with sediment or fines during the construction process. Care should be taken during construction to ensure that heavy machinery is not used within the infiltration footprint and that no construction equipment is permitted on the subgrade once the excavation is within a foot of the finished bottom elevation. Appropriate E&S controls must also be used to protect the infiltration zone at all times during construction. It is the contractor's responsibility to ensure that deposition of sediment on the permeable pavement surface does not occur by wind-borne deposition, tracking or stormwater runoff. It is recommended that E&S control devices (e.g., geotextile, compost sock and silt fence) be placed around permeable pavements until full site stabilization has been reached.

For designs with gravel drainage beds, clean, washed aggregate must be used as specified. Contamination of the clean aggregate can occur during on site storage and installation or following installation, which may cause system clogging issues post construction. Clean aggregate must be stored properly to ensure that it is protected from fines and sediments, and once placed, the aggregate should be adequately protected from sediment using approved E&S controls. Permeability testing of the permeable pavement should occur post construction to ensure proper materials and construction practices were used.

SECTION 2

GSI Construction Inspections

This section provides a summary of the key steps of the construction inspection process as well as specific critical considerations for typical GSI installations.

2.1 Construction Inspection Process

A GSI inspection process typically entails the following key steps: a pre-construction meeting, multiple construction inspections at critical times, review of materials prior to their installation for cleanliness and/or conformance with project specifications, a final inspection/site walkthrough, and post-construction inspections to verify that contractors are adequately maintaining GSI facilities during the warranty/establishment period per their contractual requirements. These various actions are further discussed below.

This section is meant to complement and be complemented by Water Environment Federation's National Green Infrastructure Certification Program (http://ngicp.org/), particularly the following fundamental components:

- *Recognize the appropriate application of equipment for the construction of a GSI facility*
- *Apply the key concepts of site layout and grade checking*
- *Recognize the purpose of common GSI construction materials*
- *Recognize the significance of and identify the procedure for proper storage and handling of materials*
- *Recognize the significance of and identify the procedure for erosion and sediment control during the construction of GSI facilities*

2.1.1 Pre-construction Meeting

A pre-construction meeting is often held at the site with the contractor, the inspector, the design professional and any other stakeholders or parties as appropriate. The following pre-construction and site preparation considerations are typically discussed at this meeting to ensure a more successful installation:

- Design intent of the GSI facility
- Roles and responsibilities and lines of communication
- Access routes, staging areas, stockpile areas and safety
- Sensitive site locations and protection of existing site features
- Schedule and construction sequencing
- Contingency plans for extreme weather events, material delays, vandalism, etc.
- Inspection frequency and critical construction times
- Special considerations/adjustments to traditional construction methods required for GSI
- Documentation of utility coordination
- Required permits
- Property agreements

- Contract documents (drawings and specifications)
- E&S plan that complies with local regulatory agency
- Health and Safety Plan

2.1.2 Construction Inspections

The following subsections highlight a variety of specific considerations that are critical for a fully functional and long-lasting GSI project. Inspectors are expected to pay close attention to these considerations and document any apparent deficiencies in the construction inspection checklists in Appendix 4-A. In addition, inspectors should familiarize themselves with the construction drawings and specifications prior to making their first inspection and should keep copies of these documents on hand at all subsequent inspections.

2.1.2.1 Safety Considerations When Working in the Right-of-Way

For GSI projects in the right-of-way, it is critical that appropriate temporary measures be installed early in the construction process to protect workers, motorists, pedestrians and GSI facilities from harm or damage. Typical construction safety plans should consider existing utilities, pedestrian and vehicle traffic controls, shoring and sheathing for excavations, confined spaces and pest control. Before site disturbance takes place, utilities should be identified and marked appropriately (Figure 2-1), and when overhead power lines or other electrical utilities are present safety measures conforming to OSHA standards should be implemented (e.g. OSHA electrical safety quick card). Traffic control measures include various types of fencing, safety drums and traffic cones (Figure 2-2). The measures utilized should be in conformance with local codes and regulations. Inspectors should observe whether appropriate right-of-way safety measures are installed and remain in place for as long as necessary to minimize safety risks. Note that this chapter is focused on construction inspections related to GSI performance and is not meant to be a comprehensive guide to construction inspections related to safety, traffic control, permit conformance, public relations or other non-GSI related construction activities.

White	PROPOSED EXCAVATION
Fluorescent Pink	TEMPORARY SURVEY MARKINGS
Red	ELECTRIC POWER LINES, CABLES, CONDUIT AND LIGHTING CABLES
Yellow	GAS, OIL, STEAM, PETROLEUM OR GASEOUS MATERIALS
Orange	COMMUNICATION, ALARM OR SIGNAL LINES, CABLES OR CONDUIT
Blue	POTABLE WATER
Purple	RECLAIMED WATER, IRRIGATION AND SLURRY LINES
Green	SEWERS AND DRAIN LINES

Figure 2-1. Utility Marking Colors
Existing utilities should be marked through the PA OneCall System or through contracted utility locators.

Figure 2-2. ROW Construction Site
Safety fencing and drums help to create a barrier for this infiltration trench

2.1.2.2 Sequencing and Staging

As many GSI projects entail retrofitting previously developed sites, sometimes in highly constrained, urbanized locations, sequencing and staging construction activities can often prove to be a significant challenge. Not only must such projects contend with limited space but also with public access (residential, commercial, etc.), noise restrictions, school schedules, material/equipment availability and delivery, seasonal considerations (see below), and a variety of other issues. With respect to construction sequencing and staging, inspectors should consider the following:

- GSI facilities, especially permeable pavements, should ideally be constructed last to avoid potential negative impacts (e.g., clogging or damage) associated with surrounding work
- If GSI facilities cannot be constructed last, then measures should be in place to protect the integrity of the GSI materials and/or subgrade until the surrounding site has been thoroughly stabilized
- GSI facilities should be kept offline by diverting runoff around them during construction and assuring that E&S controls are in place
- Excavated areas should not be left open for extended periods of time; the longer they are open, the greater the risk is of contamination, degradation and/or compaction
- Consider using an annual cover crop seeding that establishes quickly in vegetated GSI facilities as a temporary cover until the surrounding area is stabilized and the potential for erosion has been minimized and/or when the system must be left dormant over winter before planting in the spring
- Stockpiled materials should be sufficiently protected so they do not get contaminated or do not contaminate other materials or areas
- Access routes through construction sites should be established and marked out so they minimize potential negative impacts such as over-compaction and damage to installed GSI materials
- Concrete wash-out areas and other activities that could clog or otherwise degrade GSI facilities should be located where the potential impact is minimized

2.1.2.3 Public Engagement

GSI projects in public locations often attract the attention of residents and/or other interested parties. Inspectors should be aware of the procedure to direct residents with specific questions or in search of additional information to an appropriate spokesperson, website, etc. Project information handouts or flyers, possibly with online links to additional information, might also be used to help engage the public during construction.

2.1.2.4 Construction Equipment

The construction tools and equipment utilized must not cause damage to or negatively affect the function of a GSI facility. Inspectors should make the following observations with respect to construction equipment:

- Equipment is sufficient to excavate for a facility without compacting the infiltration zone
- Lightweight or wide-track vehicles that minimize soil compaction; smaller excavators, skid steers and hand tools to ensure a higher level of care and to minimize unnecessary disturbance
- Toothed buckets, ripper tools and hand rakes to scarify the subgrade
- Sheet material such as plywood that facilitates access while discouraging compaction of bioretention or amended soils
- For permeable asphalt, a track-equipped paver (i.e., not wheel-based) should be used for placement, while an 8- to 10-ton roller should be used for rolling

2.1.2.5 Erosion and Sediment Control Considerations/Avoiding Contamination

Inspectors should confirm that erosion and sediment control measures are being utilized (and maintained) such that they protect proposed and/or constructed GSI facilities, sensitive site features, and all downstream areas from contamination. At a minimum, E&S control measures and inspections should comply with Allegheny County Conservation District requirements, however additional measures may be necessary to protect infiltration zones and GSI facilities. Although compliance with environmental permits such as E&S are critical, note that this guidance document is focused on inspections related to GSI performance.

Specifically, inspectors are encouraged to consider the following:

- Observe erosion and sediment control measures at every site visit and immediately before and after rain events; such measures are important throughout the entire construction process
- Sensitive site areas should be clearly identified (fencing, signage, etc.), and construction activities should be kept sufficiently away from such areas (e.g. steep slopes)
- Site disturbance should be minimized to the area required for construction of the project; disturbed areas should be stabilized as soon as possible
- Unless absolutely necessary, GSI facilities should not be used as temporary sediment basins/traps during construction
- Silt fencing, compost socks, wattles, sand bags or other such measures are often employed to protect GSI locations from surrounding disturbed areas (Figure 2-3)
- GSI facilities should be kept offline until contributing areas are stabilized and until the GSI facilities themselves are sufficiently stabilized or established so they can receive runoff without the potential for excessive erosion; diversion channels and sand bags are two examples of how runoff can be temporarily diverted around GSI facilities (Figure 2-4)
- Erosion control or turf reinforcement matting is typically used to help stabilize surface GSI facilities such as bioretention
- GSI facilities that have been degraded by sediment-laden runoff may warrant extensive removal and replacement of materials, whether engineered soils, aggregate or other storage media; installed materials that have been compromised by sediment should be sufficiently restored to a depth where no clogging is observed
- All catch basins potentially affected by construction activities should be appropriately protected; permanent catch basin filter inserts should not generally be used to protect inlets during construction and, if they are, they should be replaced as necessary with new inserts at the end of construction

Figure 2-3. Silt Fence Around GSI
Silt fence can help protect bioretention areas until contributing areas are stabilized or until vegetation has been planted/established

Figure 2-4. Sand Bags at GSI Inflow Point
Sand bags can keep vegetated GSI facilities offline until they are sufficiently stabilized

2.1.2.6 Avoiding Compaction/Protection of Infiltration Areas

Preserving the integrity of the subgrade for GSI facilities is one of the most important factors when it comes to ensuring their long-term performance. Compacting the subgrade or over-compacting engineered soils reduces infiltration rates, and therefore, the anticipated effectiveness of GSI facilities. Compaction and over-compaction should be minimized or completely avoided. Inspectors are encouraged to consider the following:

- Appropriate measures such as fencing, barriers, signage or flagging are utilized to discourage vehicular or even foot traffic within GSI facility footprints before, during and after such facilities are installed
- Excavation for GSI facilities should be done so that construction vehicles are kept off the GSI subgrade; this can usually be accomplished by excavating from the sides of narrower GSI facilities or by starting at one end of wider GSI facilities and then working toward the other end
- Subgrade soils that have been compacted by construction activities should be scarified to a minimum depth of 3 to 6 inches by toothed buckets, ripper tools or hand rakes (scarification may be appropriate to loosen subgrade soils in some situations even if compaction has not occurred)

2.1.2.7 Excavation and Installation of Geotextiles, Liners, Storage Media and Other Facility Components

During this critical stage in a GSI facility installation, inspectors should closely observe/consider the following:

- Appropriate use of sheeting and shoring (e.g., for excavations exceeding 5 feet in depth)
- GSI facilities have been excavated to their designed depths and at the proper elevations, and excavation bottoms are level (unless otherwise specified on the construction drawings), stable and firm; subsurface berms/check dams (if applicable) have been constructed as designed
- Signs of shallower than anticipated bedrock, groundwater or other limiting layers; inspectors should immediately document this observation and discuss potential design modifications with the contractor and design professional
- Impermeable liner, non-woven geotextile, woven geotextile and/or sand should be placed immediately after approval of subgrade preparation
- Geotextile placed in accordance with manufacturer's recommendations and where indicated on the design drawings, with adjacent strips overlapping a minimum of 18 inches; the geotextile is secured at least 4 feet outside of the excavated area (Figure 2-5)
- Impermeable liner (if used) placed in accordance with manufacturer's recommendations and as indicated in the contract documents – this is important as impermeable liners are often used to protect adjacent structures or utilities from water intrusion; all seams and openings in the liner are sealed according to the manufacturer's recommendations and adjacent strips overlap adequately; liner should be protected from damage or puncture by removing loose or protruding rocks from all excavation faces
- Coarse aggregate installed in appropriate lifts, with each layer compacted with equipment, keeping equipment movement on GSI facility subgrades to a minimum; aggregate installed to grades indicated on the design drawings and geotextile folded over and overlapped on top to prevent soil intrusion into the GSI facility
- Pipes, catch basins, outlet control structures, cleanouts and all other components indicated on the drawings have been installed at their designed location, depth, configuration, etc. Note that a higher

degree of precision may be required when confirming final grades than is typical of standard construction practices.

- Alternative storage media (e.g., modular storage units) installed in accordance with manufacturer's recommendations and as indicated on the drawings
- Engineered soils installed by hand raking or other methods that enable soil placement from outside of the GSI facility footprint and thus reduce the risk of compaction or contamination. In large installations, special equipment such as soil slinger trunks may be employed to install soils outside of the GSI footprint (Figure 2-6).
- Soil materials placed in lifts of 12 to 18 inches, and spread out by means of an excavator bucket or other means to minimize compaction; placement of the soil media only occurs when it is at the correct moisture content (not wet or dry), and only when there is no precipitation occurring
- Installed soil materials left to settle for at least one storm event before the final lift so that adjustments can be made in the field to correspond to the plan elevations
- Surficial soil materials are feathered into the existing topsoil to provide a gradual interface between disparate soil types if engineered soils are directly adjacent to existing topsoil areas
- Soil materials that will underlie pavement or other structures (e.g., sand-based structural soils) are appropriately compacted for adequate structural support (not applicable to soils installed in structural cells)

Figure 2-5. Geotextile Installation
Example showing proper installation of geotextile on the left side of the GSI facility and improper installation on the right side

Figure 2-6. Soil Slinger Truck
Soil slinger trucks can help overcome logistical challenges at certain sites, while installing GSI facility soil in a manner that minimizes the risk of compaction and/or contamination

2.1.2.8 Avoiding/Protecting Existing Trees and Vegetation

Construction of GSI facilities should not unnecessarily cause harm to existing trees and vegetation. In fact, if properly designed and installed, GSI facilities can often enhance existing vegetation by making additional water available to them and in some cases even buffering them from damage by erosion. Inspectors should consider the following with respect to protecting existing trees and vegetation:

- Adequate fencing or other barriers around existing site vegetation have been installed and immediately repaired if damaged (Figure 2-7)

- Only trees and/or vegetation designated for removal or replacement on drawings are disturbed
- Construction activities, especially cut or fill, equipment movement and material or equipment storage do not take place within existing tree canopies or root zones; this should be discussed at the pre-construction meeting and documented in the contractor's sequencing and staging plan
- If excavation must occur within existing tree canopies, inspectors must confirm that the appropriate parties have been notified in advance (e.g., in the City of Pittsburgh, the Forestry Division of the Dept. of Public Works); such excavations should be closely observed, which may include careful hand excavation or soft dig techniques using either air or water

Figure 2-7. Construction Fencing
Example showing tree protection adjacent to a bioretention installation; this project also entailed careful hand excavation within tree canopies

2.1.2.9 Avoiding/Protecting Existing Utilities and Other Existing Site Features

Inspectors should confirm that the contractor has coordinated with utility companies that may be affected by the proposed GSI facility construction as early as possible (pre-bid or pre-construction meetings). The contractor is required to notify utilities through the Pennsylvania One Call System and may need to utilize a private utility locator if the location of specific utilities is uncertain in advance of excavating in their vicinity. When a previously unidentified utility is encountered, the inspector should confirm that the contractor halts work and notifies the specific utility company to discuss potential solutions (Figure 2-8).

In addition to site utilities, inspectors should look for potential impacts to other site features, such as buildings, fences, ramps, walls, benches and steps resulting from GSI installation. Inspectors should document such impacts and immediately notify the contractor. Adherence to sequencing and staging plans should help to minimize such impacts during construction.

Figure 2-8. Utility Protection
At this vegetated curb extension installation, a contractor ensures that a previously unknown existing gas line is sufficiently protected from potential damage by the GSI facility

2.1.2.10 Grading and Drainage Considerations

The effectiveness of GSI facilities is often directly related to site grading, as well as to the installed elevations of drainage pipes, catch basins and outlet control structures. Incorrect grading and incorrectly installed drainage elements can result in improper operation and a significantly reduced volume of runoff being managed by GSI facilities. Inspectors should consider the following with respect to grading and drainage:

- GSI facilities are installed at their designed elevations and depths; final elevations for surface GSI facilities must account for both surface treatments such as mulch and cobbles (in order to ensure that their installation does not block facility inlets or outlets) and anticipated settling of engineered soils
- Inflow points, especially for surface GSI facilities, are installed such that they allow positive drainage into GSI facilities and minimize any runoff bypass; these include curb cuts, trench drains, swales, end-walls, splash blocks, roof drains and conveyance pipes
- Catch basins, outlet control structures, check dams and/or weirs within GSI facilities have been installed at their designed elevations, allowing the facilities to function as intended
- Outlet and/or underdrain pipes have been installed at their designed locations, depth and configuration; low-flow orifices and weirs have been placed in outlet control structures at their designed elevations and locations

2.1.2.11 Unexpected Subsurface Conditions

If a significant void, sinkhole or other previously unknown subsurface condition such as detection of groundwater or a groundwater seep is encountered during a GSI facility installation, inspectors should immediately document this observation and discuss potential resolutions with the contractor and design professional. Inspectors should observe that all such agreed-upon resolutions/repairs are undertaken in an adequate and timely manner.

2.1.2.12 Monitoring and Observation Wells

When monitoring and/or observation wells have been specified, inspectors shall confirm that they have been installed at their designed locations and according to the design details. As these wells will facilitate future verification of GSI facility performance, it is vitally important that their installation is done correctly. Inspectors are encouraged to notify the owner if the contract documents do not propose monitoring and/or observation wells within GSI facilities.

2.1.2.13 Construction Materials

Inspectors should observe the quality, cleanliness and adequacy of GSI construction materials prior to their installation. Inspectors should request and review documentation of submittal approvals and substitutions, if applicable, including any results of laboratory testing. Any observed deficiencies with respect to GSI construction materials should be documented and the contractor should be immediately notified. Inspectors should also confirm that materials are properly stored on site, and in the case of plant material and engineered soils, that these are not stored on site for time periods that exceed the requirements of the specifications. Stockpiled materials should be sufficiently protected so they do not get contaminated or do not contaminate other materials or areas on the site.

While all materials used in a GSI facility contribute, by varying degrees, to its ultimate effectiveness, the following materials can be especially important and should be given greater consideration.

Aggregates

Aggregates are especially important materials as they are included in most GSI facility designs and often provide a significant percentage of the designed storage volume. The three most important things for inspectors to confirm with respect to GSI aggregate are the following:

- that it is open-graded and crushed (i.e., angular);

- that the size is consistent with the design drawings and specifications (most GSI aggregates range from ½ - 1 ½ inches); and
- that it has been thoroughly washed or is at least sufficiently clean (i.e., relatively free of fines and grit).

Insufficiently clean aggregate has lower storage capacity and can lead to clogging of the underlying geotextile or subgrade and thus poor long-term facility performance. Figure 2-9 shows an example of unacceptable (i.e., not clean enough) aggregate for a GSI installation, while Figure 2-10 shows acceptable aggregate.

Inspectors should confirm crushed and clean materials that meet the design specifications are utilized as subsurface aggregate. Also, the following materials are NOT to be used as substitutes for crushed and clean aggregate:

- slag
- glass
- recycled asphalt
- crushed concrete

Inspectors should immediately notify the contractor if any deficiencies with respect to GSI facility aggregates are observed. Excessively dirty aggregates that have been installed will likely have to be removed and the underlying geotextile may have to be thoroughly cleaned or replaced depending on the extent of contamination.

Figure 2-9. Aggregate with Fines
Example of unacceptable GSI facility aggregate

Figure 2-10. Clean Aggregate
Example of acceptable GSI facility aggregate

Engineered Soils/Amended Soil Media

The adequacy of engineered and/or amended soil media is of paramount importance to the long-term effectiveness of vegetated GSI facilities, as well as to the health and vitality of installed plant material. Inspectors should consider the following with respect to bioretention and/or amended soils:

- Documentation that all engineered and/or amended soils have been submitted by the contractor and reviewed and approved by the design professional; such documentation should include approval of the material source, mixing operations, all required laboratory tests and any variations or non-conformities with the specifications
- Soil materials delivered to site only after preparations for placement have been completed
- Stockpiled soils are adequately protected from weather, damage and theft

- If soil stockpiles greater than 6 feet high are to be stored for more than two weeks, the contractor shall break down and disperse soil so that mounds do not exceed the 6-foot height restriction or thoroughly mix the stockpile once a month
- Soil materials must not be handled or hauled, placed or compacted when they are wet, nor when frozen; soil handled only when the moisture content is less than 10% by volume
- Soil should be mixed in a ball mill or tub mill fitted with proper screening and paddles; windrowing the materials is not acceptable, as it does not produce uniform mixing of the components
- When mixing or amending soils with compost, the compost shall be moist, but not overly wet; compost shall not be so wet as to have water squeezed out by hand or so dry as to be easily blown by wind
- Soil materials should be installed immediately before planting is to commence; if planting is to be delayed (e.g., until the spring), steps should be taken to ensure that the GSI facility is adequately protected from degradation, erosion, etc. and properly restored before planting
- It is crucial that the contractor not be permitted to utilize substitutes for engineered soil such as “clean fill” or an alternate mix that does not meet the requirements of the specified engineered bioretention soil.

Geotextiles and Impermeable Membranes

Most GSI facility designs utilize geotextiles and/or impermeable membranes (liners) on their sides, bottoms, tops or completely surrounding them. These materials play a crucial role in GSI facilities, as they provide a barrier either between different GSI materials (e.g. between engineered soils and aggregate) or between GSI materials and adjacent materials. Geotextiles, whether woven or non-woven, are generally used to facilitate the passage of water from one material to another (e.g., from infiltration trench aggregate to surrounding subgrade soils). Impermeable membranes however, are used to *prevent* the passage of water (i.e., prevent unwanted exfiltration from GSI facilities) and thereby protect nearby structures or utilities from potential damage.

Inspectors should confirm that geotextiles and/or impermeable liners conform to the drawings and specifications prior to their placement and that they are installed according to the manufacturer’s recommendations. Generally speaking, woven fabrics are more plastic-like in feel and appearance, while non-woven geotextiles are more felt-like. Impermeable membrane material and thickness should be specified by the design professional and inspectors should ensure that membrane material and thickness meet the specifications (thinner materials should not be utilized unless approved by the design professional). Some GSI facilities, especially permeable pavements, contain geogrids for additional structural stability. Inspectors should also confirm that geogrids conform to construction documents prior to installation.

Vegetation

Inspections of plant material and trees prior to planting is typically conducted by the landscape architect or another suitably qualified professional. However, other observers should still play an important role in this process, whether it is simply confirming that the landscape architect has reviewed and approved all delivered plant materials and trees or inspecting for deficiencies that the landscape architect may have missed or not been present for. Specifically, inspectors should consider the following with respect to delivered plant materials:

- Documentation that all plant materials and trees, including any species or material substitutions, have been reviewed and approved by the landscape architect; such documentation should include approval of the plant material source, genus/species, size, landscape installer qualifications, results of all required soil analyses, and any variations or non-conformities with the specifications;

Plant Material upon Delivery:

- Plant material genus, species and cultivar conform to plant schedule, drawings and specifications
  - Substitutions must be approved by landscape architect
- Plant size and conditions conform to plant schedule, drawings, and specifications (e.g., tree caliper or height, single vs. multi-stem, container vs. ball and burlap vs. bare root, shrub height or container size, perennial and plug sizes)
- Plant material delivered to site appears to be in good health without deficiencies and meets the requirements of the contract specification. Common deficiencies the inspector should check for may include the following and may be reasons for not accepting the plant material delivery, however the contract specifications should be followed.
  - Trunks and/or branches:
    - Excessive scarring, severe creasing, cracks, bark peeling, holes, dead wood and broken branches
    - Open trunk wounds greater than 10% of trunk circumference and/or more than 2” tall
  - Foliage:
    - More than 20% of the specimen’s total foliage is damaged
    - More than 10% of the crown exhibits necrosis, chlorosis or damage from drought, pests, diseases, mechanical injury or tip dieback
  - Plant Roots:
    - Tree root ball is not secure enough to successfully transplant
    - Roots damaged by digging cuts or exposure to light, air or temperature extremes
    - Excessively rootbound (circling) root systems in container grown plants
- Plant material should be planted upon delivery. If plants must be stored on site (schedule changes or unforeseen weather event) they should be provided with adequate lighting and water and protected from damage. Plants should not be stored on site for more than a week.

Plant Material during Installation:

- Plant material is installed in correct locations, spacing and orientation in conformance with drawings and specifications
- Shade trees being planted immediately adjacent to pedestrian traffic (sidewalks and paths) should be appropriately limbed up
- The root flare of trees is visible after planting (i.e., trees have been planted at proper depth per the drawings and specifications)
- All shrubs and groundcover species have been planted at proper depths per the drawings and specifications
- All planting areas have been properly – but not overly – mulched as specified in the drawings and specifications. Avoid mulch in ponding areas or provide sufficient anchoring with the use of jute erosion control blanket. If mulch is not used, bioretention area should be densely planted or other forms of soil/surface stabilization should be utilized to prevent erosion.
- If plants are not immediately installed after delivery, inspector and/or landscape architect should confirm their suitability immediately prior to installation

Figure 2-11. Incorrectly Planted Tree
Root flare is not visible and mulch depth is excessive.

Figure 2-12. Correctly Planted Tree
Tree planted at correct depth. Root flare is visible and mulch is minimal and kept away from trunk.

Alternative Storage Media

While aggregates are the predominant storage media used in GSI facilities, there are numerous types of alternative storage media that are also employed. These products include oversized pipe, plastic arches/ chambers, plastic modular storage units, and concrete arches / chambers, among other variations. Inspectors should confirm that the alternative storage media being used at a project is consistent with the construction documents or has been documented to be an acceptable substitution approved by the design professional. Inspectors should also confirm that the media is being installed per the manufacturer's recommendations. Many manufacturers or vendors of alternative storage media prefer a representative to be present during some or all of the installation. Inspectors should verify that the contractor is sufficiently coordinating with the manufacturer or vendor, and that the installation of alternative storage media is consistent with the product's warranty requirements.

Permeable Pavements

There are several different types of permeable pavements utilized in GSI projects, with the most common being porous asphalt, pervious concrete, permeable paver units and open grid pavers. As each type of permeable pavement has its own unique requirements and considerations for successful installation, inspectors should familiarize themselves with each type prior to inspection. Failure to install permeable pavements according to best practices can lead to premature clogging and/or degradation of the material, which can in turn lead to significant costs to restore or replace.

When inspecting permeable pavement materials prior to and during installation, inspectors should keep in mind the following general and specific considerations:

General Considerations for all Permeable Pavements

- Permeable pavement mixes and/or products should always be reviewed and approved by the design professional; documentation must include all required tests (e.g., drain down and air voids for permeable asphalt), certifications, and approved variations or non-conformities with the specifications

- During construction, permeable pavement must be protected from traffic and sedimentation
- All permeable pavements should be tested for permeability at the end of construction (Figure 2-13); installations that fail to meet their specified minimum permeability should be appropriately cleaned and re-tested

Installation of Porous Asphalt

- Choker course or asphalt-treated permeable base (ATPB) course installed per plans
- Mix delivered to site in smooth, clean dump truck beds that were covered and treated with a non-petroleum release agent; haul distances should be less than 25 miles
- Mix placed within 90 minutes of being loaded to minimize cooling and asphalt drain down
- Mix installed with a track paver, typically in a single lift, on the aggregate base or ATPB to achieve the designed finished thickness
- Optimal laying temperature of between 275-290 degrees Fahrenheit or as specified confirmed by thermometer
- Compaction of the surface course occurs when the surface is cool enough to resist an 8 to 10-ton roller (typically between 200-260 degrees Fahrenheit); roller limited to one to three passes, as excessive rolling could cause aggregate breakdown and/or a reduction in the surface porosity
- Additional rolling with a small roller to smooth seams and remove marks; the small roller should move slowly and uniformly to prevent displacement of the mix and rollers should not be stopped or parked on the freshly placed mat
- After final rolling, no vehicular traffic typically permitted within the first 72 hours (7 days is recommended); barriers to be provided as necessary to prevent vehicular use
- If necessary, asphalt-treated permeable base course may be used to temporarily accommodate construction traffic, but it should be protected (e.g., covered with geotextile) during construction activities and then thoroughly vacuumed and flushed with water prior to the final lift of permeable asphalt

Installation of Pervious Concrete

- Both aggregate/cement and water/cement ratios are in conformance with specifications and approved mix design; deficiencies related to these ratios will produce unacceptable mixes with a high likelihood of failure
- Control (contraction) joints shall be installed at maximum 10-foot intervals, or as directed by the engineer. They shall be installed at a depth of 1/4 the thickness of the pavement. It is recommended that these joints be installed in the plastic concrete with a rolling joint tool (i.e., “pizza cutter”).
- Curing procedures begin within 15 minutes after placement; a fog or light mist sprayed above the surface prior to covering the concrete with an acceptable curing blanket
- The curing blanket overlaps all exposed edges and is fully secured throughout the curing period (without using dirt) to prevent dislocation due to winds or adjacent traffic conditions; the ideal curing period is at least 7 curing days
- No truck traffic allowed for 10 days (no passenger car/light trucks for 7 days)

Installation of Permeable Paver Units

- If applicable, curbs or other edge restraints installed per drawings and specifications to provide a rigid border for pavers and therefore prevent lateral paver migration
- Pavers are the type and color specified on the design drawings and/or specifications
- Pavers installed in patterns or configurations per drawings, with soldier course as applicable; inspectors should confirm early on that appropriate paver layout adjustments are made to minimize the need for cutting, especially at edges or for structures such as monitoring wells and cleanouts
- If applicable, graded aggregate paver joint filler placed after vibrating pavers into bedding course; aggregate spread and screened to be flush with tops of pavers
- Throughout construction, loose, chipped, broken, stained or otherwise damaged pavers (or pavers that do not match adjoining units) are removed and replaced; new pavers placed to match adjoining units and installed in same manner as original units, with same joint treatment and with no evidence of replacement.
- Additional pavers for future maintenance delivered to owner as specified

Figure 2-13. Permeable Pavement Testing

Permeable pavements should be tested for sufficient permeability at the end of construction

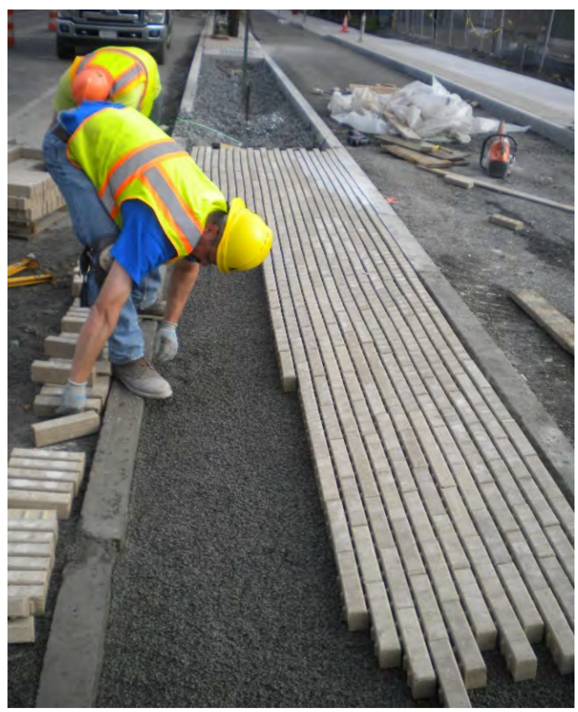


Figure 2-14. Pavers in Boardwalk Pattern

Permeable pavers being installed

2.1.2.14 Seasonal Considerations

GSI facilities can be adversely affected by seasonal factors such as extreme weather events, snow storage and extreme temperatures, among other things. Inspectors are encouraged to consider the following:

- Prior to extreme weather events such as large precipitation events, confirm that erosion and sediment controls are fully functional and that additional measures have been installed as necessary to protect GSI facilities to the extent possible
- Following extreme weather events, confirm that installed GSI facilities have not been damaged or otherwise compromised; where damage, clogging or other such degradation has occurred, ensure that the contractor takes suitable steps to restore the GSI facility and add E&S controls, whether removal and replacement of degraded material (preferred) or sufficiently cleaning degraded material

For GSI facilities installed in the late fall or winter, it is common to wait until it is warm enough to finalize soil installation, planting, mulching, etc. Inspectors should confirm the following with respect to winterization:

- GSI surface facilities that are to remain offline over the winter have measures in place to divert runoff around them (e.g., sand bags); GSI facilities should remain offline until contributing drainage areas are stabilized and the GSI facilities themselves are stabilized and plants established
- GSI surface facilities that are to remain online over the winter are protected by temporary means such as sod, compost blanket or approved matting; contributing drainage areas are stabilized and pre-treatment elements such as splash blocks are installed
- Fencing and/or other barriers are installed to discourage pedestrians from entering partially completed GSI facilities during the winter (Figure 2-15)
- Following snowmelt events, GSI facilities have not been clogged by sediment, trash or debris, and if such degradation has occurred, that it be addressed quickly by the contractor
- With respect to permeable pavements, porous asphalt should not be installed when the temperature is 55 degrees Fahrenheit or lower and the installation of permeable concrete should be discouraged in the fall, to allow more time for long-term curing and to lower the risk of degradation associated with freeze-thaw and deicers

2.1.2.15 Planting Considerations

As plants and trees within vegetated GSI facilities are integral to the system's function, inspectors must confirm that they are installed to conform to drawings, specifications and best practices. Specifically, inspectors are encouraged to attend a pre-planting meeting at the site and closely monitor the following:

- Unless otherwise approved, planting shall take place according to the schedule indicated in the contract specifications. Planting typically takes place either in the spring, as soon as the soils thaw, (April 15-June 15) or in the late summer/early fall (August 20-October 15)
- Plant materials shall be installed immediately upon their delivery to the site; if planting is delayed for more than six hours after delivery, plants and trees are appropriately stored, protected from weather and damage, and watered as needed
- Proposed locations of trees and shrubs have been staked and larger areas of multiple plantings/plug plantings have been outlined; staked locations and outlined areas are per the drawings (i.e., plants are spaced as specified and are installed at least 6 inches from edges such as curbs and sidewalks) and approved by Landscape Architect (Figures 2-16 and 2-17)

Figure 2-15. Planter in Winter
"Winterized" stormwater planter in which the planting was delayed until the spring with safety drums and caution tape to protect it

- Areas to receive plants have been prepared to conform to specifications (packed, tamped, scarified, excavated to depth of root ball, etc.)

- Wire baskets or burlap bags have been cut and removed (top half to two-thirds); tree-wrap or cardboard tubing has also been removed and no debris is left in tree pits
- Contractor has exposed and noted the tree root flare prior to planting to ensure that the base of the trunk flare is level with (or slightly above) finished grade and the tree is plumb in all directions; root flares are visible after planting and not covered by soil or mulch
- Trees are not heavily pruned at time of planting; only cross-over limbs, co-dominant leaders, and/or broken or dead branches are pruned to conform to drawings and specifications
- Trees staked only when approved and directed by landscape architect; stakes installed per specifications between 18-36 inches from trunk and removed as soon as the tree has grown sufficient roots to overcome the reason for staking (at the discretion of the landscape architect), or no later than the end of the first growing season after planting
- Mulch or other surface cover approved by landscape architect and installed (after settlement) at the depth specified over planting area; consider alternative surface covers or dense plantings in ponding areas; mulch around trees to provide clear zone of 3-6 inches from base of trunk or stem, no "mulch volcanoes."
- Approved treatments applied only as necessary to keep plant materials, planted areas and soils free of pests, pathogens or disease; best practices followed to minimize the overall use of pesticides and reduce hazards
- Plants and trees appropriately protected from damage during installation and maintenance periods

Figure 2-16. Bioretention Area

Bioretention system with plants evenly spaced and soils appropriately mulched

Figure 2-17. Plants near GSI Edge
Stormwater planter in which the plants have been installed too close to the edges

2.1.3 Final Inspection & Post Construction

Inspectors should conduct a final inspection/site walkthrough once the GSI installation has been deemed substantially complete. Inspectors will document any remaining deficiencies, notify the contractor, and then confirm that they have been addressed within a reasonable timeframe. Once all remaining deficiencies have been resolved, inspectors should document that the GSI facility appears to have been installed in accordance with the construction documents, or as otherwise approved during construction.

For vegetated GSI facilities such as bioretention, it is common practice for contractors to be contractually responsible for maintaining GSI vegetation for one to three years following installation. Such responsibility typically includes routine watering during the vegetation establishment period (Figures 2-18 and 2-19), weeding, pruning, trash removal, mulching, erosion and sediment control, and replacement of dead or unsatisfactorily growing plans. Inspectors should confirm that such maintenance is occurring per the contractor’s contract and in accordance with applicable GSI operation and maintenance guidance from the municipality, ALCOSAN, design professional, manufacturer, etc.

Figures 2-18 & 2-19. Watering During Vegetation Establishment Period
For this vegetated curb extension, the contractor set up irrigation hoses to the nearby water hydrant to water the plants during their establishment period

2.2 GSI Facility Specific Construction Considerations

2.2.1 Bioretention and Rain Gardens

2.2.1.1 Typical Construction Sequence Flow Chart

Bioretention systems can be installed in a variety of locations with a high degree of flexibility in design. Examples of bioretention system variations include:

- Bioretention beds or rain gardens in landscape areas
- Vegetated curb extensions in the right-of-way
- Planter boxes in the right-of-way or adjacent to buildings
- Bioretention swales and green gutters

Although bioretention systems vary in design, construction sequencing for the installation of the various systems has many common steps that have been consolidated in a bioretention construction installation guidance table in the following section (Table 2-1). The typical construction sequence and inspection milestones for bioretention facilities are summarized in the flow-chart below (Figure 2-20).

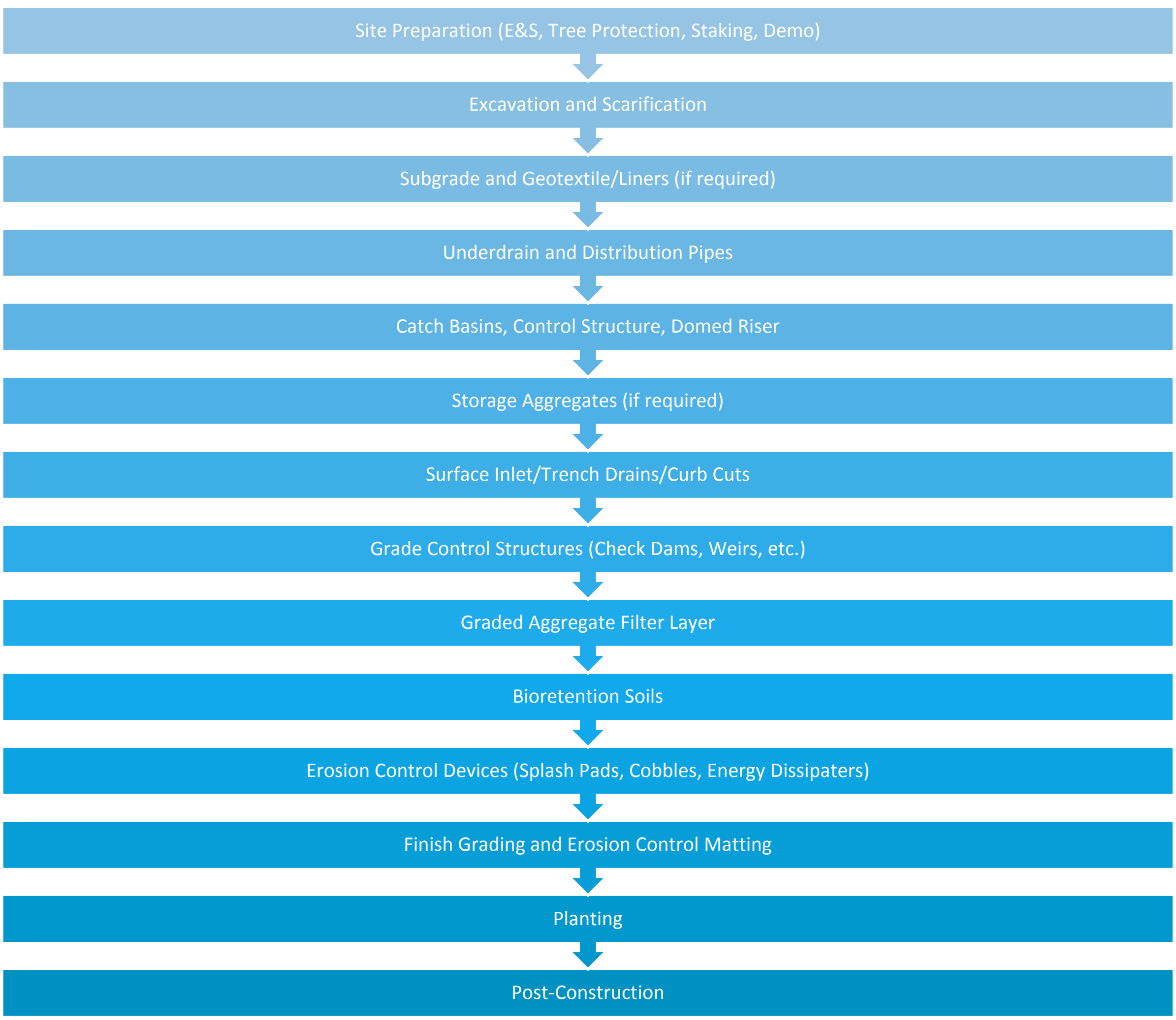


Figure 2-20. General Construction Sequence for Bioretention Systems

2.2.1.2 Construction Sequence Inspection Table

Table 2-1 provides guidelines for the inspection of bioretention system installations and is intended to be used with the Bioretention Construction Inspection Form and Checklist provided in Appendix 4-A.

Table 2-1. Bioretention System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
B1	**Erosion and Sedimentation (E&S) Controls**	• Protect infiltration zones and subgrades from sediment contamination and clogging • Protect catch basins from collecting and conveying sediment laden runoff to GSI facilities or offsite • Do not use GSI footprint area for sediment trap unless adequate design measures are in place, such as keeping sediment trap bottom elevation a minimum of 12" above GSI design bed bottom	• E&S controls installed according to plans • Bioretention surfaces are adequately protected from sediment and debris • Exposed subgrades in infiltration zones are adequately protected from sedimentation and contamination	• Prior to initial site disturbance • Regularly throughout construction • Following installation of bioretention facilities • Before and immediately following rain events	• Contractor • Owner's representative (engineering inspector)	• Sedimentation of exposed infiltration zone subgrades: Remove sediment and scarify subgrade • Sedimentation of bioretention surfaces*:* Remove sediment with equipment or hand tools and restore surface as required
B2, B3	**Site Access & Material Storage**	• Protect public safety by limiting pedestrian and vehicular access to construction site • Protect infiltration zones by placing material storage outside of infiltration zones and ensure material stockpiles are protected from erosion and/or contamination • Stake out or otherwise mark infiltration zones to avoid compaction	• Safety fencing, barricades and traffic control devices installed as needed and they meet local and state safety requirements • Material storage located according to plans with adequate E&S protection	• Regularly throughout construction	• Contractor • Owner's representative (engineering inspector)	• Install adequate fencing, barricade and traffic control as necessary • Relocate material to avoid infiltration zones and sensitive site features • Cover/stabilize exposed aggregates and soils
B4	**Tree Protection**	• Protect existing trees and root zones from damage by installing adequate tree protection and preventing equipment/material storage within tree root zones	• Tree protection fencing, etc. installed according to plans and details • No equipment/material storage within root zones/tree canopy areas • Excavate by hand or air spade around exposed tree roots or according to specifications/arborist recommendations	• Prior to initial site disturbance • Regularly throughout construction	• Contractor • Owner's representative (engineering inspector)	• Relocate material/equipment storage or construction vehicular access to avoid tree root zones • Use air spade and/or hand tools when excavating around tree roots
B5	**Utilities**	• Protect existing utilities from damage and/or service interruption by properly locating and marking existing utilities prior to the start of construction activities	• Existing utilities within limit of disturbance are to be located through PA One Call or private utility locator and properly marked out	• Prior to initial site disturbance • Regularly throughout construction	• Owner's representative (engineering inspector)	• Utilize private utility locator or other means if necessary • Verify location of existing utilities through test holes prior to major excavation activity
B6	**Demolition/Clearing & Grubbing**	• Limit demolition, clearing and grubbing to areas necessary for construction • Protect existing site features to remain	• Check that vegetation and/or existing structures and pavements marked for removal are within the area of work necessary to install GSI and other improvements	• When protection zones and GSI facility locations are marked and once demolition/clearing and grubbing begin	• Owner's representative (engineering inspector)	• Restate demolition/ clearing and grubbing limits • Re-stabilize/restore any areas that have been unnecessarily cleared or demolished
B7	**Excavation**	• Protect subgrade within infiltration zones from compaction and sedimentation during excavation by operating outside of GSI facility footprint • Provide shoring as required	• Excavation within GSI footprint to line and grades indicated on plans • Equipment kept off all infiltrating surfaces • Tree roots are cleanly cut, flush with side walls	• When excavation begins and periodically until final GSI system subgrade is exposed	• Owner's representative (engineering inspector)	• A compacted GSI facility subgrade (bottom) will require scarification to a depth of 6"-12" to help restore infiltration capacity • A silt contaminated facility subgrade (bottom) may require over-excavation to remove sediment, consult design team

Table 2-1. Bioretention System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
B8	**Subgrade**	• Ensure subgrade elevation and extent matches design plans • Bed bottoms are typically level unless otherwise indicated on plans to promote even infiltration and prevent clogging • Equipment traffic on bed bottoms to be avoided to prevent compaction • Protect from sediment once final subgrade elevation reached • Scarify subgrade as required	• Exposed subgrade to be uniform, uncompacted and free of sediment and deleterious material • Subgrade to be excavated to elevations indicated on plans • No sediment or debris accumulation has taken place • Survey verification of elevations is required	• Inspect when final subgrade is reached and excavation is completed	• Contractor (demonstrating elevations are per plan) • Owner's representative (engineering inspector)	• If facility bottom is not level, confirm that it conforms to the design plans/intent or instruct contractor to level • If sediment or debris accumulation has taken place, remove prior to installation of geotextile/liner or sub-base
B9	**Geotextile/Liner**	• Ensure geotextile is sufficiently sized to provide a minimum of 18" overlap at seams • Ensure waterproof liner seams are bonded according to specifications and manufacturer's recommendations • Ensure geotextile/liner is secured 3'-4' outside of excavation	• Geotextile/liner is clean, undamaged and installed according to plans and details • Seams are properly overlapped (geotextile) or bonded/sealed (liner)	• Confirm material meets specification/approved submittal once it arrives on site • Inspect installation of fabric/liner when installation commences and once complete	• Owner's representative (engineering inspector)	• Install per design • Overlap a minimum of 18" • Remove and replace any contaminated or damaged geotextile/liner
B10	**Underdrain/Distribution Pipes**	• Install to grade (often laid flat) and place cleanout/inspection ports as per design • Distribution pipes distribute runoff through the GSI storage bed and may be sloped or level	• Pipe size, material, location, perforations and elevation installed per plans and details • Placement and orientation of cleanouts are correct • Line and grade of pipe matches design	• Confirm material, perforations and size match specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Correct pipe orientation, perforations, material, size, location or slope if necessary • Have pipe re-laid if grade/location does not match design
B11	**Catch Basins/Control Structure/Domed Riser**	• Install to grades and connect pipes as per design • Structures to be configured per plans and details including accessory components such as weirs, slow flow orifices, filter inserts and sewer traps • Structure rim typically located above finish surface grade to allow for ponding in the bioretention system • Confirm structure elevations	• Structure size, material, location, accessory components and elevation installed per plans and details • Placement and orientation of structures and pipe connections are correct • Grade of structure and pipe connections match design and connections are water tight	• Confirm material, size and configuration match details and specifications once it arrives on site • Inspect once installation commences and following completion of work ensuring filter inserts or temporary E & S measures are in place	Owner's representative (engineering inspector)	• Correct structure/pipe orientation, material, size, location or elevation if necessary • Have structure re-installed if grade/location does not match design • Install appropriate accessories if missing
B12, B13	**Storage Aggregates**	• Place in minimum 8" lifts or per design • When storage bed is wide, place aggregate at bed edges first and move towards center of the bed; never drive over exposed bed bottoms • Compact/level with equipment until no visible aggregate movement • Do not crush aggregate (use static mode for rollers)	• Confirm material is clean and gradation meets specification when it arrives on site • Depth of aggregate matches design plans and details • Rock hasn't been crushed during compaction/leveling • Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject aggregate material if it is not clean and/or does not meet specification • Prevent construction equipment traffic over bed bottoms during aggregate placement • Operate roller in static mode

Table 2-1. Bioretention System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
B14, B15	**Graded Aggregate Filter Layer**	• Graded aggregate filter layer is placed between storage aggregate and bioretention soils • Place filter layer to depth indicated on plans and lightly compact • Do not crush aggregate with compaction equipment	• Confirm material is clean and gradation meets specification when it arrives on site • Depth of placement matches design plans and details • Rock hasn't been crushed during compaction	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject aggregate material if it is not clean and/or does not meet specification • Do not over-compact
B16	**Surface Inlet/Trench Drains/ Curb Cuts**	• Install to grades shown on plans such that surface runoff flows into the bioretention system • Structures to be configured per plans and details and should be located at relative low points to prevent surface runoff bypass around bioretention system • Surface flow inlets typically include erosion control devices such as splash pads or cobble energy dissipaters which are to be installed at lower elevation than the surface inlet • Confirm elevations, especially at locations where by-pass is possible such as curb cuts, curb cut inlets should be below the grade of the adjacent roadway to promote inflow	• Inlet size, location and elevation installed per plans and details • Placement and orientation of inlet openings according to plans and allow free runoff flow into bioretention system • Erosion control devices installed according to plans and set at correct elevation lower than surface inlet	• Confirm size, material and configuration match details and specifications (for structural elements such as trench drains) when item arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Correct grading or orientation of surface inlet to maximize capture and eliminate runoff bypass, if necessary • Have surface inlet re-installed if grade/location does not match design • Install/correct depression along gutter line to prevent bypass at surface inlets
B17, B18	**Engineered Bioretention Soils**	• Place graded aggregate filter layer over storage aggregate prior to bioretention soil placement • Place bioretention soil material in 8" lifts to depth indicated on plans and grade surface per plans and specifications • Lightly compact by hand or hydraulically (sprinkling water) to prevent reduction in infiltration rate	• Confirm material meets specification when it arrives on site and that submittal has been reviewed and approved • Depth of placement matches design plans and details • Surface grading matches plans, and soils have not been over-compacted	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	Owner's representative (engineering inspector)	• Reject bioretention soil material if it does not meet specification • Remove and replace overly compacted soil or soil material that has been contaminated with sediment or debris
B19	**Grade Control Structures (check dams, weirs, etc.)**	• Install berms, check dams and weirs to grades shown on plans to control the flow of water in the bioretention system • Structures to be located and configured per plans and details • Install erosion control devices such as splash pads or cobble energy dissipaters when indicated on plans and details	• Grade control structure height, size, location, material and elevation installed per plans and details • Placement and orientation according to plans and allow backup and free runoff flow through system as intended by design • Erosion control devices installed according to plans	• Inspect once grade control structures are installed	▪ Owner's representative (engineering inspector)	• Contractor to correct height, width or material to meet plans and specifications
B20	**Finish Grading**	• Complete finish surface grading using hand tools according to plans and details, ensuring that bioretention surface is graded to collect and infiltrate water	• Confirm grading and surface elevations are completed according to plans and details	• Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Contractor to correct surface grading that does not match plans
B21, B22	**Erosion Control Matting**	• Place as per manufacturer's installation guidelines and as shown on plans and details once fine grading is complete • Erosion mating will minimize erosion of exposed soils prior to plants taking root	• Erosion control mat product matches specification • Erosion control mat is placed in correct location and secured according to plans, details and manufacturer's recommendations	• Inspect material once it arrives on site and again after installation	• Owner's representative (engineering inspector)	• Secure or reinstall any material not conforming to specification and manufacturer's installation guidelines

Table 2-1. Bioretention System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
B23, B24	**Erosion control devices (splash pads, cobbles, energy dissipaters)**	• Install per plans and details ensuring correct material and grades • Install cobbles/riverstone or other aggregates to finish grade	• Splash pad/energy dissipater/cobbles match specifications • Cobbles/riverstone have been installed evenly and meet finish grade	• Inspect material once it arrives on site • Inspect following installation	• Owner's representative (engineering/landscape inspector)	• Reject material that doesn't meet requirements of specification • Re-install splash pad, energy dissipater or aggregates that do not match plans and details
B25, B26	**Plant Material**	• Plant material to meet design and any substitutions to be approved to ensure long-term plant health • Plants to be installed the same day as delivery and watered immediately after installation to prevent stressing the plant material • Herbaceous plugs to be stored properly and planted with soil auger, small spade or hand trowel	• Confirm plant material meets specification when it arrives on site and that any substitutions have been approved • Plant placement matches design plans and details • Plants have been installed on same day as delivery and plants have been watered	• Confirm plant material meets specifications and was selected (tagged) for installation by the landscape design professional (if required) once it arrives on site • Inspect once installation is complete	• Owner's representative (landscape inspector)	• Reject unhealthy plant material or if it does not meet plans and specifications • Replace and/or reinstall any plant material that is unhealthy or installed incorrectly
B27, B28	**Mulch or Other Surface Cover**	• Install mulch or other surface cover such as riverstone per design and ensure even placement to prevent weeds and soil erosion • Mulch or other surface covers often act as final depth of facility; ensure depth is as per design to prevent blocking inlets and reducing ponding capacity • If mulch is used, avoid ponding areas or stabilize mulch with jute erosion control matting. • Alternatives to mulch include dense planting or other non-erosive surface covers such as erosion control matting or riverstones.	• Confirm material meets specification when it arrives on site and that submittal has been reviewed and approved • Depth of placement matches design plans and details • Surface grading matches plans	• Confirm material meets specifications once it arrives on site and following completion of work	▪ Owner's representative (engineering/landscape inspector)	• Reject material if it does not meet specification • Remove and replace mulch material that has been contaminated with sediment or debris or has been installed incorrectly
B29	**Erosion & Sedimentation Control following Installation**	• Stabilize adjacent areas and ensure proper E&S controls are in place to protect surface infiltration zones from sedimentation • Keep bioretention system offline if possible until it is established	• E&S controls installed that adequately protect surface infiltration features from sedimentation • Sand bags, etc. are properly installed to divert runoff during establishment	• Immediately following installation of final surface treatment • Before and immediately following rain events	• Contractor • Owner's representative (engineering inspector)	• Sedimentation of infiltration surfaces: Remove sediment with hand tools, scarify soil surface, replace surface treatment (cobble, mulch) with clean material
B30, B31	**Post-Construction**	• Document built conditions through development of construction as-builts • Install flow monitoring equipment on-site to monitor GSI performance per plans and specifications • Complete performance testing in accordance with project specifications (e.g. surface infiltration testing)	• Confirm as-builts drawings are complete and have fully documented all field changes to the original design • Confirm that flow monitoring equipment meets requirements of plans, details and specifications • Confirm that flow monitoring equipment has been installed in the correct location and per design plans and details • Confirm that flow monitoring equipment is protected from vandalism and theft	• Confirm monitoring equipment meets specifications once it arrives on site • Inspect once following installation	• Owner's representative (engineering inspector) • Monitoring staff	• Reject monitoring equipment if it is does not meet specifications • Revise as-builts until they are complete and document all constructed site conditions • Reinstall monitoring equipment if it has not been installed according to plan or consult design/monitoring team to relocate the monitoring equipment as required to properly collect flow data

2.2.2 Infiltration Trenches

2.2.2.1 Typical Construction Sequence Flow Chart

There are several variations of infiltration trenches, however, the construction sequence of each is very similar with only a few differences that are typically related to the surface treatment. Some examples of infiltration trench variations include:

- Infiltration trenches under asphalt, sidewalks or standard pavers
- Infiltration trenches under turf/landscape areas or decorative aggregates (cobbles/riverstone)
- Infiltration tree trenches typically within a turf or mulched planting area or within sidewalk areas with tree pits
- Infiltration trenches with alternative storage media or sand-based structural soils

The construction sequence and specific steps and inspection milestones for infiltration trench systems are summarized in the flowchart below (Figure 2-21). Additionally, more detailed information related to construction inspections is provided in Table 2-2 in the following section. The Construction Sequence Inspection Table provides guidelines for inspecting the installation of infiltration trenches throughout each step in the construction sequence, including critical inspection items and techniques, documentation, and corrective actions.

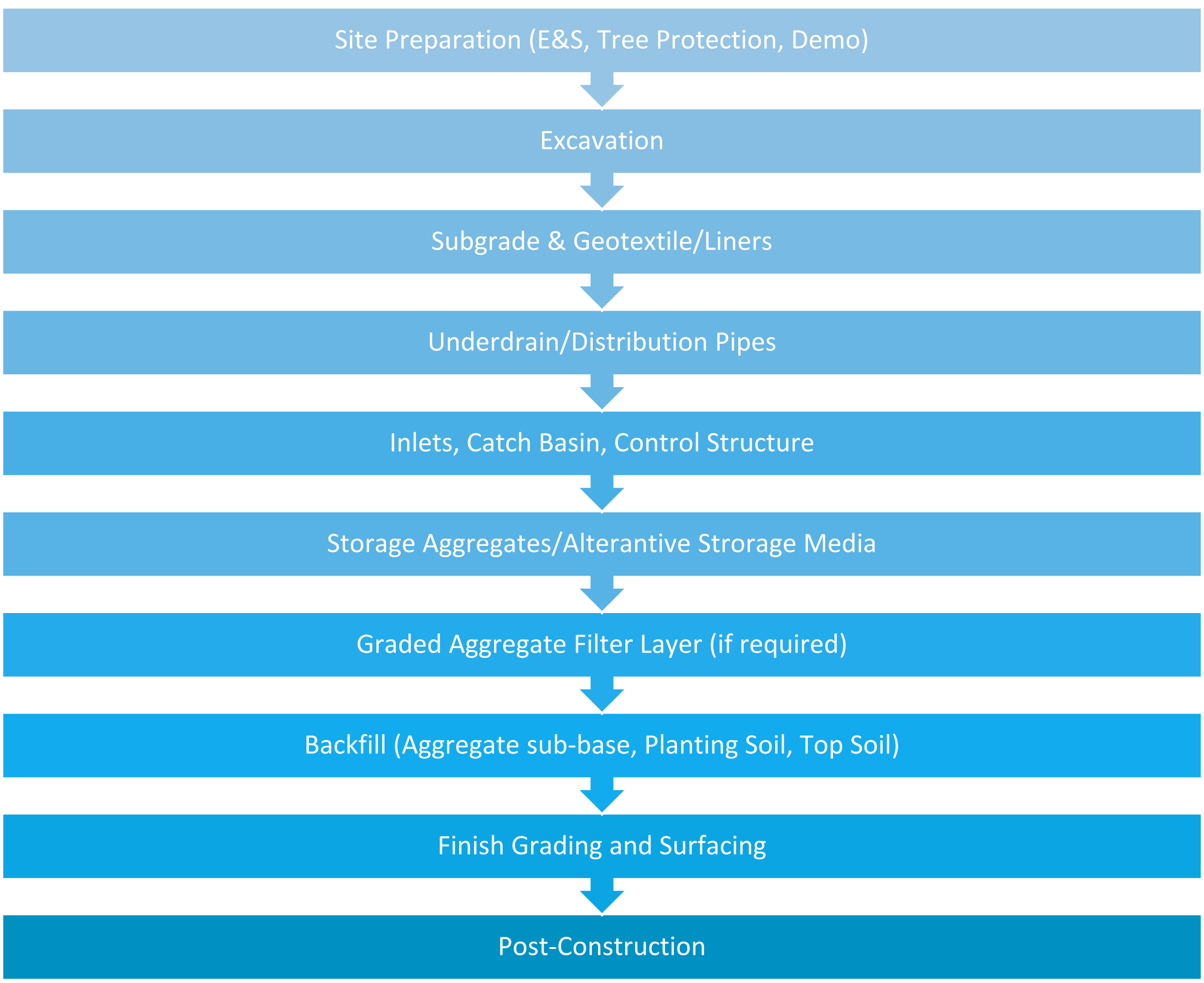


Figure 2-21. General Construction Sequence for Infiltration Trench Systems

2.2.2.2 Construction Sequence Inspection Table for Infiltration Trenches

Table 2-2 provides guidelines for the inspection of infiltration trench installations and is intended to be used with the Infiltration Trench Construction Inspection Form and Checklist provided in Appendix 4-A.

Table 2-2. Infiltration Trench System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
I1	**Erosion and Sedimentation (E&S) Controls**	• Protect infiltration zones and subgrades from sediment contamination and clogging • Protect catch basins from collecting and conveying sediment laden runoff to GSI facilities or offsite • Do not use GSI footprint area for sediment trap unless adequate design measures are in place, such as keeping sediment trap bottom elevation a minimum of 12” above GSI design bed bottom	• E&S controls installed according to plans • Infiltration trench surfaces are adequately protected from sediment and debris • Exposed subgrades in infiltration zones are adequately protected from sedimentation and contamination	• Prior to initial site disturbance • Regularly throughout construction • Following installation infiltration trenches • Before and immediately following rain events	• Contractor • Owner’s representative (engineering inspector)	• Sedimentation of exposed infiltration zone subgrades: Remove sediment and scarify subgrade • Sedimentation of infiltration trench surfaces: Remove sediment with equipment or hand tools and restore surface as required
I2, I3	**Site Access & Material Storage**	• Protect public safety by limiting pedestrian and vehicular access to construction site • Protect infiltration zones by placing material storage outside of infiltration zones and ensure material stockpiles are protected from erosion and/or contamination • Stake out or otherwise mark infiltration zones to avoid compaction	• Safety fencing, barricades and traffic control devices installed as needed and they meet local and state safety requirements • Material storage located according to plans with adequate E&S protection	• Regularly throughout construction	• Contractor • Owner’s representative (engineering inspector)	• Install adequate fencing, barricade and traffic control as necessary • Relocate material to avoid infiltration zones and sensitive site features • Cover/stabilize exposed aggregates and soils
I4	**Tree Protection**	• Protect existing trees and root zones from damage by installing adequate tree protection and preventing equipment/material storage within tree root zones	• Tree protection fencing, etc. installed according to plans and details • No equipment/material storage within root zones/tree canopy areas • Excavate by hand or air spade around exposed tree roots or according to specifications/arborist recommendations	• Prior to initial site disturbance • Regularly throughout construction	• Contractor • Owner’s representative (engineering inspector)	• Relocate material/equipment storage or construction vehicular access to avoid tree root zones • Use air spade and/or hand tools when excavating around tree roots
I5	**Utilities**	• Protect existing utilities from damage and/or service interruption	• Existing utilities within limit of disturbance are to be located through PA One Call or private utility locator and properly marked out	• Prior to initial site disturbance • Regularly throughout construction	• Owner’s representative (engineering inspector)	• Utilize private utility locator or other means if necessary • Verify location of existing utilities through test holes prior to major excavation activity
I6	**Demolition/Clearing & Grubbing**	• Limit demolition, clearing and grubbing to areas necessary for construction • Protect existing site features to remain	• Check that vegetation and/or existing structures and pavements marked for removal are within the area of work necessary to install GSI and other improvements	• When protection zones and GSI facility locations are marked and once demolition/clearing and grubbing begin	• Owner’s representative (engineering or landscape inspector)	• Restate demolition/ clearing and grubbing limits • Re-stabilize/restore any areas that have been unnecessarily cleared or demolished
I7	**Excavation**	• Protect subgrade within infiltration zones from compaction and sedimentation during excavation by operating outside of GSI facility footprint • Provide shoring as required	• Excavation within GSI footprint to line and grades indicated on plans • Equipment kept off all infiltrating surfaces • Tree roots are cleanly cut, flush with side walls	• When excavation begins and periodically until final GSI system subgrade is exposed	• Owner’s representative (engineering inspector)	• A compacted GSI facility subgrade (bottom) will require scarification to a depth of 6”-12” to help restore infiltration capacity • A silt contaminated facility subgrade (bottom) may require over-excavation to remove sediment, consult design team

Table 2-2. Infiltration Trench System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
I8	**Subgrade**	• Ensure subgrade elevation and extent matches design plans • Bed bottoms are typically level unless otherwise indicated on plans to promote even infiltration and prevent clogging • Equipment traffic on bed bottoms to be avoided to prevent compaction • Protect from sediment once final subgrade elevation reached • Scarify subgrade as required	• Exposed subgrade to be uniform, uncompacted and free of sediment and deleterious material • Subgrade to be excavated to elevations indicated on plans • No sediment or debris accumulation has taken place • Survey verification of elevations is required	• Inspect when final subgrade is reached and excavation is completed	• Contractor (demonstrating elevations are per plan) • Owner’s representative (engineering inspector)	• If facility bottom is not level, confirm that it conforms to the design plans/intent or contractor to level • If sediment or debris accumulation has taken place contractor to remove prior to installation of geotextile/liner or sub-base
I9	**Geotextile/Liner**	• Ensure geotextile is sufficiently sized to provide a minimum of 18” overlap at seams • Ensure waterproof liner seams are bonded according to specifications and manufacturer’s recommendations • Ensure geotextile/liner is secured 3’-4’ outside of excavation	• Geotextile/liner is clean, undamaged, and installed according to plans and details • Seams are properly overlapped (geotextile) or bonded/sealed (liner)	• Confirm material meets specification/approved submittal once it arrives on site • Inspect installation of fabric/liner when installation commences and once complete	• Owner’s representative (engineering inspector)	• Install per design • Overlap a minimum of 18” • Remove and replace any contaminated or damaged geotextile/liner
I10	**Underdrain/Distribution Pipes**	• Install to grade (often laid flat) and place cleanout/inspection ports as per design • Distribution pipes distribute runoff through the GSI storage bed and may be sloped or level	• Pipe size, material, location, perforations and elevation installed per plans and details • Placement and orientation of cleanouts are correct • Line and grade of pipe matches design	• Confirm material, perforations, and size match specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner’s representative (engineering inspector)	• Correct pipe orientation, perforations, material, size, location or slope if necessary • Have pipe re-laid if grade/location does not match design
I11	**Inlets, Catch Basins, Control Structure**	• Install to grades and connect pipes as per design • Structures to be configured per plans and details including accessory components such as weirs, slow flow orifices, filter inserts and sewer traps • Structure rim typically located above finish surface grade to allow for ponding in the bioretention system • Confirm structure elevations	• Structure size, material, location, accessory components and elevation installed per plans and details • Placement and orientation of structures and pipe connections are correct • Grade of structure and pipe connections match design and connections are water tight	• Confirm material, size, and configuration match details and specifications once it arrives on site • Inspect once installation commences and following completion of work ensuring filter inserts or temporary E&S measures are in place	• Owner’s representative (engineering inspector)	• Correct structure/pipe orientation, material, size, location or elevation if necessary • Have structure re-installed if grade/location does not match design • Install appropriate accessories if missing
I12	**Weir and Baffles (if Applicable)**	• Install structures according to plans and specifications	• Confirm submittal has been reviewed and approved • Confirm elevations are correct and structures have been installed according to plans and specifications	• Confirm structures meet specifications once they arrive on site • Inspect once installation commences and following completion of work	• Owner’s representative (engineering inspector)	• Reject structure if it does not meet specifications or plans • Have structure re-installed if grade/location does not match design
I13, I14	**Storage Aggregates or Alternative Storage Media**	• Place in minimum 8” lifts or per design • When storage bed is wide, place aggregate at bed edges first and move towards center of the bed; never drive over exposed bed bottoms • Compact/level with equipment until no visible aggregate movement • Do not crush aggregate (use static mode for rollers)	• Confirm material is clean and gradation meets specification when it arrives on site • Depth of aggregate matches design plans and details • Rock hasn’t been crushed during compaction/ leveling • Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner’s representative (engineering inspector)	• Reject aggregate material if it is not clean and/or does not meet specification • Prevent construction equipment traffic over bed bottoms during aggregate placement • Operate roller in static mode

Table 2-2. Infiltration Trench System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
I15, I16	**Graded Aggregate Filter Layer**	• Graded aggregate filter layer is placed between storage aggregate and backfill material when infiltration trench is designed for surface infiltration – e.g. finish grade is planting soil and landscape or decorative cobbles/riverstone • Place filter layer to depth indicated on plans and lightly compact • Do not crush aggregate with compaction equipment	• Confirm material is clean and gradation meets specification when it arrives on site • Depth of placement matches design plans and details • Rock hasn't been crushed during compaction	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject aggregate material if it is not clean and/or does not meet specification • Do not over-compact
I17, I18	**Backfill (Aggregate sub-base, planting soil or top soil for turf)**	• Fully wrap geotextile over storage aggregates with minimum overlap of 18" to prevent migration of fines into infiltration trench • Place graded aggregate filter layer over storage aggregate rather than geotextile when infiltration trench is designed for surface infiltration • Place backfill material to depth indicated on plans and compacted to provide a level surface for finish grade • Compact per plans and specifications	• Confirm that geotextile has been properly wrapped over the top of storage aggregates with 18" min overlap prior to backfill • Confirm material meets specification when it arrives on site • Depth of placement matches design plans and details • Geotextile hasn't been damaged or perforated prior to backfill placement	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject backfill material if it is not clean and/or does not meet specification • Completely cover top of trench aggregate with geotextile or with graded aggregate prior to installing backfill material • Replace damaged or punctured geotextile material
I19	**Finish Grading and Surfacing**	• Complete finish surface grading according to plans and details, ensuring that infiltration trench surface is graded to collect and infiltrate water when included in design • Install surface treatment – pavement, turf or landscape plantings, trees, etc. according to plans and details	• Confirm grading and surface elevations are completed according to plans and details • Confirm that vegetated surfaces are protected from erosion with use of erosion control blanket or other means until vegetation is established • Confirm pavements are installed to line and grade shown on plans and details	• Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Contractor to correct surface grading that does not match plans • Contractor to correct or replace pavements that are not installed according to plans and details.
I20	**Erosion & Sedimentation Control following Installation**	• Stabilize adjacent areas and ensure proper E&S controls are in place to protect surface infiltration zones from sedimentation • Keep vegetated areas that are part of the infiltration trench system offline if possible until vegetation is established	• E&S controls installed that adequately protect surface infiltration features from sedimentation • Sand bags, etc. are properly installed to divert runoff during establishment (if required)	• Immediately following installation of final surface treatment • Before and immediately following rain events	• Contractor • Owner's representative (engineering inspector)	• Sedimentation of infiltration surfaces: Remove sediment with hand tools, scarify soils surfaces, replace surface treatment (cobble, mulch) with clean material
I21, I22	**Post-Construction**	• Document built conditions through development of construction as-builts • Install flow monitoring equipment on-site to monitor GSI performance per plans and specifications • Complete performance testing in accordance with project specifications	• Confirm as-builts drawings are complete and have fully documented all field changes to the original design • Confirm that flow monitoring equipment meets requirements of plans, details and specifications • Confirm that flow monitoring equipment has been installed in the correct location and per design plans and details • Confirm that flow monitoring equipment is protected from vandalism and theft	• Confirm monitoring equipment meets specifications once it arrives on site • Inspect once following installation	• Owner's representative (engineering inspector) • Monitoring staff	• Reject monitoring equipment if it is does not meet specification • Revise as-builts until they are complete and document all constructed site conditions • Reinstall monitoring equipment if it has not been installed according to plan or consult design/monitoring team to relocate the monitoring equipment as required to properly collect flow data

2.2.3 Permeable Pavements

2.2.3.1 Typical Construction Sequence Flow Chart

Permeable pavements are divided into several different pavement types:

- Porous asphalt
- Pervious concrete
- Permeable block pavers
- Open grid pavers
- Permeable flexible pavers

The construction sequence and specific steps and milestones required to construct each type of permeable pavement are summarized in the flowchart below (Figure 2-22). Additionally, more detailed information related to construction inspections is provided in Table 2-3 in the following section. The Construction Sequence Inspection Table provides guidelines for inspecting the installation of permeable pavements throughout each step in the construction sequence, including critical inspection items and techniques, documentation and corrective actions.

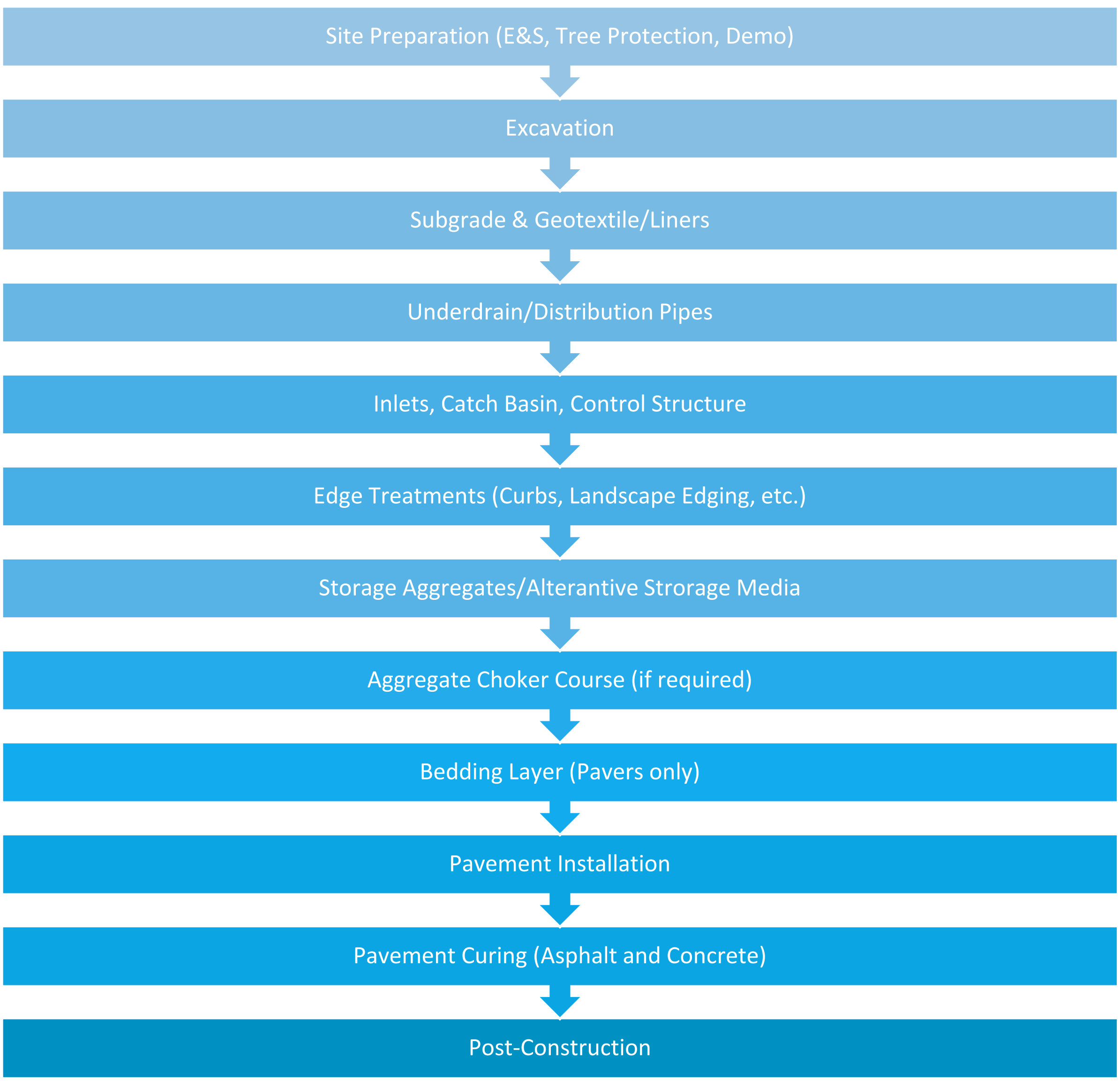


Figure 2-22 General Construction Sequence for Permeable Pavement Systems

2.2.3.2 Construction Sequence Inspection Table for Permeable Pavements

Table 2-3 provides guidelines for the inspection of permeable pavement installations and is intended to be used with the Permeable Pavement Construction Inspection Form and Checklist provided in Appendix 4-A

Table 2-3. Permeable Pavement System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
P1	**Erosion and Sedimentation (E&S) Controls**	• Protect permeable pavements surfaces from sedimentation • Protect infiltration zones and subgrades from contamination and clogging • Protect catch basins from collecting and conveying sediment laden runoff to GSI facilities or offsite	• E&S controls installed according to plans • Permeable pavement surfaces are adequately protected from sediment and debris • Exposed subgrades in infiltration zones are adequately protected from sedimentation and contamination	• Prior to initial site disturbance • Regularly throughout construction • Following installation of permeable pavements • Before and immediately following rain events	• Contractor • Owner's representative (engineering inspector)	• Sedimentation of exposed infiltration zone subgrades: Remove sediment and scarify subgrade • Sedimentation of permeable pavement surfaces: Vacuum pavement surface and power wash and repeat vacuuming if necessary
P2, P3	**Site Access & Material Storage**	• Protect public safety by limiting pedestrian and vehicular access to construction site • Protect infiltration zones by placing material storage outside of infiltration zones and ensure material stockpiles are protected from erosion and/or contamination • Stake out or otherwise mark infiltration zones to avoid compaction	• Safety fencing, barricades and traffic control devices installed as needed and they meet local and state safety requirements • Material storage located according to plans with adequate E&S protection	• Regularly throughout construction	• Contractor • Owner's representative (engineering inspector)	• Install adequate fencing, barricade, and traffic control as necessary • Relocate material to avoid infiltration zones and sensitive site features • Cover/stabilize exposed aggregates and soils
P4	**Tree Protection**	• Protect existing trees and root zones from damage by installing adequate tree protection and preventing equipment/material storage within tree root zones	• Tree protection fencing, etc. installed according to plans and details • No equipment/material storage within root zones/tree canopy areas • Excavate by hand or air spade around exposed tree roots or according to specifications/arborist recommendations	• Prior to initial site disturbance • Regularly throughout construction	• Contractor • Owner's representative (engineering inspector)	• Relocate material/equipment storage or construction vehicular access to avoid tree root zones • Use air spade and/or hand tools when excavating around tree roots
P5	**Utilities**	• Protect existing utilities from damage and/or service interruption	• Existing utilities within limit of disturbance are to be located through PA One Call or private utility locator and properly marked out	• Prior to initial site disturbance • Regularly throughout construction	• Owner's representative (engineering inspector)	• Utilize private utility locator or other means if necessary • Verify location of existing utilities through test holes prior to major excavation activity
P6	**Demolition/Clearing & Grubbing**	• Limit demolition, clearing and grubbing to areas necessary for construction • Protect existing site features to remain	• Check that vegetation and/or existing structures and pavements marked for removal are within the area of work necessary to install GSI and other improvements	• When protection zones and GSI facility locations are marked and once demolition/clearing and grubbing begin	• Owner's representative (engineering or landscape inspector)	• Restate demolition/ clearing and grubbing limits • Re-stabilize/restore any areas that have been unnecessarily cleared or demolished
P7	**Excavation**	• Protect subgrade within infiltration zones from compaction and sedimentation during excavation by operating outside of GSI facility footprint • Provide shoring as required	• Excavation within GSI footprint to line and grades indicated on plans • Equipment kept off all infiltrating surfaces • Tree roots are cleanly cut, flush with side walls	• When excavation begins and periodically until final GSI system subgrade is exposed	• Owner's representative (engineering inspector)	• A compacted GSI facility subgrade (bottom) will require scarification to a depth of 6"-12" to help restore infiltration capacity • A silt contaminated facility subgrade (bottom) may require over-excavation to remove sediment, consult design team

Table 2-3. Permeable Pavement System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
P8	**Subgrade**	• Ensure subgrade elevation and extent matches design plans • Bed bottoms are typically level unless otherwise indicated on plans to promote even infiltration and prevent clogging • Equipment traffic on bed bottoms to be avoided to prevent compaction • Protect from sediment once final subgrade elevation reached • Scarify subgrade as required	• Exposed subgrade to be uniform, uncompacted and free of sediment and deleterious material • Subgrade to be excavated to elevations indicated on plans • No sediment or debris accumulation has taken place • Survey verification of elevations is required	• Inspect when final subgrade is reached and excavation is completed	• Contractor (demonstrating elevations are per plan) • Owner's representative (engineering inspector)	• If facility bottom is not level, confirm that it conforms to the design plans/intent or instruct contractor to level • If sediment or debris accumulation has taken place remove prior to installation of geotextile/liner or sub-base
P9	**Geotextile/Liner**	• Ensure geotextile is sufficiently sized to provide a minimum of 18" overlap at seams • Ensure waterproof liner seams are bonded according to specifications and manufacturer's recommendations • Ensure geotextile/liner is secured 3'-4' outside of excavation	• Geotextile/liner is clean, undamaged and installed according to plans and details • Seams are properly overlapped (geotextile) or bonded/sealed (liner)	• Confirm material meets specification/approved submittal once it arrives on site • Inspect installation of fabric/liner when installation commences and once complete	• Owner's representative (engineering inspector)	• Install per design • Overlap a minimum of 18" • Remove and replace any contaminated or damaged geotextile/liner
P10	**Underdrain/Distribution Pipes**	• Install to grade (often laid flat) and place cleanout/inspection ports as per design • Distribution pipes distribute runoff through the GSI storage bed and may be sloped or level	• Pipe size, material, location, perforations and elevation installed per plans and details • Placement and orientation of cleanouts are correct • Line and grade of pipe matches design	• Confirm material, perforations and size match specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Correct pipe orientation, perforations, material, size, location or slope if necessary • Have pipe re-laid if grade/location does not match design
P11	**Inlets, Catch Basins, Control Structure**	• Install to grades and connect pipes as per design • Structures to be configured per plans and details including accessory components such as weirs, slow flow orifices, filter inserts and sewer traps • Confirm structure elevations	• Structure size, material, location, accessory components and elevation installed per plans and details • Placement and orientation of structures and pipe connections are correct • Grade of structure and pipe connections match design and connections are water tight	• Confirm material, size, and configuration match details and specifications once it arrives on site • Inspect once installation commences and following completion of work ensuring filter inserts or temporary E&S measures are in place	• Owner's representative (engineering inspector)	• Correct structure/pipe orientation, material, size, location or elevation if necessary • Have structure re-installed if grade/location does not match design • Install appropriate accessories if missing
P12	**Edge Treatments**	• Install new edge treatments/restraints to provide clean, durable edge for the pavement/pavers • Protect existing curbs and other structures from being undermined by GSI excavation • Edge treatment type is designed based on anticipated loads, concrete curbs/edge treatments are typically required for vehicular traffic while metal landscape edge may be sufficient for pedestrian/recreation uses	• Edge treatments/curbs have been installed according to plans and details • Existing curbs and other structures have not been undermined by GSI excavation	• Confirm edge treatment material meets specification once it arrives on site • Inspect once when installation commences and once complete	• Owner's representative (engineering inspector)	• Install per design and/or manufacturer's recommendation • Prevent damage to existing curbs/structures by providing a buffer between curbs/structures and deep excavation • Replace or reinstall any damaged or poorly installed edge treatments
P13, P14	**Storage Aggregates**	• Place in minimum 8" lifts or per design • Place aggregate at bed edges first and move towards center of the bed. Drive dump trucks over aggregate already placed at edges to access middle of bed, never drive over exposed bed bottoms • Compact with vibratory roller in static mode until no visible aggregate movement • Do not crush aggregate with (use static mode for rollers)	• Confirm material is clean and gradation meets specification when it arrives on site • Depth of aggregate matches design plans and details • Rock hasn't been crushed during compaction • Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject aggregate material if it is not clean and/or does not meet specification • Prevent construction equipment traffic over bed bottoms during aggregate placement • Operate roller in static mode

Table 2-3. Permeable Pavement System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
P15, P16	**Aggregate Choker Course**	• Place to depth indicated on plans and compacted to provide a level surface for paving • Compact with roller in static mode until no visible aggregate movement • Do not crush aggregate with roller • Pervious concrete only: pre-moisten aggregate immediately prior to concrete placement	• Confirm material is clean and gradation meets specification when it arrives on site • Depth of placement matches design plans and details • Rock hasn't been crushed during compaction • Pervious concrete: aggregate has been pre-moistened and no standing water is present	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject aggregate material if it is not clean and/or does not meet specification • Operate equipment in static mode
P17, P18	**Bedding Layer (Pavers only) and Geogrid (if Applicable)**	• Place to depth indicated on plans and compacted to provide a level surface for pavers • Compact per plans and specifications • Do not crush aggregate with roller • Ensure geogrid material meets specifications and has been reviewed and approved	• Confirm material is clean and gradation meets specification when it arrives on site • Depth of placement matches design plans and details • Rock hasn't been crushed during compaction • Geogrid has been installed according to plans and specifications	• Confirm bedding layer and/or geogrid material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject aggregate material if it is not clean and/or does not meet specification • Operate equipment in static mode
P19	**Weir and Baffles (if Applicable)**	• Install structures according to plans and specifications	• Confirm submittal has been reviewed and approved • Confirm elevations are correct and structures have been installed according to plans and specifications	• Confirm structures meet specifications once they arrive on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject structure if it does not meet specifications or plans • Have structure re-installed if grade/location does not match design
P20, P21, P22	**Asphalt Pavement Installation**	• Pavement material installed in lifts and to depths indicated on plans • Pavement installed at correct temperature of bituminous pavement and ambient temperature of 55° F or above • Compact with roller in static mode when pavement has cooled enough to resist an 8 to 10-ton roller • Do not over-compact	• Pavement material submittal meets requirements of specification and has been certified by material producer • Pavement installed in lifts and to depths indicated on plans and details • Placement installation techniques meet the requirements in specification • Compaction adequate with little to no visible variation at seams	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject pavement material if it does not meet specification • Operate equipment in static mode
P20, P21, P23	**Concrete Pavement Installation**	• Build a test panel (such as a single parking stall) in an approved location to verify concrete quality, placement, jointing and curing methods and equipment • Installation techniques meet requirement specifications including screening and compaction equipment, jointing procedures and curing methods • Use of static roller screed, hand compaction rollers and "pizza cutter" joint rollers are recommended to place a smooth compacted surface on pavement without closing the void space • Pre-moisten base course before concrete placement and immediately cover for curing	• Pavement material submittal meets requirements of specification and has been certified by material producer • Forms are installed properly, and pavement installed in lifts and to depths indicated on plans and details • Placement installation techniques and jointing and finishing meet the requirements in specification • Concrete is immediately covered and remains securely covered after placement for curing • Base course adequately pre-moistened before concrete placement	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject pavement material if it does not meet specification • Alter installation technique and/or equipment based on results of test panel installation and testing (if required) • Operate equipment in static mode

Table 2-3. Permeable Pavement System Construction Inspection Guidelines

Task Number	Construction Task	Task Summary	Inspection Items	Inspection Timing	Inspection Responsibility	Potential Corrective Actions
P20, P21, P24	**Paver Installation**	• Install pavers according to plan pattern • Ensure joints are filled with approved aggregate or other material and compacted per specifications • Install edge treatments per plans and details to provide stability and meet loading requirements	• Pavement material submittal meets requirements of specification and has been certified by material producer • Confirm joint material is clean and gradation meets specification when it arrives on site • Pavers installed in correct pattern and according to specifications and/or manufacturer's recommendations	• Confirm material meets specifications once it arrives on site • Inspect once installation commences and following completion of work	• Owner's representative (engineering inspector)	• Reject paver or aggregate material if it is not clean and/or does not meet specification • Instruct contractor to follow specifications and manufacturer's recommendations
P25, P26	**Pavement Curing and Erosion & Sedimentation Control following Installation**	• Install barricades or temporary fencing to protect pavement from vehicular and pedestrian traffic during curing period • Stabilize adjacent areas and ensure proper E&S controls are in place to protect newly installed permeable pavements from sedimentation	• Barricades/fencing installed to protect permeable pavements from traffic during curing period • E&S controls installed according to plans • Permeable pavement surfaces are adequately protected from sediment and debris	• Immediately following installation of permeable pavements • Before and immediately following rain events	• Contractor • Owner's representative (engineering inspector)	• For sedimentation of permeable pavement surfaces vacuum pavement surface and power wash and repeat vacuuming if necessary
P27	**Post-Construction**	• Test pavement porosity to ensure surface drains at rate that meets specification • Document built conditions through development of construction as-builts • Install flow monitoring equipment on-site to monitor GSI performance per plans and specifications	• Review surface infiltration test data to ensure surface permeability rates meet requirements of specification • Confirm as-builts drawings are complete and have fully documented all field changes to the original design • Confirm that flow monitoring equipment meets requirements of plans, details and specifications • Confirm that flow monitoring equipment has been installed in the correct location and per design plans and details • Confirm that flow monitoring equipment is protected from vandalism and theft	• Review testing results during or following testing • Confirm monitoring equipment meets specifications once it arrives on site • Inspect once following installation	• Owner's representative (engineering inspector) • Monitoring Staff	• Vacuum sweep pavement surface and retest surface permeability when permeability rates are lower than required; may require additional material testing • Reject monitoring equipment if it is does not meet specification • Revise as-builts until they are complete and document all constructed site conditions • Reinstall monitoring equipment if it has not been installed according to plan or consult design/monitoring team to relocate the monitoring equipment as required to properly collect flow data

2.2.4 Other GSI Facilities

In addition to the primary GSI facility types and their variations discussed in this document, the following types of GSI facilities may also be constructed as part of a source water reduction project in appropriate locations. Implementation of constructed wetlands and vegetated roofs typically requires a higher degree of design and construction specialization due to the complexity of the system components and site preparation requirements (e.g. structural testing/design of rooftop and hydrology of proposed wetland site). The following general construction information for these GSI types has been provided as supplemental information, however, municipalities/municipal agencies are strongly encouraged to engage design professionals and industry experts with proven experience in the design and construction of these systems when planning to install constructed wetlands or vegetated roof systems.

2.2.4.1 Constructed Wetlands

During installation of constructed stormwater wetlands, inspectors should consider the following:

- For wetlands lined with a liner, confirm that liner seams pass specified tests (Figure 2-23)
- For wetlands lined with clay, confirm that the clay installation is in conformance with construction drawings and specifications
- Wetlands are graded according to the drawings (typically with several water depth zones), which is key for achieving optimal system performance (Figure 2-24)
- Installed plants are being adequately maintained during their establishment period
- Inlet and outlet pipe elevations installed to conform to drawings and design intent (e.g., consistent slope and no abrupt elevation changes)
- If pumps are utilized for recirculation, confirm that pump vaults and pumps conform to drawings and specifications

Figure 2-23. Impermeable Liner
Liners used for constructed wetlands must be properly sealed and pass all specified tests

Figure 2-24. Constructed Stormwater Wetlands
Constructed stormwater wetlands must be graded to conform to design drawings to achieve optimal performance

2.2.4.2 Vegetated Roofs

During installation of vegetated (green) roofs, inspectors should consider the following:

- Appropriately installed and protected waterproofing
- Appropriate drainage layer and/or root barrier
- Consistent growing media depths across the roof that match plans and specifications
- Equal and consistent spreading of sedum cuttings/plants across roof
- Proper connection of drainage tile to roof drains
- Installation of pavers and/or adjustments to planting areas to allow foot traffic to HVAC units, skylights/windows, etc.

Appendix 4-A
Construction Inspection Checklists

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW)
Green Stormwater Infrastructure (GSI) Practices
CONSTRUCTION INSPECTION FORM

INSPECTION INFORMATION				
Inspector:			Date of Inspection:	
Contractor Present?	☐ Yes	☐ No	Start Time:	End Time:
Inspection Type:	☐ Follow Up	☐ Regular	Current Weather:	
Photographs Taken?	☐ Yes	☐ No		
Reason for Inspection:	☐ Material Review ☐ Other:	☐ Regularly Scheduled/ Milestone ☐ Field Change/Question	☐ Pre-Construction ☐ Final Closeout	

SITE INFORMATION		
Site Description/Name:		
Site Address:		
Collection System Type:	☐ Combined Sewer	☐ Separated Sewer
Facility Types to Be Inspected on Site:	☐ Bioretention ☐ Infiltration Trench	☐ Permeable Pavement ☐ Other:

MUNICIPAL INFORMATION	
Municipality or Municipal Authority:	
Contact Name:	Phone:
Contact Address:	Email:

CONTRACTOR INFORMATION	
Primary Contractor:	
Contact Name / Person Present:	Phone:
Contact Address:	Email:

PRE-CONSTRUCTION CHECKLIST			
Site Plans & Details Reviewed?	☐ Yes	☐ No	☐ N/A
GSI Construction Specifications Reviewed?	☐ Yes	☐ No	☐ N/A
Soils Tested and Results Reviewed?	☐ Yes	☐ No	☐ N/A
Construction Schedule and Sequence Reviewed?	☐ Yes	☐ No	☐ N/A
Pre-Construction Meeting Complete?	☐ Yes	☐ No	☐ N/A
If yes, date of meeting:	If no, scheduled meeting date:		

CONSTRUCTION SITE INSPECTION – BIORETENTION SYSTEM				
Site Name:				
Bioretention System Type: ☐ Basin ☐ Rain Garden ☐ Planter ☐ Swale ☐ Other:				
CONSTRUCTION SITE CONDITIONS – BIORETENTION SYSTEM See Table 2-1 in the GSI Construction Inspection Guide for more detailed information on each construction task.				
TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES/ACTIONS
B1	**E & S:** E&S controls installed and properly maintained to prevent fouling of GSI facilities?			
B2	**Site Access/Safety:** Pedestrian and vehicle access restricted with adequate public safety controls in place?			
B3	**Material Storage:** Storage areas located according to plans and adequately protected?			
B4	**Tree Protection:** Tree protection installed according to plans and no equipment/material storage within root zones?			
B5	**Utilities:** Existing utilities within the limit of disturbance located and properly marked out?			
B6	**Demolition/Clearing & Grubbing**: Demo/Clearing zones are limited to area of work only?			
B7	**Excavation**: Excavation within GSI footprint to line and grades indicated on plans? Equipment kept off of all infiltrating surfaces? Tree roots are cleanly cut, flush with side walls?			
B8	**Subgrade:** Exposed sub-grade is uniform, uncompacted and free of sediment and deleterious materials? Subgrade elevation in accordance with plans? Protected from sediment once final elevation reached?			
B9	**Geotextile/Liners:** Geotextile/liner is clean, undamaged, and installed according to plans and details? Seams are properly overlapped?			
B10	**Underdrain/Distribution Pipes:** Size, material, location, perforations, and elevation of pipe per plans?			
B11	**Catch Basins/Outlet Structure/Domed Riser:** Size, material, location, components, pipe connections, and elevations per plans?			
B12	**Storage Aggregates:** Aggregate material is clean and sized according to plans and specifications? Material submittal reviewed and approved?			
B13	**Storage Aggregate Placement**: Aggregate has been placed in proper lifts to depths indicated on plans and has been compacted according to specifications? Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement?			
B14	**Graded Aggregate Filter Layer:** Aggregate material is clean and sized according to plans and specifications?			

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES
B15	**Graded Aggregate Filter Layer Placement**: Aggregate Filter Layer place between storage aggregate and backfill material? Filter Layer placed to depth indicated on plans?			
B16	**Surface Inlet/Trench Drains/Curb Cuts:** Inlet size, location, and elevation per plans and details? Placement and orientation allows runoff flow into system? Erosion control devices installed per plans and lower than surface inlet?			
B17	**Engineered Bioretention Soil:** Soil media product meets requirements of specifications? Submittal and testing information submitted and approved?			
B18	**Engineered Bioretention Soil Placement:** Depth of placement matches design plans and details? Soil materials placed in proper lifts? Soil lightly compacted by hand or sprinkled with water to ensure they are not over compacted?			
B19	**Grade Control Structures:** Check dams, weirs, ect. height, size, location, material, and elevation installed per plans and details? Placement allows backup (per design) with positive flow relief through system? Erosion control devices installed according to plans?			
B20	**Finish Grading:** Grading and surface elevations match plans and details? Finish surface grading completed using hand tools? Surface able to collect and infiltrate water?			
B21	**Erosion Control Matting:** Erosion control mat product matches specifications? Submittals reviewed and approved?			
B22	**Erosion Control Matting Installation:** Erosion control mat placed according to plan location and grade? Manufacturer's recommendations followed?			
B23	**Erosion Control Devices:** Splash Pad/energy dissipator/cobble matches specifications? Submittals reviewed and approved?			
B24	**Erosion Control Devices Installation:** Installed evenly and meet finish grade per plans? Correct materials used?			
B25	**Plant Material:** Plant materials meets specification when it arrived on site? Any substitutions in plant material approved to ensure plant health?			
B26	**Plant Material Installation:** Plants installed same day as delivery? Plants watered immediately after installation? Placement matches design plans and details?			
B27	**Mulch:** Material meets specifications? Submittal information submitted and approved?			
B28	**Mulch Placement:** Depth of placement matches design plans and details? Surface grading matches plans? Mulch placed evenly to prevent weeds and soil erosion?			
B29	**E & S Controls:** Adjacent areas are stabilized and/or proper E & S controls are in place to protect surface infiltration zones from sedimentation? Infiltration areas free from sediment following rain events?			

B30	**As-Builts:** As-builts drawings are complete and properly document any field changes to the design?			
B31	**Flow Monitoring Equipment:** Flow monitoring equipment meets the requirements of the plan, details, and specification? Equipment in correct locations per design? Equipment properly protected from vandalism and theft?			

OTHER RELEVANT OBSERVATIONS/FIELD REQUIRED CHANGES TO DESIGN

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW)
Green Stormwater Infrastructure (GSI) Practices
CONSTRUCTION INSPECTION FORM

INSPECTION INFORMATION				
Inspector:			Date of Inspection:	
Contractor Present?	☐ Yes	☐ No	Start Time:	End Time:
Inspection Type:	☐ Follow Up	☐ Regular	Current Weather:	
Photographs Taken?	☐ Yes	☐ No		
Reason for Inspection:	☐ Material Review ☐ Other:	☐ Regularly Scheduled/ Milestone ☐ Field Change/Question		☐ Pre-Construction ☐ Final Closeout

SITE INFORMATION		
Site Description/Name:		
Site Address:		
Collection System Type:	☐ Combined Sewer	☐ Separated Sewer
Facility Types to Be Inspected on Site:	☐ Bioretention ☐ Infiltration Trench	☐ Permeable Pavement ☐ Other:

MUNICIPAL INFORMATION	
Municipality or Municipal Authority:	
Contact Name:	Phone:
Contact Address:	Email:

CONTRACTOR INFORMATION	
Primary Contractor:	
Contact Name / Person Present:	Phone:
Contact Address:	Email:

PRE-CONSTRUCTION CHECKLIST			
Site Plans & Details Reviewed?	☐ Yes	☐ No	☐ N/A
GSI Construction Specifications Reviewed?	☐ Yes	☐ No	☐ N/A
Soils Tested and Results Reviewed?	☐ Yes	☐ No	☐ N/A
Construction Schedule and Sequence Reviewed?	☐ Yes	☐ No	☐ N/A
Pre-Construction Meeting Complete?	☐ Yes	☐ No	☐ N/A
If yes, date of meeting:	If no, scheduled meeting date:		

CONSTRUCTION SITE INSPECTION – INFILTRATION TRENCH				
Site Name:				
Infiltration Trench Type:	☐ Tree Trench/Trench below Vegetation	☐ Trench below Pavement	☐ Surface Flow Infiltration	☐ Other:

CONSTRUCTION SITE CONDITIONS – INFILTRATION TRENCH See Table 2-2 in the GSI Construction Inspection Guide for more detailed information on each construction task.				
TASK NUMBER	**CONSTRUCTION TASK**	**STATUS**	**PHOTO NO.**	**NOTES/ACTIONS**
I1	**E & S:** E&S controls installed and properly maintained to prevent fouling of GSI facilities?			
I2	**Site Access/Safety:** Pedestrian and vehicle access restricted with adequate public safety controls in place?			
I3	**Material Storage:** Storage areas located according to plans and adequately protected?			
I4	**Tree Protection:** Tree protection installed according to plans and no equipment/material storage within root zones?			
I5	**Utilities:** Existing utilities within the limit of disturbance located and properly marked out?			
I6	**Demolition/Clearing & Grubbing**: Demo/Clearing zones are limited to area of work only?			
I7	**Excavation**: Excavation within GSI footprint to line and grades indicated on plans? Equipment kept off of all infiltrating surfaces? Tree roots are cleanly cut, flush with side walls?			
I8	**Subgrade:** Exposed sub-grade is uniform, uncompacted and free of sediment and deleterious materials? Subgrade elevation in accordance with plans? Protected from sediment once final elevation reached?			
I9	**Geotextile/Liners:** Geotextile/liner is clean, undamaged, and installed according to plans and details? Seams are properly overlapped?			
I10	**Underdrain/Distribution Pipes:** Size, material, location, perforations, and elevation of pipe per plans?			
I11	**Inlets, Catch basins, Outlet Structure:** Size, material, location, and elevations per plans?			
I12	**Weir and Baffles (if Applicable):** Structures submitted meet requirements of specification? Submittal has been reviewed and approved?			
I13	**Storage Aggregates:** Aggregate material is clean and sized according to plans and specifications? Material submittal reviewed and approved?			
I14	**Storage Aggregate Placement**: Aggregate has been placed in proper lifts to depths indicated on plans and has been compacted according to specifications? Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement?			

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES
I15	**Graded Aggregate Filter Layer:** Aggregate material is clean and sized according to plans and specifications?			
I16	**Graded Aggregate Filter Layer Placement**: Aggregate Filter Layer place between storage aggregate and backfill material? Filter Layer placed to depth indicated on plans? Compaction equipment has not crushed aggregate?			
I17	**Backfill:** Material meets specifications? Material submittal reviewed and approved?			
I18	**Backfill Installation:** Geotextile his been properly wrapped over the top of storage aggregates with 18" minimum overlap? Depth of placement matched design plans and detail? Geotextile hasn't been damaged?			
I19	**Finish Grading and Surfacing:** Grading and surface elevations match plans and details? Vegetated surfaces are protected from erosion? Pavement installed to line and grade shown on plans?			
I20	**E & S Controls:** Adjacent areas are stabilized and/or proper E & S controls are in place to protect surface infiltration zones from sedimentation? Infiltration areas free from sediment following rain events?			
I21	**As-Builts**: As-builts drawings are complete and properly document any field changes to the design?			
I22	**Flow Monitoring Equipment:** Flow monitoring equipment meets the requirements of the plan, details, and specification? Equipment in correct locations per design? Equipment properly protected from vandalism and theft?			

OTHER RELEVANT OBSERVATIONS/FIELD REQUIRED CHANGES TO DESIGN

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW)
Green Stormwater Infrastructure (GSI) Practices
CONSTRUCTION INSPECTION FORM

INSPECTION INFORMATION				
Inspector:			Date of Inspection:	
Contractor Present?	☐ Yes	☐ No	Start Time:	End Time:
Inspection Type:	☐ Follow Up	☐ Regular	Current Weather:	
Photographs Taken?	☐ Yes	☐ No		
Reason for Inspection:	☐ Material Review ☐ Other:	☐ Regularly Scheduled/ Milestone ☐ Field Change/Question	☐ Pre-Construction ☐ Final Closeout	

SITE INFORMATION		
Site Description/Name:		
Site Address:		
Collection System Type:	☐ Combined Sewer	☐ Separated Sewer
Facility Types to Be Inspected on Site:	☐ Bioretention ☐ Infiltration Trench	☐ Permeable Pavement ☐ Other:

MUNICIPAL INFORMATION	
Municipality or Municipal Authority:	
Contact Name:	Phone:
Contact Address:	Email:

CONTRACTOR INFORMATION	
Primary Contractor:	
Contact Name / Person Present:	Phone:
Contact Address:	Email:

PRE-CONSTRUCTION CHECKLIST			
Site Plans & Details Reviewed?	☐ Yes	☐ No	☐ N/A
GSI Construction Specifications Reviewed?	☐ Yes	☐ No	☐ N/A
Soils Tested and Results Reviewed?	☐ Yes	☐ No	☐ N/A
Construction Schedule and Sequence Reviewed?	☐ Yes	☐ No	☐ N/A
Pre-Construction Meeting Complete?	☐ Yes	☐ No	☐ N/A
If yes, date of meeting:	If no, scheduled meeting date:		

CONSTRUCTION SITE INSPECTION - PERMEABLE PAVEMENT				
Site Name:				
Permeable Pavement Type: ☐ Permeable Block Pavers ☐ Porous Asphalt ☐ Porous Concrete ☐ Open Grid Pavers				
CONSTRUCTION SITE CONDITIONS - PERMEABLE PAVEMENT See Table 2-3 in the GSI Construction Inspection Guide for more detailed information on each construction task.				
TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES/ACTIONS
P1	**E & S:** E&S controls installed and properly maintained to prevent fouling of GSI facilities?			
P2	**Site Access/Safety:** Pedestrian and vehicle access restricted with adequate public safety controls in place?			
P3	**Material Storage:** Storage areas located according to plans and adequately protected?			
P4	**Tree Protection:** Tree protection installed according to plans and no equipment/material storage within root zones?			
P5	**Utilities:** Existing utilities within the limit of disturbance located and properly marked out?			
P6	**Demolition/Clearing & Grubbing**: Demo/Clearing zones are limited to area of work only?			
P7	**Excavation**: Excavation within GSI footprint to line and grades indicated on plans? Equipment kept off of all infiltrating surfaces? Tree roots are cleanly cut, flush with side walls?			
P8	**Subgrade:** Exposed sub-grade is uniform, uncompacted and free of sediment and deleterious materials? Subgrade elevation in accordance with plans?			
P9	**Geotextile/Liners:** Geotextile/liner is clean, undamaged, and installed according to plans and details? Seams are properly overlapped?			
P10	**Underdrain/Distribution Pipes:** Size, material, location, perforations, and elevation of pipe per plans?			
P11	**Inlets, Catch basins, Control Structure:** Size, material, location, and elevations per plans?			
P12	**Edge Treatments:** Edge treatments/curbs have been installed according to plans and details? Curbs and other structures have not been undermined by GSI excavations?			
P13	**Storage Aggregates:** Aggregate material is clean and sized according to plans and specifications? Material submittal reviewed and approved?			
P14	**Storage Aggregate Placement**: Aggregate has been placed in proper lifts to depths indicated on plans and has been compacted according to specifications? Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement?			
P15	**Aggregate Choker Course:** Aggregate material is clean and sized according to plans and specifications?			

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES
P16	**Choker Course Placement:** Choker course placed to depth indicated on plans and has been compacted adequately to provide a level surface for paving?			
P17	**Bedding Layer (Pavers only):** Bedding aggregate is clean and sized according to plans and specifications? Bedding aggregate placed to depths indicated on plans and compacted per specifications?			
P18	**Geogrid:** Geogrid material submitted meets requirements of specification? Submittal has been reviewed and approved?			
P19	**Weir and Baffles (if Applicable):** Structures submitted meet requirements of specification? Submittal has been reviewed and approved?			
P20	**Permeable Pavement:** Pavement material submittal meets requirements of specification and has been certified by material producer? Submittal has been reviewed and approved? Supplier/manufacturer is correct?			
P21	**Permeable Pavement Installation:** Pavement installed to depths on plan? Road crown constructed? Pavement protected from sediment during installation?			
P22	**Asphalt Pavement Installation:** Pavement installed in lifts and to depths indicated on plans? Pavement installation techniques meet requirements in specification? Compaction adequate?			
P23	**Concrete Pavement Installation:** Test Panel Installation: Forms installed properly? Placement technique conforms to specifications? Testing/core sample indicates material meets specifications for density, permeability, and void content? General Installation: Forms installed properly? Placement techniques meet requirements of specification? Jointing and finishing meets specification? Concrete is immediately covered and remains securely covered after placement for curing?			
P24	**Paver Installation:** Pavers installed in correct pattern and according to plans and specifications? Joints filled with approved aggregate material and surface compacted with vibratory plate compactor and/or in accordance with plans, specifications, and manufacturer's recommendations?			
P25	**Pavement Curing:** Pavement is protected from vehicular/pedestrian traffic and curing techniques meet requirements of specification?			
P26	**E & S Controls:** Adjacent areas are stabilized and/or proper E & S controls are in place to protect pavement surface from sedimentation before, during, and following pavement installation until areas are fully stabilized?			
P27	**Pavement Testing:** Surface permeability tests indicate that pavement surface drains at a rate that meets specification?			

OTHER RELEVANT OBSERVATIONS/FIELD REQUIRED CHANGES TO DESIGN

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW)
Green Stormwater Infrastructure (GSI) Practices
CONSTRUCTION INSPECTION FORM

INSPECTION INFORMATION				
Inspector:			Date of Inspection:	
Contractor Present?	☐ Yes	☐ No	Start Time:	End Time:
Inspection Type:	☐ Follow Up	☐ Regular	Current Weather:	
Photographs Taken?	☐ Yes	☐ No		
Reason for Inspection:	☐ Material Review ☐ Other:	☐ Regularly Scheduled/ Milestone ☐ Field Change/Question	☐ Pre-Construction ☐ Final Closeout	

SITE INFORMATION		
Site Description/Name:		
Site Address:		
Collection System Type:	☐ Combined Sewer	☐ Separated Sewer
Facility Types to Be Inspected on Site:	☐ Bioretention ☐ Infiltration Trench	☐ Permeable Pavement ☐ Other:

MUNICIPAL INFORMATION	
Municipality or Municipal Authority:	
Contact Name:	Phone:
Contact Address:	Email:

CONTRACTOR INFORMATION	
Primary Contractor:	
Contact Name / Person Present:	Phone:
Contact Address:	Email:

PRE-CONSTRUCTION CHECKLIST			
Site Plans & Details Reviewed?	☐ Yes	☐ No	☐ N/A
GSI Construction Specifications Reviewed?	☐ Yes	☐ No	☐ N/A
Soils Tested and Results Reviewed?	☐ Yes	☐ No	☐ N/A
Construction Schedule and Sequence Reviewed?	☐ Yes	☐ No	☐ N/A
Pre-Construction Meeting Complete?	☐ Yes	☐ No	☐ N/A
If yes, date of meeting:	If no, scheduled meeting date:		

CONSTRUCTION SITE INSPECTION – BIORETENTION SYSTEM				
Site Name:				
Bioretention System Type: ☐ Basin ☐ Rain Garden ☐ Planter ☐ Swale ☐ Other:				
CONSTRUCTION SITE CONDITIONS – BIORETENTION SYSTEM See Table 2-1 in the GSI Construction Inspection Guide for more detailed information on each construction task.				
TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES/ACTIONS
B1	**E & S:** E&S controls installed and properly maintained to prevent fouling of GSI facilities?			
B2	**Site Access/Safety:** Pedestrian and vehicle access restricted with adequate public safety controls in place?			
B3	**Material Storage:** Storage areas located according to plans and adequately protected?			
B4	**Tree Protection:** Tree protection installed according to plans and no equipment/material storage within root zones?			
B5	**Utilities:** Existing utilities within the limit of disturbance located and properly marked out?			
B6	**Demolition/Clearing & Grubbing**: Demo/Clearing zones are limited to area of work only?			
B7	**Excavation**: Excavation within GSI footprint to line and grades indicated on plans? Equipment kept off of all infiltrating surfaces? Tree roots are cleanly cut, flush with side walls?			
B8	**Subgrade:** Exposed sub-grade is uniform, uncompacted and free of sediment and deleterious materials? Subgrade elevation in accordance with plans? Protected from sediment once final elevation reached?			
B9	**Geotextile/Liners:** Geotextile/liner is clean, undamaged, and installed according to plans and details? Seams are properly overlapped?			
B10	**Underdrain/Distribution Pipes:** Size, material, location, perforations, and elevation of pipe per plans?			
B11	**Catch Basins/Outlet Structure/Domed Riser:** Size, material, location, components, pipe connections, and elevations per plans?			
B12	**Storage Aggregates:** Aggregate material is clean and sized according to plans and specifications? Material submittal reviewed and approved?			
B13	**Storage Aggregate Placement**: Aggregate has been placed in proper lifts to depths indicated on plans and has been compacted according to specifications? Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement?			
B14	**Graded Aggregate Filter Layer:** Aggregate material is clean and sized according to plans and specifications?			

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES
B15	**Graded Aggregate Filter Layer Placement**: Aggregate Filter Layer place between storage aggregate and backfill material? Filter Layer placed to depth indicated on plans?			
B16	**Surface Inlet/Trench Drains/Curb Cuts:** Inlet size, location, and elevation per plans and details? Placement and orientation allows runoff flow into system? Erosion control devices installed per plans and lower than surface inlet?			
B17	**Engineered Bioretention Soil:** Soil media product meets requirements of specifications? Submittal and testing information submitted and approved?			
B18	**Engineered Bioretention Soil Placement:** Depth of placement matches design plans and details? Soil materials placed in proper lifts? Soil lightly compacted by hand or sprinkled with water to ensure they are not over compacted?			
B19	**Grade Control Structures:** Check dams, weirs, ect. height, size, location, material, and elevation installed per plans and details? Placement allows backup (per design) with positive flow relief through system? Erosion control devices installed according to plans?			
B20	**Finish Grading:** Grading and surface elevations match plans and details? Finish surface grading completed using hand tools? Surface able to collect and infiltrate water?			
B21	**Erosion Control Matting:** Erosion control mat product matches specifications? Submittals reviewed and approved?			
B22	**Erosion Control Matting Installation:** Erosion control mat placed according to plan location and grade? Manufacturer's recommendations followed?			
B23	**Erosion Control Devices:** Splash Pad/energy dissipator/cobble matches specifications? Submittals reviewed and approved?			
B24	**Erosion Control Devices Installation:** Installed evenly and meet finish grade per plans? Correct materials used?			
B25	**Plant Material:** Plant materials meets specification when it arrived on site? Any substitutions in plant material approved to ensure plant health?			
B26	**Plant Material Installation:** Plants installed same day as delivery? Plants watered immediately after installation? Placement matches design plans and details?			
B27	**Mulch:** Material meets specifications? Submittal information submitted and approved?			
B28	**Mulch Placement:** Depth of placement matches design plans and details? Surface grading matches plans? Mulch placed evenly to prevent weeds and soil erosion?			
B29	**E & S Controls:** Adjacent areas are stabilized and/or proper E & S controls are in place to protect surface infiltration zones from sedimentation? Infiltration areas free from sediment following rain events?			

B30	**As-Builts:** As-builts drawings are complete and properly document any field changes to the design?			
B31	**Flow Monitoring Equipment:** Flow monitoring equipment meets the requirements of the plan, details, and specification? Equipment in correct locations per design? Equipment properly protected from vandalism and theft?			

OTHER RELEVANT OBSERVATIONS/FIELD REQUIRED CHANGES TO DESIGN

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW)
Green Stormwater Infrastructure (GSI) Practices
CONSTRUCTION INSPECTION FORM

INSPECTION INFORMATION				
Inspector:			Date of Inspection:	
Contractor Present?	☐ Yes	☐ No	Start Time:	End Time:
Inspection Type:	☐ Follow Up	☐ Regular	Current Weather:	
Photographs Taken?	☐ Yes	☐ No		
Reason for Inspection:	☐ Material Review ☐ Other:	☐ Regularly Scheduled/ Milestone ☐ Field Change/Question	☐ Pre-Construction ☐ Final Closeout	

SITE INFORMATION		
Site Description/Name:		
Site Address:		
Collection System Type:	☐ Combined Sewer	☐ Separated Sewer
Facility Types to Be Inspected on Site:	☐ Bioretention ☐ Infiltration Trench	☐ Permeable Pavement ☐ Other:

MUNICIPAL INFORMATION	
Municipality or Municipal Authority:	
Contact Name:	Phone:
Contact Address:	Email:

CONTRACTOR INFORMATION	
Primary Contractor:	
Contact Name / Person Present:	Phone:
Contact Address:	Email:

PRE-CONSTRUCTION CHECKLIST			
Site Plans & Details Reviewed?	☐ Yes	☐ No	☐ N/A
GSI Construction Specifications Reviewed?	☐ Yes	☐ No	☐ N/A
Soils Tested and Results Reviewed?	☐ Yes	☐ No	☐ N/A
Construction Schedule and Sequence Reviewed?	☐ Yes	☐ No	☐ N/A
Pre-Construction Meeting Complete?	☐ Yes	☐ No	☐ N/A
If yes, date of meeting:	If no, scheduled meeting date:		

CONSTRUCTION SITE INSPECTION – INFILTRATION TRENCH

Site Name:

Infiltration Trench Type: ☐ Tree Trench/Trench below Vegetation ☐ Trench below Pavement ☐ Surface Flow Infiltration ☐ Other:

CONSTRUCTION SITE CONDITIONS – INFILTRATION TRENCH

See Table 2-2 in the GSI Construction Inspection Guide for more detailed information on each construction task.

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES/ACTIONS
I1	**E & S:** E&S controls installed and properly maintained to prevent fouling of GSI facilities?			
I2	**Site Access/Safety:** Pedestrian and vehicle access restricted with adequate public safety controls in place?			
I3	**Material Storage:** Storage areas located according to plans and adequately protected?			
I4	**Tree Protection:** Tree protection installed according to plans and no equipment/material storage within root zones?			
I5	**Utilities:** Existing utilities within the limit of disturbance located and properly marked out?			
I6	**Demolition/Clearing & Grubbing**: Demo/Clearing zones are limited to area of work only?			
I7	**Excavation**: Excavation within GSI footprint to line and grades indicated on plans? Equipment kept off of all infiltrating surfaces? Tree roots are cleanly cut, flush with side walls?			
I8	**Subgrade:** Exposed sub-grade is uniform, uncompacted and free of sediment and deleterious materials? Subgrade elevation in accordance with plans? Protected from sediment once final elevation reached?			
I9	**Geotextile/Liners:** Geotextile/liner is clean, undamaged, and installed according to plans and details? Seams are properly overlapped?			
I10	**Underdrain/Distribution Pipes:** Size, material, location, perforations, and elevation of pipe per plans?			
I11	**Inlets, Catch basins, Outlet Structure:** Size, material, location, and elevations per plans?			
I12	**Weir and Baffles (if Applicable):** Structures submitted meet requirements of specification? Submittal has been reviewed and approved?			
I13	**Storage Aggregates:** Aggregate material is clean and sized according to plans and specifications? Material submittal reviewed and approved?			
I14	**Storage Aggregate Placement**: Aggregate has been placed in proper lifts to depths indicated on plans and has been compacted according to specifications? Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement?			

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES
I15	**Graded Aggregate Filter Layer:** Aggregate material is clean and sized according to plans and specifications?			
I16	**Graded Aggregate Filter Layer Placement**: Aggregate Filter Layer place between storage aggregate and backfill material? Filter Layer placed to depth indicated on plans? Compaction equipment has not crushed aggregate?			
I17	**Backfill:** Material meets specifications? Material submittal reviewed and approved?			
I18	**Backfill Installation:** Geotextile his been properly wrapped over the top of storage aggregates with 18" minimum overlap? Depth of placement matched design plans and detail? Geotextile hasn't been damaged?			
I19	**Finish Grading and Surfacing:** Grading and surface elevations match plans and details? Vegetated surfaces are protected from erosion? Pavement installed to line and grade shown on plans?			
I20	**E & S Controls:** Adjacent areas are stabilized and/or proper E & S controls are in place to protect surface infiltration zones from sedimentation? Infiltration areas free from sediment following rain events?			
I21	**As-Builts**: As-builts drawings are complete and properly document any field changes to the design?			
I22	**Flow Monitoring Equipment:** Flow monitoring equipment meets the requirements of the plan, details, and specification? Equipment in correct locations per design? Equipment properly protected from vandalism and theft?			

OTHER RELEVANT OBSERVATIONS/FIELD REQUIRED CHANGES TO DESIGN

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW)
Green Stormwater Infrastructure (GSI) Practices
CONSTRUCTION INSPECTION FORM

INSPECTION INFORMATION				
Inspector:			Date of Inspection:	
Contractor Present?	☐ Yes	☐ No	Start Time:	End Time:
Inspection Type:	☐ Follow Up	☐ Regular	Current Weather:	
Photographs Taken?	☐ Yes	☐ No		
Reason for Inspection:	☐ Material Review ☐ Other:	☐ Regularly Scheduled/ Milestone ☐ Field Change/Question	☐ Pre-Construction ☐ Final Closeout	

SITE INFORMATION		
Site Description/Name:		
Site Address:		
Collection System Type:	☐ Combined Sewer	☐ Separated Sewer
Facility Types to Be Inspected on Site:	☐ Bioretention ☐ Infiltration Trench	☐ Permeable Pavement ☐ Other:

MUNICIPAL INFORMATION	
Municipality or Municipal Authority:	
Contact Name:	Phone:
Contact Address:	Email:

CONTRACTOR INFORMATION	
Primary Contractor:	
Contact Name / Person Present:	Phone:
Contact Address:	Email:

PRE-CONSTRUCTION CHECKLIST			
Site Plans & Details Reviewed?	☐ Yes	☐ No	☐ N/A
GSI Construction Specifications Reviewed?	☐ Yes	☐ No	☐ N/A
Soils Tested and Results Reviewed?	☐ Yes	☐ No	☐ N/A
Construction Schedule and Sequence Reviewed?	☐ Yes	☐ No	☐ N/A
Pre-Construction Meeting Complete?	☐ Yes	☐ No	☐ N/A
If yes, date of meeting:	If no, scheduled meeting date:		

CONSTRUCTION SITE INSPECTION - PERMEABLE PAVEMENT				
Site Name:				
Permeable Pavement Type: ☐ Permeable Block Pavers ☐ Porous Asphalt ☐ Porous Concrete ☐ Open Grid Pavers				
CONSTRUCTION SITE CONDITIONS - PERMEABLE PAVEMENT See Table 2-3 in the GSI Construction Inspection Guide for more detailed information on each construction task.				

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES/ACTIONS
P1	**E & S:** E&S controls installed and properly maintained to prevent fouling of GSI facilities?			
P2	**Site Access/Safety:** Pedestrian and vehicle access restricted with adequate public safety controls in place?			
P3	**Material Storage:** Storage areas located according to plans and adequately protected?			
P4	**Tree Protection:** Tree protection installed according to plans and no equipment/material storage within root zones?			
P5	**Utilities:** Existing utilities within the limit of disturbance located and properly marked out?			
P6	**Demolition/Clearing & Grubbing**: Demo/Clearing zones are limited to area of work only?			
P7	**Excavation**: Excavation within GSI footprint to line and grades indicated on plans? Equipment kept off of all infiltrating surfaces? Tree roots are cleanly cut, flush with side walls?			
P8	**Subgrade:** Exposed sub-grade is uniform, uncompacted and free of sediment and deleterious materials? Subgrade elevation in accordance with plans?			
P9	**Geotextile/Liners:** Geotextile/liner is clean, undamaged, and installed according to plans and details? Seams are properly overlapped?			
P10	**Underdrain/Distribution Pipes:** Size, material, location, perforations, and elevation of pipe per plans?			
P11	**Inlets, Catch basins, Control Structure:** Size, material, location, and elevations per plans?			
P12	**Edge Treatments:** Edge treatments/curbs have been installed according to plans and details? Curbs and other structures have not been undermined by GSI excavations?			
P13	**Storage Aggregates:** Aggregate material is clean and sized according to plans and specifications? Material submittal reviewed and approved?			
P14	**Storage Aggregate Placement**: Aggregate has been placed in proper lifts to depths indicated on plans and has been compacted according to specifications? Geotextile/liner is undamaged and infiltrating subgrades have not been compacted during placement?			
P15	**Aggregate Choker Course:** Aggregate material is clean and sized according to plans and specifications?			

TASK NUMBER	CONSTRUCTION TASK	STATUS	PHOTO NO.	NOTES
P16	**Choker Course Placement:** Choker course placed to depth indicated on plans and has been compacted adequately to provide a level surface for paving?			
P17	**Bedding Layer (Pavers only):** Bedding aggregate is clean and sized according to plans and specifications? Bedding aggregate placed to depths indicated on plans and compacted per specifications?			
P18	**Geogrid:** Geogrid material submitted meets requirements of specification? Submittal has been reviewed and approved?			
P19	**Weir and Baffles (if Applicable):** Structures submitted meet requirements of specification? Submittal has been reviewed and approved?			
P20	**Permeable Pavement:** Pavement material submittal meets requirements of specification and has been certified by material producer? Submittal has been reviewed and approved? Supplier/manufacturer is correct?			
P21	**Permeable Pavement Installation:** Pavement installed to depths on plan? Road crown constructed? Pavement protected from sediment during installation?			
P22	**Asphalt Pavement Installation:** Pavement installed in lifts and to depths indicated on plans? Pavement installation techniques meet requirements in specification? Compaction adequate?			
P23	**Concrete Pavement Installation:** Test Panel Installation: Forms installed properly? Placement technique conforms to specifications? Testing/core sample indicates material meets specifications for density, permeability, and void content? General Installation: Forms installed properly? Placement techniques meet requirements of specification? Jointing and finishing meets specification? Concrete is immediately covered and remains securely covered after placement for curing?			
P24	**Paver Installation:** Pavers installed in correct pattern and according to plans and specifications? Joints filled with approved aggregate material and surface compacted with vibratory plate compactor and/or in accordance with plans, specifications, and manufacturer's recommendations?			
P25	**Pavement Curing:** Pavement is protected from vehicular/pedestrian traffic and curing techniques meet requirements of specification?			
P26	**E & S Controls:** Adjacent areas are stabilized and/or proper E & S controls are in place to protect pavement surface from sedimentation before, during, and following pavement installation until areas are fully stabilized?			
P27	**Pavement Testing:** Surface permeability tests indicate that pavement surface drains at a rate that meets specification?			

OTHER RELEVANT OBSERVATIONS/FIELD REQUIRED CHANGES TO DESIGN

CHAPTER 5

GSI Operations and Maintenance Guidance

SECTION 1

Introduction to O&M

After successful construction of green stormwater infrastructure (GSI) projects, proper operation and maintenance (O&M) is required to ensure long-term performance of the GSI facility. GSI requires maintenance to remain functional and to serve as an aesthetic asset to the community. O&M for GSI is not optional under the GROW program – it is required to comply with maintenance agreements established as part of the GROW grant approval process.

This document provides guidelines to facilitate successful O&M of green stormwater infrastructure projects within the ALCOSAN service area. This chapter includes information on general best practices for GSI operation and maintenance tasks, corrective actions to address common deficiencies, and site conditions that typically affect GSI maintenance needs. It is intended to detail GROW program requirements for GSI maintenance plans, as well as provide an overview of budgeting for maintenance tasks. This chapter primarily covers bioretention and rain gardens, infiltration trenches and surface detention, and permeable pavements.

Section 1 introduces the chapter as well as provides information on GROW program GSI operation and maintenance requirements, including owner responsibilities and reporting requirements.

Section 2 details O&M activities and frequencies by GSI type. It includes general recommendations for routine, non-routine and reactive maintenance.

Section 3 provides guidelines to assess GSI conditions through maintenance inspections for each GSI technology and illustrates typical site conditions that indicate when maintenance is required including potential corrective actions.

Section 4 provides planning-level maintenance budgeting guidelines and factors that influence maintenance costs. Annual self-certification checklists to be used for maintenance reporting are provided in Appendix 5-A**.**

This O&M chapter was developed to assist municipalities and municipal sewer authorities in planning for, developing and implementing GSI maintenance plans GSI projects funded under ALCOSAN's GROW grant program. It is not intended to provide detailed standard operating procedures for GSI maintenance, required equipment lists or maintenance training. There is a wealth of information available at the state and national level that provides more detailed information and guidance to supplement maintenance planning efforts. A list of recommended resources that may be helpful in developing project maintenance plans is provided in Appendix 5-B.

1.1 GROW Program GSI O&M Requirements Overview

1.1.1 Operations and Maintenance Requirements

Every GROW-funded GSI project is required to develop a project specific operation and maintenance plan which must be approved and submitted to ALCOSAN. GROW grant awardees are required to operate and maintain the GSI project in accordance with the GROW program agreement for at least 20 years following the date on which construction of each source control is certified by ALCOSAN to be complete.

1.1.2 Operations and Maintenance Plan

It is the responsibility of the owner of the GSI practice to develop an appropriate O&M plan. General maintenance activities and frequencies are provided in Section 2 to help develop a GSI O&M plan. The following items are the minimum requirements for all GSI O&M Plans under the GROW program.

- As-built drawings showing labeled locations of each GSI system included in the maintenance plan
- Identification and contact information of entities, maintenance contractor or municipal departments responsible for maintaining the GSI practice
- Contact information for the individuals responsible for GSI facility inspections and annual self reporting (see Section 1.2.3 for requirements)
- Narrative overview describing the site, drainage area, flow routing, storage volume, draw-down times, peak flow estimates and discharge points/connections
- For each GSI system, anticipated routine and non-routine maintenance tasks, their frequencies and corrective action
- List of required maintenance equipment
- References to manufacturer's maintenance recommendations and manufacturer's warranties where applicable
- Description of required coordination with outside entities that are responsible for maintenance activities on or adjacent to the project site that could affect the GSI facility (e.g., utility tree trimming around overhead wires, existing landscape maintenance in areas adjacent to the GSI facility, municipal street sweeping, winter snow removal, etc.)
- Inspection and maintenance log
- Safety requirements
- Planting plan and plant lists, as applicable
- Special O&M requirements for the establishment period, as applicable
- Winterization requirements, as applicable

1.1.3 Operations and Maintenance Inspection and Compliance Reporting

ALCOSAN requires periodic inspections of GROW-funded GSI practices to ensure that they are properly operated and maintained to provide effective stormwater management. Two types of maintenance inspections are recommended under the GROW program: annual self-certification inspections conducted by the municipality, site owner or site manager, and periodic maintenance inspections conducted by ALCOSAN. ALCOSAN's role in the operation and maintenance of GROW-funded projects is described in the project's GROW grant agreement.

1.1.3.1 Annual Self-Certification Inspection

Every GROW GSI project should complete the self-certification checklist on an annual basis and submit the checklist to ALCOSAN. Sample annual self-certification checklists for each GSI technology are provided in Appendix 5-A. Completed checklists should include an assessment of GSI facility conditions, required maintenance activities and documentation of when the activities were performed. A diagram showing the self-certification process is provided in Figure 1-1.

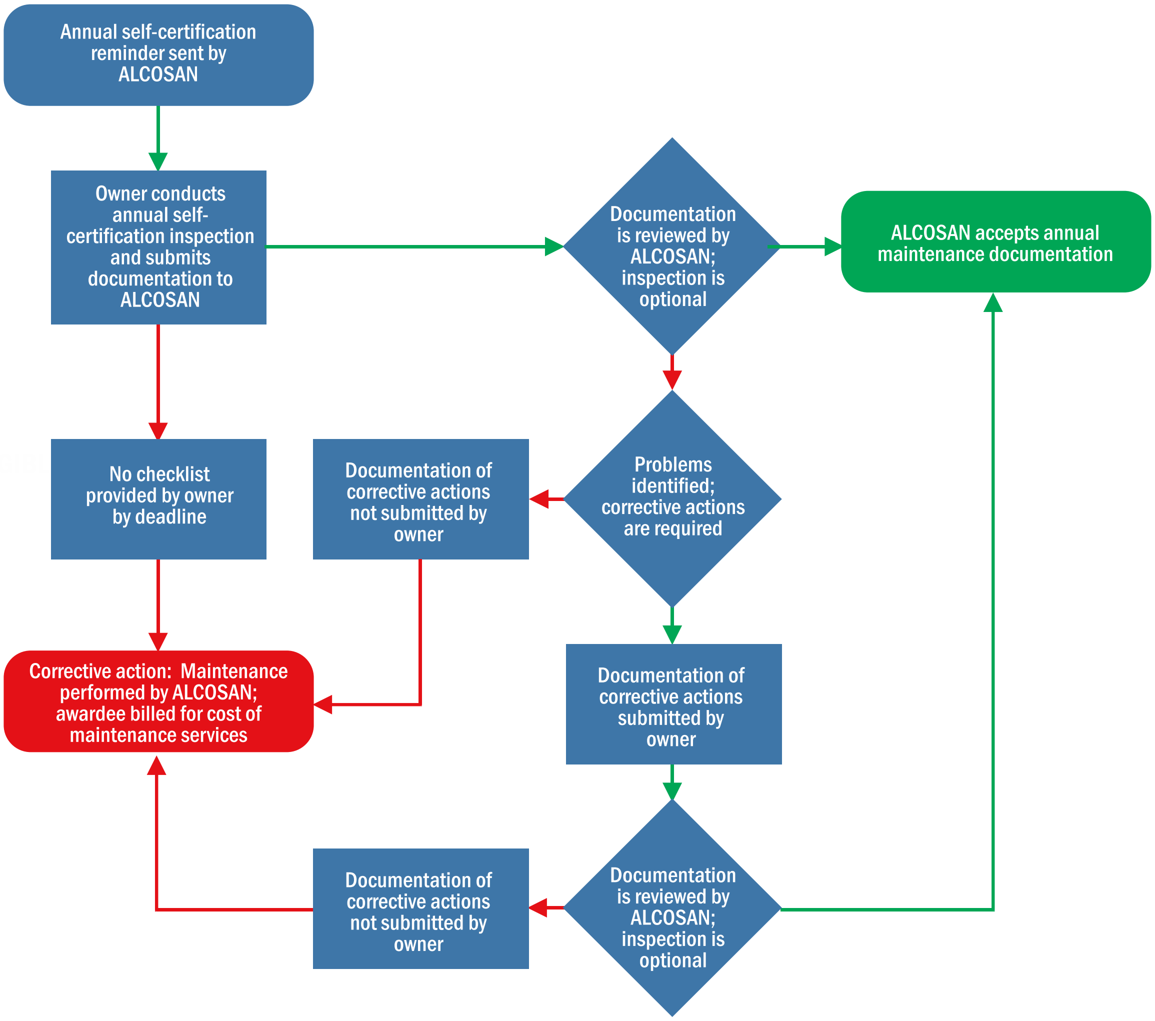


Figure 1-1. Diagram of Annual Self-Certification Process

SECTION 2

Operations and Maintenance Guidelines

2.1 Maintenance Activity Guidelines

An effective O&M program is essential to the long-term success and functionality of green stormwater infrastructure (GSI) systems. Because many GSI systems rely upon vegetation and soils to capture, filter and treat stormwater, vegetation management is an important component of GSI maintenance that will change over time as plant material establishes and grows. In addition, tasks such as the removal of litter, debris and sediment are critical to ensure long-term performance by preventing system clogging and maintaining system permeability and aesthetics. Establishing GSI maintenance procedures and their frequencies for each GROW-funded project will ensure long- term performance of GSI systems in the ALCOSAN service area.

The following sections contain descriptions of the specific maintenance tasks applicable to GSI systems funded by the GROW program. Maintenance tasks are organized by GSI technology and both routine and non-routine or reactive maintenance activities are described.

2.1.1 General Maintenance Activities

There are many maintenance activities that are common to most GSI systems, including activities such as system inspections, general care and good housekeeping, conveyance system maintenance, general repairs and hardware care. Table 2-1 describes these activities in more detail including the activity objective and the GSI technologies to which they pertain. Additional routine and non-routine maintenance activities that are specific to individual GSI technologies are provided in the following sections.

Table 2-1. General Routine and Non-Routine (Reactive) Maintenance Activities for all GSI Technologies

Routine Maintenance				GSI System Type		
Category	**Maintenance Activity**	**Description of Activity**	**Objective**	**Bioretention**	**Infiltration Trench**	**Permeable Pavements**
Inspection	GSI Inspection	Visually inspect GSI system components to ensure the system is functioning and being maintained as indicated in the Operation & Maintenance (O&M) plan.	Assess need for system maintenance and repair; assess long term system performance (e.g., drain down time).	X	X	X
General Surface Care	Trash and Sediment Removal	Remove trash, sediment and/or debris from GSI surfaces (e.g., sidewalks, gutters, splash pads, permeable pavements, etc.).	Prevent clogging of infrastructure, maintain access for inspections, and maintain aesthetics.	X	X	X
	Organic Debris Removal	Remove organic material (leaves, pet waste, etc.) from GSI system surfaces.		X	X	X
	Sediment removal from vegetated areas and/or forebays	Remove accumulated sediment from vegetated system surface, forebay area, energy dissipaters, surface inlets (curb cuts, splash pads, etc.).		X		
Collection System and Pretreatment Device Maintenance	Cleaning	Empty and clean stormwater inlets, catch basins or other conveyance system or overflow structures.	Prevent system and pipe clogging and maintain efficient inflow, overflow, and drain down.	X	X	X
	Pretreatment Device Replacement	Replace missing, damaged or clogged pretreatment device.		X	X	X
Non-Routine (Reactive) Maintenance						
General Repairs	Erosion Repair	Fill eroded areas within GSI or draining onto GSI, place erosion fabric and, if necessary, seed or plant and mulch. Replacement materials, including plants, soil and gravel, must meet design specifications of original materials.	Prevent erosion, scour, and sedimentation on the surface of GSI systems and maintain system performance and aesthetics.	X	X	X
	Concrete Repair	Repair severe cracks or replace concrete.	Maintain structure integrity.	X	X	X
	Settlement Repair	Fill sinkholes or settling with stone, cover with soil, and mulch (as applicable) when settling is 12 to 24 inches deep or more.	Maintain structural integrity and appropriate ponding depth and remove public safety hazards.	X		
	Painting	Paint appropriate structures (fences, planter walls, etc.) when existing paint is in poor condition.	Prevent surface degradation and maintain aesthetics.	X		
	Graffiti Removal	Remove graffiti from signage, structures or GSI surfaces	Maintain aesthetics	X	X	X

Table 2-1. General Routine and Non-Routine (Reactive) Maintenance Activities for all GSI Technologies

Non-Routine (Reactive) Maintenance				GSI System Type		
Category	**Maintenance Activity**	**Description of Activity**	**Objective**	**Bioretention**	**Infiltration Trench**	**Permeable Pavements**
Hardware Care	Cleaning	Clean and grease appurtenances with bolts, locks or hinges when accessed.	Maintain hardware functionality and access to structures.	X	X	X
	Replace grates, caps, covers	Replace missing or damaged grates, covers or caps on inlets, catch basins, cleanouts or other structures.	Protect public safety, prevent unintended access/fouling, maintain performance, and improve aesthetics.	X	X	X
System Restoration	Vegetated System Restoration	Restoration activities required due to high particulate loading or unforeseen event (e.g., flooding or vandalism). May include erosion repair, regrading or recontouring side slopes, replanting, rebuilding or reinforcing structures and energy dissipaters, structure cleaning and pipe jetting. If extreme damage takes place, soil and vegetation restoration and/or replacement may be required.	Restore system functionality, prevent further degradation, and reduce the risk of future damage.	X	X	
	Permeable Pavement and Subsurface Infiltration System Restoration	Restoration activities required due to unforeseen event. May include erosion repair, regrading or recontouring side slopes of adjacent vegetated areas, pavement vacuuming and/or power washing, structure cleaning and pipe jetting. If extreme damage takes place, permeable pavement restoration or installation of underdrain may be required.	Restore system functionality, prevent further degradation, and reduce the risk of future damage.		X	X

2.1.1.1 Routine Inspections

One of the most critical maintenance tasks for the long-term success of GSI systems is general inspection, especially following the initial installation of the GSI system and until a regular maintenance routine is established. Regular and appropriately timed inspections are necessary to ensure the proper operation of GSI facilities over the full life cycle of the installation. Inspectors should be trained in the proper function and appearance of the GSI system and inspections should be seasonally informed to enable timely detection of maintenance needs. Inspections are critical to help to identify non-routine maintenance needs such as erosion and structure repairs and should take place frequently following initial system installation and after significant rain events.

2.1.1.2 General Care and Collection System Maintenance

General care of GSI includes removal of trash, litter, organic debris and sediment. Trash, litter and organic debris must be cleared to maintain aesthetics, to prevent system clogging and to maintain adequate access to system structures. Trash is not only unsightly but can also provide a habitat for vectors such as mosquitoes or clog overflows or other conveyance structures. In vegetated systems, sediment and organic debris, such as decaying leaves and grass, should be removed to prevent surface clogging. Sediment and debris removal at inflow points and sediment forebays is important to prevent runoff bypass and to prevent migration of sediment and debris into infiltration areas. The degree of debris and litter accumulation is widely variable and is influenced by several factors, including surrounding land uses and activities, pedestrian traffic and the presence of trees. Debris should always be removed and disposed of in accordance with local, state and federal law while preventing pollution and public safety hazards.

Figure 2-1. Neglected Forebay

Example of unmaintained sediment forebay in a street planter which has caused surface sedimentation and unsightly trash accumulation.

Collection system maintenance includes cleaning inlets, overflow structures and associated pretreatment devices, such as inlet filter inserts. The effectiveness of pretreatment devices to remove sediment and debris may decrease as the device fills so regular cleaning and inspection is necessary to protect downstream GSI facilities from degradation and clogging. Pretreatment device maintenance varies widely, and manufacturer recommendations should generally be followed to ensure adequate performance. Collection system maintenance and inspection may be required more frequently in the first year following GSI facility installation until site specific maintenance needs are assessed.

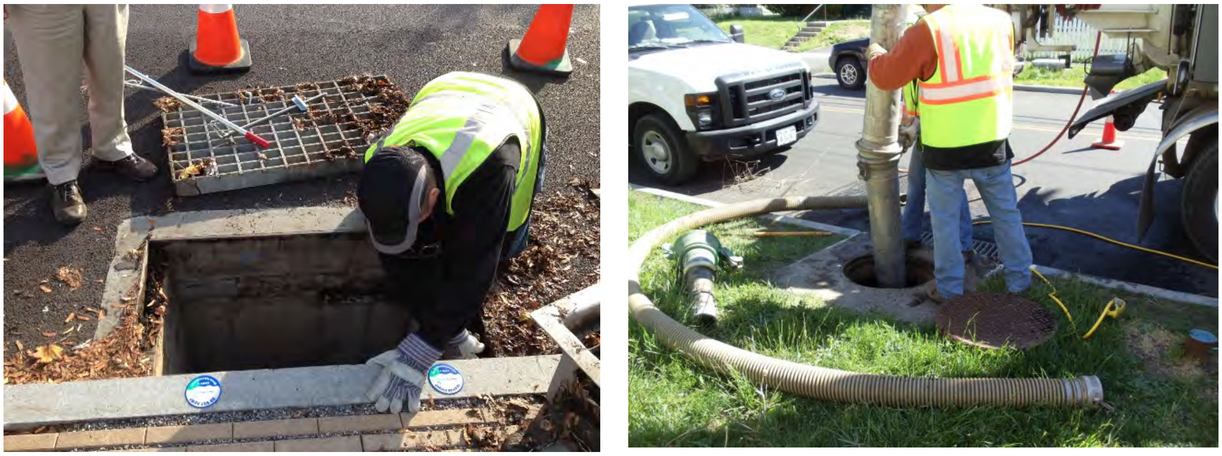


Figure 2-2. Collection System Maintenance
Regular conveyance system maintenance may be completed by hand or with a vactor truck.

2.1.1.3 General Repairs and Hardware Care

Non-routine and reactive maintenance includes structural repairs, erosion repair both in the GSI facility and in adjacent areas that could drain to the facility, repairing sinkholes or other areas of settlement, general surface upkeep (e.g., painting) and hardware care for stormwater structures. Erosion repair is critical to prevent soil rutting and channelization within vegetated GSI facilities, and to prevent clogging of permeable pavements or subsurface infiltration trenches when surrounding soils erode and contaminate pavements and infiltration surfaces. Weirs and other surface flow controls as well as monitoring equipment such as flow meters should be checked to ensure they are functioning properly.

Figure 2-3. Erosion in Bioretention Area
Erosion damage in a bioretention area with inadequate energy dissipation and lack of vegetative growth

Bioretention areas, rain gardens and vegetated slopes are particularly vulnerable to erosion damage during heavy rain events and should be checked frequently in the first year or two after installation. Any damage created from a rain event, including erosion or rock displacement, should be remedied to maintain proper function of the GSI system and keep further damage from occurring.

2.1.2 Vegetated System Maintenance Activities

Figure 2-4. Bioretention in a Parking Lot Island

Although system design and function vary among vegetated GSI systems, their required maintenance activities are relatively similar. Maintenance activities for vegetated systems include tasks to maintain function and aesthetics. For vegetated systems to maintain long-term functionality, routine inspections and maintenance are required. Routine maintenance activities include general care as described above (e.g., trash, litter, organic debris and sediment removal, stormwater drainage structure cleaning) as well as a variety of horticultural activities (Table 2-2). Horticultural activities, including weeding, pruning, mulching, edging, mowing and watering may be needed to maintain the health of vegetation and root systems, maintain aesthetics and maximize pollutant and runoff volume removal.

Table 2-2. Routine Vegetated GSI System Maintenance Activities

Routine Maintenance			Vegetated System Type	
Maintenance Activity	Task Description	Objective	Bioretention System Variations	Tree Trench or Trench Below Vegetation
Weeding	Remove undesired vegetation by hand.	Reduce competition for desired vegetation and improve aesthetics.	X	X
Mowing	Mow turf areas adjacent to or within GSI system.	Allow access to GSI system for maintenance or other uses and improve visual sight lines and aesthetics.	X	X
Mulching	Replace or add mulch with hand tools to design depth per O&M plan.	Replenish organic material in soil, reduce erosion and weeds, retain soil moisture and filter pollutants.	X	X
Remove and Prune Plants	Prune woody vegetation (trees/ shrubs); remove/ split and transplant herbaceous plants to avoid overcrowding.	Maintain adequate plant coverage, avoid overcrowding, prevent overshading, maintain utility clearances and sight distances.	X	X
Watering/ Irrigation	Maintain irrigation system if present or hand water as needed.	Establish vegetation with a minimum 80% survival rate. Prevent die-off and plant stress by hand watering or irrigation during establishment and periods of drought.	X	X
Cutting Back Vegetation	Seasonal cut back/ mowing of herbaceous vegetation and meadow grasses. Remove cut/ mowed plant material.	Mow meadow grasses during establishment period to specified height to eliminate weeds and competition with desired species. Cut back herbaceous vegetation before start of growing season to promote new growth.	X	X

Table 2-2. Routine Vegetated GSI System Maintenance Activities

Routine Maintenance			Vegetated System Type	
Maintenance Activity	**Task Description**	**Objective**	**Bioretention System Variations**	**Tree Trench or Trench Below Vegetation**
Clear overflow and drainage structures	Remove sediment, trash, organic debris from overflow structure grates, piping, roof scuppers and downspouts.	Prevent clogging of infrastructure, maintain access for inspections and aesthetics.	X	X
Winterization	Remove excess leaves, sediment and debris. Use signage, bollards, flagging to discourage and prevent snow storage within bioretention areas. Drain and close internal irrigation system (if present).	Prevent degradation of bioretention system over winter and salt loading associated with snow storage.	X	X

2.1.2.1 Routine Horticultural Care

Vegetated GSI systems require annual plant, soil and mulch maintenance to ensure optimum function. Much of this landscape care can be performed by a variety of entities including landscape contractors, public works and parks staff, and even volunteers such as garden clubs and park/tree tender groups. Most horticultural care activities take place once or twice a year corresponding to the start and end of the growing season (spring and fall), while other activities such as weeding are required throughout the growing season. Detailed information on maintenance activity frequencies and service levels is provided in Section 2.2.

Figure 2-5. Tree Pruning
Typical horticultural maintenance includes tree pruning

Horticultural care activities for GSI systems are similar to traditional landscape maintenance activities and include mowing, weeding, mulching, pruning, spacing and cutting back plants. Typically, vegetated GSI systems are composed of native plantings that, once established, require less maintenance. During establishment, however, more frequent weeding and mowing may be required to eliminate undesired species and reduce competition for desired native species. Pruning and removal of dead plant or tree material helps to maintain plant health and may be more critical in public spaces and along rights-of-way where maintaining sight lines and a more manicured aesthetic is desired. Mulch replacement may be required more frequently in areas where there are high pollutant loadings such as adjacent to industrial uses or along rights-of-way, otherwise mulch is typically replenished only periodically to maintain adequate depth (1 to 3 inches). Because native plants are typically selected for optimum fertility, establishment and growth, nutrients

Watering is often included in a construction contract for one to two years during the plant establishment period to ensure success of the planting plan.

and pesticides should not be applied unless required for corrective action, since they can contribute pollutant loads to receiving waters.

2.1.2.2 Routine Watering

Watering of plants in bioretention systems is typically needed only during establishment and periods of drought. In these scenarios, watering should be conducted to supplement rainfall to provide approximately 1 inch of water per week during the growing season. Because plants are a vital part of bioretention, successful vegetative establishment is extremely important to maintain longevity of the facility and adequate water during establishment is critical to vegetation health and success. Frequently, watering can be included in a construction contract for one to two years during the plant establishment period to ensure healthy plant growth.

Figure 2-6. Example of Vegetation Watering

A temporary irrigation hose in this vegetated system helps ensure proper watering during plant establishment.

2.1.2.3 Winter Maintenance

Minimal winter maintenance is required for vegetated systems and it typically consists of implementing strategies to prevent impacts to dormant vegetation and to maintain or protect system functionality over the winter. Tasks generally include flushing and turning off any irrigation equipment and removing organic debris such as leaf litter and vegetation clippings. If possible, signage, training and/or other methods should be used to discourage snow storage in the vegetated system to prevent salt and sediment loading that might be damaging to plant health and soil permeability.

2.1.2.4 Non-Routine Maintenance

In addition to routine maintenance activities, non-routine or reactive maintenance may be required based on inspection observations or performance concerns. Non-routine and reactive maintenance includes vegetation replacement, pest and disease control, invasive species and mosquito control, soils management, aggregate/structure replacement, and underdrain/pipe cleaning (Table 2-3).

Table 2-3. Non-Routine Vegetated GSI System Maintenance Activities

Non-Routine (Reactive) Maintenance			Vegetated System Type	
Maintenance Activity	Task Description	Objective	Bioretention System Variations	Tree Trench or Trench below Vegetation
Replacement of Dead or Dying Plant Material	Reseed or replant bare spots or poor performing plants.	Maintain plant health, system function and aesthetics.	X	X
Turf Repair	Reseed or sod bare spots.	Prevent erosion and maintain aesthetics.	X	X
Manage/Amend Soil or Growth Media	Remove vegetation (save as much plant material as possible for replanting), remove and replace or amend soil with compost/sand with backhoe, excavator, or by hand if small area. If soils have low biological activity or nutrients, soil may be treated to restore soil biota/organic matter without a need for removal. Fertilizers should generally be avoided as they contribute pollutant loads to receiving waters.	Maintain or restore infiltration capacity, soil fertility/organic matter, pollutant removal capacity and plant health.	X	X

Table 2-3. Non-Routine Vegetated GSI System Maintenance Activities

Non-Routine (Reactive) Maintenance			Vegetated System Type	
Maintenance Activity	Task Description	Objective	Bioretention System Variations	Tree Trench or Trench below Vegetation
Pest and Disease Management	Treat vegetation with environmentally benign insecticides or other treatments as needed to remove, destroy or minimize pests and disease. Remove animal carcasses and/or fill animal burrows with stone and compact.	Prevent damage to vegetation by harmful insects (e.g., bag worms, wax scale, caterpillars, aphids, etc.); galls, mildew and fungus to maintain vegetation health and longevity. Prevent damage to underground structures and animal infestations which may damage vegetation.	X	X
Cobble, Stone, or Gravel Replacement at Energy Dissipaters	Remove sediment, trash and organic debris and replace armoring material in kind where washout, erosions or channelization is observed. Stabilize surrounding vegetation and mulch areas disturbed during maintenance. Re-evaluate velocity if problem persists and/or it is suspected that aggregate size is not adequate to resist flow velocities.	Prevent erosion, scour and sedimentation on the surface of bioretention systems and maintain system aesthetics.	X	
Invasive Vegetation Control	Remove invasive vegetation by hand pulling to ensure removal of roots and/or treat with environmentally benign and non-soluble herbicide or other appropriate methods.	Reduce competition for desired vegetation and improve aesthetics.	X	X
Mosquito Control	Prevent standing water by sediment removal, soil restoration, structure cleaning or use environmentally benign mosquito treatment in structures known to hold water to prevent mosquitos.	Prevent mosquito population proliferation and possible spread of disease.	X	
Underdrain Cleaning/Pipe Jetting	Hydro-jet or rotary cut debris/roots from underdrains and distribution pipes (if present).	Maintain proper subsurface drainage, ponding depths and drain down times.	X	X

2.1.2.5 Non-routine Horticultural Activities and Surface Care

Non-routine maintenance horticultural activities and surface care includes vegetation replacement, invasive species control, soil management and repair/replacement of hydraulic structures and energy dissipaters. Removing invasive species is critical to promote desired plant growth by reducing competition. Dead and dying vegetation should be replaced as needed to maintain system functionality, reduce potential erosion and improve aesthetics.

Figure 2-7. Sediment in Bioretention Area
Example of a bioretention area that has been impacted by sediment-laden runoff

Soil amendments/replacement and hydraulic structure repair activities are typically only necessary due to lack of maintenance, improper design/installation, vandalism or some other unplanned use or event. The degree to which reactive maintenance is required may depend on surrounding land uses, system size and drainage area, and the level of pedestrian and vehicular traffic. For example, lack of proper erosion and sediment controls can cause clogging and sedimentation of bioretention soils, leading to reduced permeability and extended ponding. Sediment removal and soil restoration with compost and sand amendments may restore the system functionality. Inspections following heavy rainfalls should be conducted to evaluate system performance and to mitigate erosion and/or sedimentation.

Lack of proper E&S controls can cause clogging and sedimentation of the bioretention surface, which causes reduced permeability and extended ponding.

2.1.2.6 Non-routine Pest Management & Mosquito Control

Pest management is important to long-term system functionality and to protect public health. Typical pest management activities include insect and disease control to maintain plant health and promote plant longevity. Burrowing animals should be removed when observed as they can eat plants and plant roots and damage subsurface components (e.g., pipes). A properly draining green roof or bioretention system should not require mosquito control. However, in some cases inlet sumps or other pretreatment devices that contain standing water may require mosquito treatment. Because wetlands are designed to hold water, their structures and pretreatment devices may be more susceptible to mosquito problems, but well-designed wetlands with healthy biodiversity and habitat do not typically become mosquito problems as natural predators keep mosquito populations at bay. In bioretention systems, a general design standard prevents conditions where water remains standing on the surface for more than two to three days as mosquitoes require that time to progress through their larval stage.

2.1.2.7 Non-routine Underdrain Cleaning/Pipe Jetting

Vegetated system underdrains and conveyance pipes should be periodically inspected to determine if cleaning/pipe jetting is required. In some cases, system problems such as prolonged ponding, soil saturation or excessive drain down times may indicate a maintenance problem with the underdrain or outlet pipes within the system. In these cases, pipe inspection may be required to determine if the underdrain needs to be cleaned or hydro-jetted to restore system functionality.

2.1.3 Infiltration Trench Maintenance Activities

Infiltration beds and/or trenches are often located under parking lanes, sidewalks, parking lots or other pervious and impervious recreational areas (e.g., basketball courts, athletic fields, etc.). To protect the system from clogging, pretreatment devices are typically installed in conveyance structures, such as inlet filter inserts, to capture and remove sediment and debris from runoff before it is discharged to the subsurface infiltration system.

Figure 2-8. Tree Trench under Sidewalk

Typical routine maintenance activities for infiltration trenches include the general maintenance activities discussed in section 2.1.1 as well as the activities described in Table 2-4 below.

Table 2-4. Routine Infiltration Trench Maintenance Activities

Routine Maintenance			Infiltration Trench Type		
Maintenance Activity	**Task Description**	**Objective**	**Tree Trench or Trench Below Vegetation**	**Trench Below Pavement**	**Surface Flow Infiltration Trench**
Structure and System Vacuum Cleaning	Clean trash/ sediment/ organic debris from inlets, pretreatment devices subsurface access points and flow control/conveyance structures.	Prevent system clogging and maintain efficient inflow, overflow and drain down.	X	X	X
Pipe Inspection/Pipe Jetting	Inspect and clean by hydro-jetting conveyance, distribution and underdrain pipes when 10% or more of cross-sectional area of the pipe is blocked by debris.	Prevent pipe clogging and maintain efficient inflow, overflow and drain down.	X	X	X

Table 2-4. Routine Infiltration Trench Maintenance Activities

Routine Maintenance			Infiltration Trench Type		
Maintenance Activity	**Task Description**	**Objective**	**Tree Trench or Trench Below Vegetation**	**Trench Below Pavement**	**Surface Flow Infiltration Trench**
Maintenance of Surface Aggregates (when present)	Remove accumulated sediment, trash, organic debris from surface of infiltration trench when it impedes sheet flow into the facility.	Prevent clogging of infrastructure; maintain performance, access for inspections and aesthetics.	X		X
Bolt & Lock Care	Clean and grease appurtenances each time component with bolts or locks is opened.	Maintain access to structures for inspection and maintenance. Prevent hardware damage.	X	X	X
Tree & Turf Care	Conduct seasonal and annual maintenance for all trees and groundcovers associated with tree trenches and vegetated surfaces over subsurface infiltration systems. See vegetative system maintenance for more information.	Maintain vegetation health, minimize erosion and improve aesthetics.	X		X
Winterization	Remove excess leaves, sediment and debris. Use signage, training or flagging to discourage and prevent snow storage within footprint of surficial trenches.	Prevent degradation of infiltration trench system over winter and potential sediment contamination and salt loading to trees due to snow storage.	X	X	X

2.1.3.1 Routine Structure, Pipe, and Surface Maintenance

Because subsurface infiltration trenches are located below ground, opportunities to visually observe system maintenance needs are limited and routine inspections of system structures and access ports are critical. Trench systems should be inspected for evidence of standing water (past or present) at the surface and for evidence of ponding water within the subsurface system (as apparent through inlets, cleanouts, observation wells, overflow structures or other structures). Pretreatment device maintenance is critical to long-term performance of subsurface infiltration systems, therefore inlets that convey runoff to the trench should be routinely inspected and maintained as needed. Additionally, flow control structures, such as weirs, orifices and overflow pipes within the outlet structure should be inspected for clogging, blockage, damage or degradation. Conveyance and flow control structures should be routinely cleaned, and pretreatment devices should be replaced when damaged. When excessive sediment is observed in distribution or overflow pipes, pipe jetting should be performed to prevent system clogging and maintain sufficient flow capacity. It is recommended that more frequent inspections take place during the first year of installation until site-specific maintenance frequency needs are established. Trenches located in rights-of-way and adjacent to high traffic areas will typically require more frequent maintenance or more robust pretreatment devices to prevent system degradation.

Figure 2-9. Pipe Condition Inspection

An inspector feeds a video camera through a cleanout and perforated distribution pipe within an infiltration trench, while reviewing pipe conditions on a video monitor.

Surface maintenance requirements depend on the surface type (e.g., vegetated, stone or paved), but for all trench systems, sediment and debris removal is critical to preventing pollutant laden runoff from entering the trench system. Surface flow trenches may require more frequent maintenance to retain surface permeability. Tree and plant care for vegetated infiltration trenches consists of standard landscape maintenance practices, such as establishment watering, mowing turf, removing leaves and periodic tree pruning.

2.1.3.2 Winter Maintenance

There is very little winter maintenance required for infiltration trench systems and it typically consists of surface cleaning activities and implementing strategies to prevent impacts to the system from snow storage and deicing activities. Surface cleanup tasks generally include removing organic debris such as leaf litter and vegetation clippings. If possible signage or other indicators should be installed to discourage snow storage within the footprint of trenches to prevent salt loading, which can impact tree health and to prevent sedimentation.

Pipe jetting should be performed to prevent system clogging and maintain sufficient flow capacity when excessive sediment is observed.

2.1.3.3 Non-Routine Maintenance

In addition to routine maintenance activities, non-routine or reactive maintenance may be required based on inspection observation or performance concerns. Non-routine and reactive maintenance includes vegetation replacement, mosquito control, component replacement and orifice installation (Table 2-5).

Table 2-5. Non-Routine Infiltration Trench Maintenance Activities

Non-Routine (Reactive) Maintenance			Infiltration Trench Type		
Maintenance Activity	**Task Description**	**Objective**	**Tree Trench or Trench Below Vegetation**	**Trench Below Pavement**	**Surface Flow Infiltration Trench**
Replacement of Dead or Dying Trees	Replace dead or poor performing trees.	Maintain tree health, system function and aesthetics.	X		
Turf Repair	Reseed or sod bare spots.	Prevent erosion and maintain aesthetics.	X		X
Replace missing components	Replace missing cleanout covers, inlet & catch basin grates/ covers, or other missing surface structures or components.	Protect public safety, prevent unintended access and improve aesthetics.	X	X	X
Cobble, Stone, Gravel Replacement at Surface Inflow Points	Remove sediment, trash and organic debris and replace armoring material in kind where washout, erosion or channelization is observed. Re-evaluate velocity if problem persists and/or it is suspected that aggregate size is not adequate to resist flow velocities.	Prevent erosion, scour and sedimentation on the surface of infiltration trench systems and maintain system aesthetics.	X		X
Mosquito Control	Prevent standing water by sediment removal, structure cleaning, or pipe jetting. Use environmentally benign mosquito treatment or install screens/barriers in structures known to hold water to prevent mosquitos.	Prevent mosquito population proliferation and possible spread of disease.	X	X	X
Install Orifice for Drainage	Drill orifice in hydraulic control structure (orifice cap, weir, etc.) when excessive ponding is observed or system drain down exceeds 72 hours.	Maintain proper subsurface drainage, ponding depths, and dewatering rates.	X	X	X

2.1.3.4 Non-routine Surface Care

Non-routine surface care activities include vegetation replacement, repair and replacement of structure components, and repair/replacement of energy dissipaters, if present. Dead and dying vegetation should be replaced as needed to maintain system functionality, reduce potential erosion and improve aesthetics.

Component repair/replacement is typically only necessary due to lack of maintenance, improper design/installation, vandalism, or some other unplanned use or event. The degree to which reactive maintenance is required may depend on the type of infiltration trench, system size and drainage area, and the level of pedestrian and vehicular traffic. Typically, trenches under pavements require little surface maintenance, while tree trenches or surface flow trenches may require more care to repair erosion and clean and replace surface gravels.

Figure 2-10. Sediment and Debris Clogging of Inlet
Lack of pretreatment and inlet cleaning can clog pipes in subsurface infiltration trenches and reduce storage and infiltration capacity.

2.1.3.5 Mosquito Control and Slow Release Orifice Installation

A properly draining infiltration trench should not require mosquito control, however, in some cases inlet sumps or other pretreatment devices that contain standing water can require mosquito treatment or the installation of screens or solid covers to prevent mosquitos. Corrective actions are typically required when drain down times exceed 72 hours. If structure cleaning and pipe jetting does not correct the problem, the system may require installation of a slow release orifice. It is generally recommended that all GSI systems include an underdrain or control structure capable of being converted to a slow release drain if infiltration capacity is reduced or drainage problems occur. If necessary, a new slow release outlet should be constructed to facilitate adequate drain down of the system while preserving the stormwater management performance to the maximum extent possible.

2.1.4 Permeable Pavement Maintenance Activities

Permeable pavement maintenance activities center around one goal: to prevent the pavement and underlying infiltration/storage bed from clogging. Permeable pavement requires regular vacuuming or surface cleaning to ensure long-term performance.

Typical routine maintenance activities for permeable pavements include the general maintenance activities discussed in section 2.1.1 as well as the activities described in Table 2-6 below.

Figure 2-11. Porous Asphalt
The surface of porous asphalt requires regular vacuum sweeping to maintain surface porosity.

Table 2-6. Routine Permeable Pavement Maintenance Activities

Routine Maintenance			Pavement Type			
Maintenance Activity	Task Description	Objective	Porous Asphalt	Porous Concrete	Permeable Block Pavers	Open Grid Pavers
Remove trash and /or organic debris	Remove loose trash and organic debris from pavement surfaces by sweeping, leaf blower or other means.	Prevent system clogging and maintain surface porosity and aesthetics.	X	X	X	X
Vacuum sweep pavement	Vacuum clean trash/ sediment/ organic debris from pavement surfaces using street cleaning equipment with suction, sweeping and suction, or high-pressure wash and suction. Small, hand-operated vacuums may be appropriate for smaller areas such as sidewalks. For permeable pavers, suction should be adjusted to prevent excessive removal of paver joint aggregate material (when present).	Prevent system clogging and maintain surface porosity and aesthetics.	X	X	X	
Erosion and sediment control	Mulch, plant or stabilize with erosion control fabric any adjacent exposed soils or areas of erosion that may drain onto the pavement surface.	Prevent system clogging and maintain surface porosity and aesthetics.	X	X	X	X
Maintenance of surface aggregates within paver joints or open grid cells	Install additional jointing aggregate when material level is more than 1/2-inch lower than surface of paver.	Prevent clogging of paver joints with debris and sediment, maintain level surface and aesthetics.			X	X
Replace broken pavers or open grid pavers	Remove individual broken pavers by hand and replace in kind including any required joint aggregate.	Maintain structural integrity of pavement and aesthetics.			X	X
Winter Maintenance	Plow surface of pavement when snow event is greater than 2 inches or when necessary for safe vehicular/ pedestrian access. Use plow with rubber blade tip or set plow blade 1/2 to 1" above pavement surface.	Prevent heavy snow accumulation, pavement surface icing, and maintain public safety while maintaining surface permeability.	X	X	X	X
	Apply salt or environmentally friendly deicers (CMA, KCl, $CaCl_2$) for snow events greater than 0.25 inches, sleet and freezing rain events, and after plowing or when necessary for safe vehicular/pedestrian access. Never apply sand, cinders or other abrasive anti-skid materials.					
	Do not store snow piles on top of permeable pavement.					

2.1.4.1 Routine Surface Care

Routine maintenance of the permeable pavement includes inspection; trash, litter, sediment and organic debris removal; and vacuum sweeping. To prevent subsurface clogging, conveyance systems that carry runoff to the storage bed under permeable pavements require regular cleaning including pretreatment device cleaning and replacement. Keeping the pavement free of trash, litter and debris not only maintains aesthetics, it keeps the surface openings clear to allow surface infiltration.

Figure 2-12. Vacuum Sweeper

Regenerative air sweepers blow air on pavement surfaces to loosen dirt and debris during vacuuming.

Keeping the pavement free of trash, litter and debris keeps the surface openings clear for infiltration.

In addition to trash and debris removal, mechanical vacuum sweeping is required for most permeable pavements to prevent surface clogging over time. Regular mechanical street sweepers have a multi-brush system that first moves the particles to the center of the unit then lifts the debris up onto a conveyor belt for temporary storage. This type of street sweeper is not as effective in penetrating into the permeable pavement and removing sediment particles. A regenerative air street sweeper shoots air at an angle, thus loosening the particles at or near the surface of the pavement. It then lifts the particles into a hopper. This type of vacuum sweeper will more effectively remove surface-deposited sediment. They may also be able to restore surface infiltration to some types of permeable pavement that have not been properly maintained or that have been clogged by sediment or debris. The required frequency of vacuuming depends on the surrounding land cover, the level of vehicular traffic and the type of pavement. Permeable pavements in right-of-way areas or in areas adjacent to trees and other vegetation may require more frequent vacuuming and/or sweeping to remove trash, debris and organic matter.

Permeable pavements should never be used for material storage such as sand, soil or mulch.

It is important to note that adjacent landscaping and landscaping activities contribute to many clogging problems observed with permeable pavement. It is critical that adjacent vegetated areas be inspected for erosion and bare soils that may erode and drain onto the permeable pavement surface. Also, lack of proper material storage can affect performance of permeable pavements. At no time should permeable pavement areas be used for material storage such as sand, soil or mulch.

Figure 2-13. Material Storage and Sediment on Permeable Pavements
Permeable pavements should never be used for particulate material storage and adjacent vegetated areas should be regularly maintained to prevent erosion and sediment run on.

Permeable block pavers require slightly different surface maintenance compared to porous asphalt, porous concrete and other epoxy- coated aggregate and rubber permeable pavements. Most permeable pavers rely on spaces between the unit pavers for surface infiltration. The spaces between the pavers are typically filled with pea gravel. The aggregate serves to help filter debris and prevent migration into the storage bed below the pavers, therefore the aggregate will require occasional cleaning and replacement. If vacuuming permeable block pavers, the vacuum may need to be operated at a lower power to prevent complete removal of aggregate between voids (unless more intensive vacuuming is required to alleviate clogged areas). Vacuum operation should be adjusted so that the vacuum draws out the first inch or so of stone and dirt in the openings between permeable pavers, as this is where most unwanted sediment/debris typically collects. After vacuuming, aggregates should be replaced in the joints between pavers.

Figure 2-14. Excess Gravel on Permeable Pavers
Permeable pavers in a residential alley require vacuuming to remove excess gravel and organic debris from adjacent properties.

2.1.4.2 Winter Maintenance

Understanding the correct winter maintenance protocols for permeable pavements is critical to their long-term performance. Inadequate maintenance or the use of certain materials can reduce or eliminate surface permeability. The following general winter maintenance practices are recommended, although manufacturer's recommendations should be followed for proprietary permeable pavement materials.

- ***Plowing***:
  - Use a plastic/rubber plow blade or plow guard for plowing permeable pavement surfaces or, if that's not possible, raise the plow blade slightly higher (1/2") than for conventional pavements.

– When plowing on top of permeable block pavers, raise plow blade to a slightly higher level (1” above the surface) than for other types of permeable pavement (asphalt, concrete, etc.) to prevent the plow from catching paver edges and dislodging paver units.

- ***Storage of snow piles***:
  – It is generally recommended not to leave plowed snow piles on top of permeable pavement surfaces to melt. This will result in sediment from the plow operations being deposited on the permeable pavement leading to additional maintenance.
  – Move snow piles to standard/conventional pavement area or to grassy/lawn area nearby. Refer to project site plan if necessary, to identify location of landscape elements, permeable and non-permeable pavement surfaces, and snow storage areas.
- ***Deicers/Salting***:
  – Use an environmentally friendly road salt/deicer in moderation on permeable pavement surfaces as they typically require less than conventional pavements. Use 25 to 50% of the amount of deicing salt that is typically applied to conventional pavement or as needed to maintain acceptable driving/walking conditions.
  – Recommended environmentally friendly salts include calcium magnesium acetate (CMA) and potassium acetate (KA). Calcium chloride ($CaCl_2$) can also be used, which is similar to sodium chloride, but can be used in smaller amounts. A mix of sodium chloride or calcium chloride and CMA or KA is better than one of the salts alone.

2.1.4.3 Non-Routine Maintenance

In addition to routine maintenance activities, non-routine or reactive maintenance may be required based on inspection observations or performance concerns. Non-routine and reactive maintenance includes pavement power washing, pipe jetting, weeding between unit pavers, pavement repair, mosquito control and orifice installation (Table 2-7).

Table 2-7. Non-Routine Permeable Pavement Maintenance Activities

Non-Routine (Reactive) Maintenance			Pavement Type			
Maintenance Activity	Task Description	Objective	Porous Asphalt	Porous Concrete	Permeable Block Pavers	Open Grid Pavers
Power washing pavements	Power wash as necessary to remove sediment and restore clogged areas. Power wash at a low pressure with wand spraying at 45-degree angle. Follow with high suction vacuum if clogging persists.	Prevent or restore surface clogging and maintain surface porosity and aesthetics.	X	X	X	
Pipe jetting	Hydro-jet conveyance, distribution and underdrain pipes when 10% or more of cross-sectional area of the pipe is blocked by debris.	Prevent pipe clogging and maintain efficient inflow, overflow and drain down.	X	X	X	X
Weeding between pavers/open grid pavers	Remove weeds or undesired vegetation growing between pavers by hand or hand tools. Remove sediment and vacuum sweep pavers and replace aggregate joint material.	Prevent paver surface clogging, maintain aesthetics and restore surface permeability.			X	X

Table 2-7. Non-Routine Permeable Pavement Maintenance Activities

Non-Routine (Reactive) Maintenance			Pavement Type			
Maintenance Activity	Task Description	Objective	Porous Asphalt	Porous Concrete	Permeable Block Pavers	Open Grid Pavers
Pavement Repair	Neatly sawcut porous asphalt or porous concrete pavement for repairs. Protect exposed sub-base from sediment during repair work and replace the aggregate base under permeable pavement as needed. Replace geotextile and choker course as needed. Generally acceptable to patch with standard pavement when utility trench is less than 10% of the total permeable pavement area.	Maintain structural integrity of pavement and maintain system function following necessary utility repair/installation.	X	X		
	Remove pavers or open grid pavers individually by hand for repair. Protect exposed sub-base from sediment during repair work and use the same aggregate base as under permeable block pavers as needed. Replace geotextile as needed. Replace permeable block pavers or open grid pavers by hand, replace aggregate joint/cell material, and properly level pavers.				X	X
Mosquito Control	Prevent standing water by sediment removal, structure cleaning or pipe jetting.	Prevent mosquito population proliferation and possible spread of disease.	X	X	X	X
	Use environmentally benign mosquito treatment or install screens/barriers in structures known to hold water to prevent mosquitos.					
Install Orifice for Drainage	Drill orifice in hydraulic control structure (orifice cap, weir, etc.) when excessive ponding is observed or when system drain down exceeds 72 hours.	Maintain proper subsurface drainage, ponding depths and dewatering rates.	X	X	X	X

2.1.4.4 Non-routine Surface Care

Non-routine and reactive maintenance includes pavement power washing, weeding between unit pavers and pavement repair. Power washing is a corrective action that is sometime necessary when permeable pavement surfaces are slow draining, clogged or become stained by oils, greases or other materials. Typically, power washing is done in conjunction with vacuuming. To prevent degradation to the pavement surface (e.g., raveling, spalling), power washer pressure should be relatively low (no greater than 500 PSI) and the power washer wand should spray the pavement surface at a 45-degree angle to help dislodge sediment and debris without pushing it down further into the pavement voids.

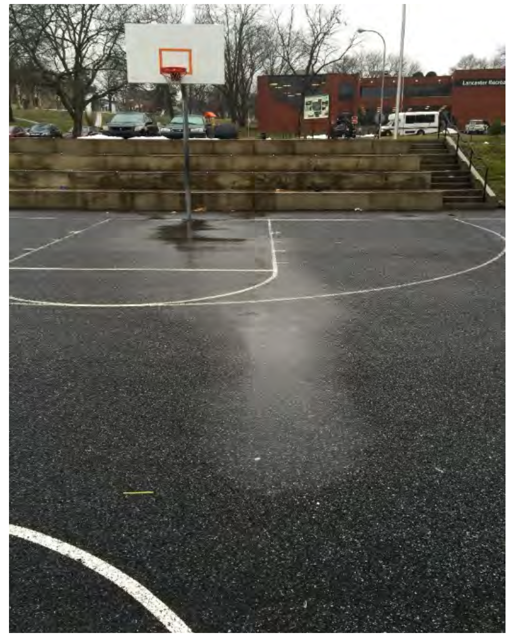


Figure 2-15. Puddles on Porous Asphalt
Surface puddles on a porous asphalt basketball court indicate the pavement is partially clogged by run-on and requires corrective action such as power washing and high-suction vacuuming.

With proper maintenance, weeding in the joints of permeable block pavers typically should not be required and vegetation in the pavers is a sign that too much sediment has accumulated. Weeds should be removed by hand or with an environmentally safe herbicide, and the pavers should be vacuumed and paver jointing material replaced.

If subsurface utility maintenance, repair or replacement is required within a permeable pavement system, care must be taken to prevent damage to the subsurface storage bed below the pavement. During trenching and utility work, the subsurface storage bed should be protected from sedimentation and utility trench backfill within the GSI system should utilize new material that meets the design specifications of original bed aggregate (typically clean, washed, uniformly graded aggregate). Surface patching may utilize standard pavement when the disturbance area comprises a small portion of the total permeable pavement area (typically less than 10 percent). Permeable block pavers may be removed and reused or replaced over the utility trench.

2.1.4.5 Mosquito Control and Slow Release Orifice Installation

A properly draining permeable pavement system should not require mosquito control. However, in some cases inlet sumps or other pretreatment devices that contain standing water can require mosquito treatment or the installation of screens or solid covers to prevent mosquitos. Corrective actions are required when the subsurface bed below the permeable pavement system has a drain down time exceeding 72 hours. If structure cleaning and pipe jetting does not correct the problem, the system may require installation of a slow release orifice. It is generally recommended that all GSI systems include an underdrain or control structure capable of being converted to a slow release drain, if infiltration capacity is reduced or drainage problems occur. If necessary, a new slow release outlet should be constructed to facilitate adequate drain down of the system.

2.2 Maintenance Frequencies and Level of Service

Establishing maintenance frequencies is critical to developing a maintenance plan that is effective in adequately maintaining GSI facilities to ensure long-term performance over the life of the installation and to maintain aesthetics. Site maintenance needs will vary depending on site location and surrounding land uses, public access and visibility, drainage area size, and system loading ratio (ratio of impervious area to GSI facility area). One way to categorize maintenance needs among different project locations is to define general service levels that are influenced by site and GSI facility characteristics. Level of Service (LOS) refers to a desired result or level of maintenance for GSI systems. The desired level of maintenance may vary depending on a site's visibility, adjacent land uses and maintenance budget/contract, etc.

The desired level of maintenance may vary depending on a site's visibility, adjacent land uses and maintenance budget/contract, etc.

While site specific maintenance requirements should be established during GSI design and subsequent maintenance plan development and should include input by site managers and maintenance staff, the following maintenance service levels are provided to give guidance on typical level of service categories and the maintenance task frequencies associated with them. The frequencies are basic recommendations and may need to be adjusted based on specific site conditions or circumstances affecting maintenance requirements.

High Level of Service: Recommended maintenance standards for a high visibility site, formal landscape area, high public use area, a facility with a high loading ratio, or a GSI facility exposed to frequent loading of runoff with higher levels of debris and pollutants. High LOS facilities will typically require a higher annual maintenance commitment/budget.

Moderate Level of Service: Recommended maintenance standards for a medium visibility site, a facility with a medium to high loading ratio, or a GSI facility exposed to moderate loading of runoff with higher levels of debris and pollutant. Moderate LOS facilities will typically require a moderate annual maintenance commitment/budget.

Low Level of Service: Recommended maintenance standards for a low visibility site, naturalized landscape area, low public use area, with lower loading ratio and pollutant loading. Low LOS facilities will typically require a lower annual maintenance commitment/budget with reduced frequency of some maintenance tasks.

Figure 2-16. Example of Maintenance Service Levels

Examples of high, moderate and low maintenance service levels for bioretention systems in different settings. Clockwise from top left, high LOS bioretention within a high use/visibility pedestrian plaza, moderate LOS bioretention adjacent to a park basketball court, and low LOS bioretention in a suburban single-family neighborhood.

2.2.1 Routine Maintenance

Routine operations and maintenance activities are tasks that can typically be expected to be performed at variable frequencies on a monthly, quarterly, biannual or annual basis. The frequencies provided are recommended for optimum long-term performance of typical GSI systems, but individual site requirements and maintenance frequencies may vary significantly.

Table 2-8. Routine Maintenance Task Frequencies by Service Level and GSI Type

	Maintenance Activity	Recommended Typical Frequency[1] High Service Level	 Moderate Service Level	 Low Service Level
All GSI Technologies	GSI Inspection[3]	Monthly	Quarterly	Biannually
	Trash & Sediment Removal	Monthly	Quarterly	Biannually
	Organic Debris Removal	Quarterly	Biannually	Annually
	Sediment removal from vegetated areas and/or forebay	Monthly	Quarterly	Annually
	Collection System Cleaning	After each 1-inch storm event	Monthly	Quarterly
	Collection System Pretreatment Device Replacement	Device missing, damaged or nonfunctioning		
Vegetated GSI Systems	Weeding	Monthly	Quarterly	Biannually
	Mowing (if turf grass is present)	Weekly or biweekly during growing season	Quarterly	Annually
	Mulching	Biannually	Annually	
	Remove & Prune Plants	Biannually	Annually	
	Watering/Irrigation	Establishment/As needed		
	Cutting Back Vegetation	Annually		
	Clear overflow and drainage structures	After each 1-inch storm event	Monthly	Quarterly
	Winterization	Annually		
Infiltration Systems	Structure & System Vacuum Cleaning	Biannually		Annually
	Pipe Inspection/Pipe Jetting	Annual Inspection/Jetting as needed when 10% or more of cross section area is clogged with debris/sediment		
	Inlet Pretreatment Maintenance	Quarterly	Biannually	Annually
	Maintenance of Surface Aggregates (when present)	Quarterly	Biannually	Annually
	Bolt & Lock Care	As needed		
	Tree Care	Biannually or as needed	Annually or as needed	
	Winterization	Annually		

Table 2-8. Routine Maintenance Task Frequencies by Service Level and GSI Type

	Maintenance Activity	Recommended Typical Frequency[1] High Service Level	Moderate Service Level	Low Service Level
Permeable Pavement Systems	Remove trash and /or organic debris	Quarterly	Biannually	Annually
	Vacuum sweep pavement	Quarterly	Biannually	Annually
	Erosion and Sediment Control[2]	As needed		
	Inlet Pretreatment Maintenance	Quarterly	Biannually	Annually
	Maintenance of surface aggregates within paver joints or open grid cells	Biannually	Annually	As needed
	Replace broken pavers or open grid pavers[2]	As needed		
	Winter Maintenance	As needed		

Notes:

[1] These frequencies are recommended for optimum long-term performance of GSI systems, however individual site requirements and maintenance frequencies may vary significantly.

[2] Need for maintenance activity is determined by inspections or because of conditions observed during other maintenance activities.

[3] In addition to the frequencies listed, it may be necessary to inspect some GSI systems following high intensity or extreme storm events, especially in the first year after installation or until typical maintenance needs are established. Based on observations during inspection, stormwater structure cleaning, erosion repair or other maintenance tasks may be required.

2.2.2 Non-Routine (Reactive) Maintenance

Non-routine or reactive operations and maintenance activities are tasks that may or may not be required at a regular frequency. Most non-routine maintenance activities are performed as needed or when conditions are observed that require corrective actions to repair and prevent degradation to GSI facilities. In some cases, non-routine maintenance tasks are performed following an extreme storm event, flood damage or if required because of unintended uses or inadequate maintenance. The frequencies provided are recommended to maintain or restore GSI facility functions, however individual site conditions or unforeseen circumstances may warrant different frequencies.

Table 2-9. Non-Routine Maintenance Task Frequencies by Service Level and GSI Type

	Maintenance Activity[2]	Recommended Frequency[1] High Service Level	Moderate Service Level	Low Service Level
All GSI Technologies	Erosion Repair	As needed		
	Concrete Repair	As needed		
	Settling	As needed		
	Painting	As needed		
	Graffiti Removal	If present		
	Hardware Cleaning	As needed		

Table 2-9. Non-Routine Maintenance Task Frequencies by Service Level and GSI Type

	Maintenance Activity[2]	Recommended Frequency[1] High Service Level	Moderate Service Level	Low Service Level
	Replace grates, caps, covers	As needed		
Vegetated GSI Systems	Replacement of Dead or Dying Plant Material	Annually or as needed to maintain 90% vegetative cover	Annually or as needed to maintain 80% vegetative cover	As needed to maintain minimum 75% vegetative cover
	Turf Repair	As needed		
	Manage/Amend Soil	Every 1-2 years or as determined by inspection	Every 2 years or as determined by inspection	As needed determined by inspection
	Pest and Disease Management	If present		
	Cobble, Stone, Gravel Replacement at Energy Dissipaters or Sidewalls	As needed due to structural failure/ damage or loose, missing or displaced material		
	Invasive Vegetation Control	If present/low tolerance		If present/moderate tolerance
	Mosquito Control	If present/low tolerance		If present/moderate tolerance
	Underdrain Cleaning/Pipe Jetting	As needed if 10% or more of the cross-sectional area of the pipe is clogged with debris/ sediment		
Subsurface Infiltration Systems	Replacement of Dead or Dying Trees	As needed		
	Turf Repair	As needed		
	Replace missing components	As needed		
	Cobble, Stone, Gravel Replacement at Surface Inflow Points	As needed due to structural failure/ damage or loose, missing or displaced material		
	Mosquito Control	If present/low tolerance		If present/moderate tolerance
	Install orifice for drainage	As needed determined by inspection		
Permeable Pavement Systems	Power washing pavements	Every 2 years or as needed	Every 3 years or as needed	As needed
	Pipe Jetting	As needed if 10% or more of the cross-sectional area of the pipe is clogged with debris/ sediment		
	Weeding between pavers/ open grid pavers	As needed		
	Pavement Repair	As needed		
	Mosquito Control	If present/low tolerance		If present/moderate tolerance
	Install orifice for drainage	As needed determined by inspection		

[1] These frequencies are recommended for optimum long-term performance of GSI systems, however individual site requirements and maintenance frequencies may vary significantly.

[2] Need for maintenance activity is determined by inspections or because of conditions observed during other maintenance activities.

Operations and Maintenance Inspection and Documentation

Once GSI facilities are constructed, ALCOSAN suggests that owners conduct annual inspections to ensure that GSI facilities are properly maintained and continue to provide effective stormwater management. For GROW grant recipients, annual self-certification inspections should be conducted by the municipality, site owner or site manager and the checklists should be submitted to ALCOSAN on an annual basis. Any maintenance requirements identified through inspections are to be completed in accordance with the protocols described in this guidance document and according to the GSI maintenance agreement.

3.1 Annual Self-Certification

Grant recipients are requested to submit an Annual Self-Certification checklist for every GSI facility on an annual basis. The checklist will describe GSI conditions at the time of inspection and any maintenance activities, including corrective actions that have taken place. While submission of self-certification checklists is requested on an annual basis, many GSI systems will require more frequent inspection and maintenance activities. Recommended maintenance activities and frequencies provided in Section 2 should be utilized to develop individual GSI maintenance plans and should serve as the basis for ongoing system maintenance activities. The following sections provide detailed descriptions of GSI system inspection items and are intended to provide guidance for completing the Annual Self-Certification checklists provided in Appendix 5-A.

3.1.1 Bioretention

Table 3-1 provides guidelines for the inspection of bioretention system conditions and indications of potential maintenance needs. It is intended to be used with the Bioretention and Rain Garden Annual Self-Certification Inspection Form and Checklist provided in Appendix 5-A.

3.1.2 Infiltration Trenches

Table 3-2 provides guidelines for the inspection of infiltration trench system conditions and indications of potential maintenance needs. It is intended to be used with the Subsurface Infiltration Trench Annual Self-Certification Inspection Form and Checklist provided in Appendix 5-A.

3.1.3 Permeable Pavements

Table 3-3 provides guidelines for the inspection of permeable pavement system conditions and indications of potential maintenance needs. It is intended to be used with the Permeable Pavement Annual Self-Certification Inspection Form and Checklist provided in Appendix 5-A.

Table 3-1. Bioretention Facility Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
General Site Conditions					
Obstructed Access to Site or Structures for O&M	Access is not obstructed	Access feasible but inhibited	Access to site and critical structures in the site is not feasible	System and structures must be accessible to conduct inspections and monitor system functionality.	• Prune or remove obstructing vegetation • Remove objects/barriers as needed
Stormwater Runoff Bypassing System Inlets (curb cuts, inlet pipe, etc.)	Water easily enters facility, or no indication of bypass as indicated by watermarks, debris buildup, signs of erosion	Indication of moderate bypass observed during rainfall or by watermarks, debris buildup, signs of erosion	Indication of significant bypass observed during rainfall or by watermarks, debris buildup or erosion	Water unintentionally bypassing the system indicates that the system is not able to manage stormwater at full capacity. Prevent runoff bypass to ensure system provides stormwater management benefits.	• Clean or regrade areas around GSI system to direct surface runoff to inlets and correct flow path to facility • Install new inlets at low points surrounding system to promote surface conveyance to system
Unpleasant Odors	Unpleasant odor not detected (minor smell from compost or other soil amendments is acceptable)	N/A	Unpleasant odor detected (minor smell from compost or other soil amendments is acceptable)	Odors may be an indication of surface clogging preventing runoff from reaching the soil layer or underdrain clogging preventing adequate drain down of the facility. (Minor smell from compost or other soil amendments is acceptable.)	• Conduct infiltration testing and remediate bioretention soil as necessary • Inspect underdrain and outlet control structure for clogging. CCTV and jet clean underdrain, if clogged • Ensure weed barrier or geotextile fabric has been used properly and is not clogged • Remove any decaying organic material or other source of odor
Vandalism / Damage to Components or Entire System	No evidence of vandalism or damage such as trampling or impacts from nearby construction	Some vandalism or damage present but not impacting the function of the GSI system	Significant vandalism or damage present that affects the function of the GSI system	Vandalism, including graffiti and removal of structures, can compromise the overall performance and/or aesthetics of the system.	• Remove graffiti • Plant individual replacement plants • Repair the GSI structures and inlets • Install protective barriers or implement other strategies to prevent continued vandalism

Table 3-1. Bioretention Facility Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Unauthorized Modifications	No significant unauthorized modifications made to surface or structures	Minor modification to surface or structures that does not impact function of facility	Major modification that affects functionality of facility	Unauthorized modifications can cause the system to function improperly or reduce performance of the system.	• Return GSI system to original configuration
Rodent Damage / Burrowing	No evidence of burrowing or rodent damage observed	N/A	Evidence of burrowing or other rodent damage observed	Prevent structural, landscape and stormwater flow-based issues. Burrows can undermine structural components, leading to unwanted settlement. Burrows can create unintended flow paths, causing piping and erosion problems and may damage plants and plant root systems.	• Consult with a licensed professional pest control service for eradication or trapping and relocation • Repair any damage
Evidence of Illegal Dumping or Hazardous Material on Site	No evidence of hazardous materials or illegal dumping identified on site	N/A	Hazardous materials or illegal dumping identified on site	Illegal dumping or hazardous material impacts aesthetics and can create a dangerous environment at the site and can contribute pollutant loading to surface waters.	• Remove materials and dispose of properly • Install signage warning against illegal dumping • Consider lighting, video monitoring, etc.
Standing Water					
Indication of Prolonged Ponding on Surface	No indication of prolonged ponding on system surface	Isolated indications of prolonged ponding on less than 15% of surface	Indications of prolonged ponding on greater than 15% of surface	GSI system will not be able to manage intended volume of runoff if drain down is too slow and storage capacity is reduced. Drain down times of more than 72 hours can result in unpleasant odors, unhealthy plants, and mosquitos.	• Conduct infiltration testing of surface and restore/replace surface soils and mulch if infiltration rates are too low (less than specified design rate or 1”-2” per hour) • Inspect underdrain for clogging • Ensure weed barrier or geotextile fabric is not clogged

Table 3-1. Bioretention Facility Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Mosquitos or Mosquito Larvae Observed	No mosquitos or larvae observed	Insignificant number of mosquitos or larvae observed	Significant number of mosquitos observed, or larvae is present	Mosquitos or larvae observed around or within system can indicate that the system is not functioning correctly, and water is not draining adequately. Ensure proper drainage of system surface and ensure structures or underdrain are clear and not clogged.	• Identify and remove the causes of standing water on site and/or appropriately treat water to prevent mosquitos
Surface Conditions					
Excessive Trash/ Debris/ Leaf Accumulation	No significant trash, debris or leaf litter observed	Moderate amount of trash, debris or leaf litter	Trash, debris or leaf litter appears to be affecting facility functionality	Excessive trash and debris inhibit plant growth, clog surface/ inhibit the infiltration rate of the bioretention soil. Debris can clog outflow structure grates and may inhibit overflow and cause minor flooding. May cause unpleasant aesthetics and odors.	• Remove trash, debris and organic matter regularly • Assess maintenance frequency/timing and adjust as necessary • Maintain/prune nearby vegetation. Clear leaves in the fall
Sediment Accumulation at Curb Cut, Forebay or System Low Points	System is largely free of sediment and silt	Insignificant sediment or silt accumulated in system (less than 15% of surface)	Sediment or silt present on over 15% of system surface	Excessive sediment accumulation can cause stormwater runoff bypass at inlets and can inhibit surface infiltration, water quality benefits and conveyance.	• Scrape and remove sediment using shovels and dispose of properly • Identify and correct sediment sources if necessary • Remove sediment on an annual basis or more frequently if needed

Table 3-1. Bioretention Facility Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Erosion and/or subsequent sediment deposits at Inlet, Outlet, Overflow, Check Dams, Facility Bottom or Side Slopes	No erosion and/ or subsequent sediment deposits observed	Insignificant erosion and/ or sediment deposits observed that does not affect the functioning of the system	Erosion and/ or subsequent sediment deposits observed that threatens to cause damage to plants, create clogging, or otherwise impact performance	Erosion and sedimentation reduce the bioretention soil infiltration capacity, cause damage to plants, and can clog underdrains and outflow structures.	• Repair erosion damage and remove sediment • Identify and correct sources of the erosion • Add flow dispersion and/or stabilization measures
Lack of Mulch Cover	No bioretention soil visible	Insignificant areas of exposed bioretention soil in less than 10% of the system	Significant areas of visible bioretention soil in greater than 10% of the system	Adequate mulch cover provides weed control, maintains soil moisture and protects from erosion.	• Re-cover any bare spots on bioretention surface with mulch • Ensure mulch type meets specs used during construction
Visible Surface Contaminants/ Pollution	No evidence of significant surface contaminants or pollution	Minor evidence of surface contaminants or pollution on less than 10% of surface	Surface contaminants or pollution on over 10% of surface	Prevent impairment of plant, environmental and human health. Prevent surface water contamination.	• Identify and correct the sources of the pollution • Remove contaminated material and dispose of properly • Restore bioretention surface as needed
Poor Condition of Rip Rap/ Cobbles/ Energy Dissipaters	Energy dissipater is free of buildup and is secure	Insignificant signs of erosion, accumulation of debris and soil or dislodged cobbles	Significant portion of cobbles dislodged or missing, significant erosion and material buildup	Maintain velocity control and energy dissipation both entering and within GSI system to prevent erosion and sedimentation.	• Remove debris and soil accumulation • Stabilize loose cobbles and replace missing cobbles • Evaluate energy dissipater configuration
Evidence of Poor Flow Distribution Throughout Surface	Flow appears evenly distributed throughout the system based on surface grading	Water does not appear evenly distributed through the system but at least 75% of the system is receiving flow	Water does not appear evenly distributed through the system with less than 75% of the system receiving flow	Poor flow distribution results in reduced water contact with the surface area, which minimizes infiltration and treatment benefits.	• Rake mulch to evenly distribute and allow for evenly distributed flow • Remove mulch, regrade bioretention soil, replace mulch

Table 3-1. Bioretention Facility Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Surface Degradation/ Subsidence (e.g. missing gravel, uneven settlement, sinkholes)	No significant sign of degradation/ subsidence	Slight degradation in isolated areas less than 10% of the surface	Major degradation in greater than 10% of surface	Surface degradation or subsidence can cause an unsafe condition and impact the functionality of the system.	• Monitor for source of degradation/ subsidence and eliminate/repair • Patch/fill area of degradation/ subsidence
Destabilized Contributing Conveyance Swale/Drainage Area	Contributing conveyance swale or drainage area free of bare patches and signs of erosion	Minor bare patches and some evidence of erosion present but does not appear to affect system functionality	Significant bare patches and erosion in contributing swales or drainage area affecting system function	Sediment-laden runoff from eroded contributing areas can cause surface clogging, vegetation damage and structure and pipe clogging.	• Repair eroded areas • Stabilize bare patches with turf, mulch, groundcover, etc. • Install temporary/permanent erosion and sedimentation controls as needed
Vegetation					
Excessive Weed Growth	No significant weeds evident	Some weeds noticeable in less than 10% of the planted area	Over 10% of the planted area contains weeds	Excessive weed growth may impact aesthetics and desired plant health by increasing competition.	• During the growing season, remove weeds on monthly basis or as needed based on desired service level • Evaluate surrounding area for source of weeds and suppress them if necessary
Dead, Diseased, Dying or Missing Plants	No evidence of dead, diseased, dying or missing plants	Several dead, diseased, dying or missing plants that do not create significant bare spots	Significant dead, diseased, dying or missing plants creating bare spots	Healthy plants help to filter and infiltrate runoff, provide habitat, and improve aesthetics. Low plant density increases opportunity for weeds and invasive species to establish.	• Replace dead, diseased, dying or missing plants with appropriate replacements • Consult with horticultural expert or trained landscape professional to treat insects or plant disease • Evaluate winter maintenance regime to ensure that GSI footprint is not used for snow storage and subject to salt loading

Table 3-1. Bioretention Facility Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Vegetation Obstructing Sidewalk or Line of Sight at Roadway or Intersection	No vegetation blocking the vision or movement of motorists, bicyclists, or pedestrians	Vegetation close to line of site for motorists, bicyclists, or pedestrians but is not yet blocking vision	Vegetation blocking the vision or movement of motorists, bicyclists or pedestrians	Obstructions cause a hazardous condition by blocking the movement or vision of motorists, bicyclists and pedestrians.	• Schedule regular pruning by a trained landscape professional • Transplant problem plants if necessary
Vegetation Blocking Flow at Curb Cut/Inlet Structure/Outlet Structure	No vegetation is blocking flow to or from the system	Vegetation appears to be poorly-sited, spreading or overgrown but is not blocking flow	Vegetation is poorly-sited, spreading or overgrown and blocking flow	Excessive plant growth can block stormwater flows to or from the facility and cause stormwater to excessively pond or bypass the unit.	• Prune, thin, transplant or remove vegetation blocking flows • Consult a trained landscape professional if necessary
Vegetation Blocking Operation & Maintenance (O&M) Access to GSI System Components	No vegetation is obstructing O&M of outlet structures, underdrains, or irrigation components	Vegetation appears to be poorly-sited, spreading or overgrown but is not obstructing system components	Vegetation is poorly-sited, spreading or overgrown and is obstructing outlet structures, underdrains or irrigation components	Plant growth around system components interferes with or blocks the inspection and O&M of key components, such as outlet/inlet structures.	• Prune, thin, transplant or remove vegetation impeding O&M of facility • Consult a trained landscape professional if necessary
Structures					
Irrigation System Damaged, Leaking or Out of Adjustment (If Applicable)	No ponded water or saturated soils identified during dry periods, wilted or browning plants, or water deposited on paved surfaces	Insignificant ponded water or saturated soils identified during dry periods, wilted or browning plants, or water deposited on paved surfaces	Significant water or saturated soils identified during dry periods, wilted or browning plants, or water deposited on paved surfaces	Malfunctioning irrigation systems can reduce storage/infiltration capacity of the system when overapplying or cause plant degradation if not functioning during drought periods.	• Irrigation systems must be maintained by a qualified professional • Evaluate need for irrigation system if plants are established and warranty phase is over • Replace dead or dying plants as needed

Table 3-1. Bioretention Facility Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Structural Damage (Bioretention/ Planter/Vegetated Swale Edge Treatment, Check Dams or Outlet Structure)	No structural damage observed	Minor structural damage not affecting the functioning of the system	Major structural damage that could affect functionality, such as damage by vehicles, construction work or natural disasters	Flow control structures and edge treatments are important to ensure design performance is maintained. Damage may reduce ponding, increase unintended overflow and bypass, and impede velocity controls.	• Repair damage /replace components as needed
Underdrain Blockage or Excessive Sediment/ Debris in Control Structure	No evidence of blockage	Minor blockage of structure area, does not appear to affect system functionality	Significant blockage, affecting function of system	Create prolonged ponding, flooding and/ or premature overflow events, especially during excessive run-off events.	• CCTV and jet clean underdrain • Remove trash and debris • Assess source of sediment/debris
Monitoring Equipment Damaged or Missing	Monitoring equipment in place and undamaged	Monitoring equipment with minor damage but not affecting the function of the equipment	Monitoring equipment missing or damaged such that function is affected	Monitoring equipment must be present and properly functioning as required by the GROW program.	• Repair/replace equipment

Table 3-2. Infiltration Trench Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
General Site Conditions					
Obstructed Access to Site or Structures for O&M	Access is not obstructed	Access feasible but inhibited	Access to site/critical structures is not feasible	System and structures must be accessible to conduct inspections and monitor system functioning.	• Prune or remove vegetation • Remove objects/barriers as needed
Stormwater Runoff Bypassing System Inlets	Water easily enters facility, or no indication of bypass as indicated by watermarks, debris buildup, signs of erosion	Indication of moderate bypass observed during rainfall or by watermarks, debris buildup, signs of erosion	Indication of significant bypass observed during rainfall or by watermarks, debris buildup, or erosion	Water unintentionally bypassing the system indicates that the system is not able to manage stormwater at full capacity. Prevent runoff bypass to ensure system provides sewer flow removal benefits.	• Regrade areas around GSI system to direct surface runoff to inlets and correct flow path to facility • Create new flow path to facility or install new inlets
Unpleasant Odors	Unpleasant odor not detected	N/A	Unpleasant odor detected	Odors may be an indication of surface clogging preventing rainfall from reaching the storage layer or underdrain (when present) clogging preventing adequate drain down of the facility.	• Inspect underdrain and outlet control structure for clogging. CCTV and jet clean underdrain, if clogged • Clear structures by hand, hand tools, or vactor truck • Remove any decaying organic material or other source of odor
Vandalism / Damage to Components or Entire System	No evidence of vandalism or damage visible	Some vandalism or damage present but not impacting the function of the GSI system	Significant vandalism or damage present that affects the function of the GSI system	Vandalism, including graffiti and removal of structures, can compromise the overall performance and/or aesthetics of the system.	• Remove graffiti • Repair the GSI structures/inlets • Install protective barriers/grate locks or implement other strategies to prevent continued vandalism
Unauthorized Modifications	No significant unauthorized modifications made to surface or structures	Minor modification to surface or structures that does not impact function of facility	Major modification that affects functionality of facility	Unauthorized modifications can cause the system to function improperly or reduce performance of the system.	• Return system to original configuration

Table 3-2. Infiltration Trench Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Evidence of Illegal Dumping or Hazardous Material on Site	No evidence of hazardous materials or illegal dumping identified on site	N/A	Hazardous materials or illegal dumping identified on site	Illegal dumping or hazardous material can create a dangerous environment at the site and can contribute pollutant loading to surface waters.	• Remove materials and dispose of properly • Install signage warning against illegal dumping • Consider lighting, video monitoring, etc.
Standing Water					
Standing Water on Surface or in Structures Indicating that the System is Not Draining Completely	No excessive standing water observed in monitoring well or structures	N/A	Standing water observed in monitoring well or structures during dry period (more than 48 hours after storm)	GSI system will not be able to manage intended volume of runoff if drain down is too slow and storage capacity is reduced. Drain down times more than 72 hours can result in unpleasant odors and mosquitos.	• CCTV and jet clean underdrain • Clear structures by hand, hand tools, or vactor truck • Observe drain down after storm events
Mosquitos or Mosquito Larvae Observed	No mosquitos or larvae observed	Insignificant number of mosquitos observed	Significant number of mosquitos observed, or larvae is present	Mosquitos or larvae observed around the system can indicate that the system is not functioning correctly, and water is pooling.	• Identify and remove any standing water on site and/or appropriately treat water to prevent mosquitos
Surface Conditions					
Excessive Trash/ Debris/ Leaf Accumulation	No significant trash, debris or leaf litter observed	Moderate amount of trash, debris or an excessive amount of debris or leaf litter	Trash, debris or leaf litter appears to be affecting facility functionality	Trash and debris can clog inlet and outlet structures, distribution pipes and cause poor site aesthetics. Excessive structure clogging can lead to impaired infiltration functions.	• Remove trash, debris, and organic matter regularly • Assess Maintenance Frequency/ Timing and adjust as necessary • Maintain/Prune Nearby Vegetation. Clear leaves in the fall.

Table 3-2. Infiltration Trench Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Sediment Accumulation on Trench Surface (if applicable)	Surface is largely free of sediment or silt	Insignificant sediment or silt accumulated on surface (less than 10% of surface)	Sediment or silt present on over 10% of surface	Sediment accumulation can impede flow into trench and cause system clogging.	• Scrape and remove sediment using shovels and dispose of properly • Restore surface treatments and replace gravel/cobbles as needed • Remove sediment on an annual basis or more frequently if needed • Identify and correct sources if necessary
Structural Damage to Surface and/ or Edge Pretreatments (if present)	No structural damage observed	Minor structural damage not affecting the functioning of the system	Major structural damage that could affect functionality, such as damage from vehicles, construction work or natural disasters	Structural damage may reduce ability to prevent clogging of aggregate in infiltration bed.	• Repair damage /replace components as needed
Destabilized Contributing Landscape Areas	Contributing landscape area free of bare patches and signs of erosion	Minor bare patches and some evidence of erosion present	Significant bare patches and erosion in contributing landscaped areas	Destabilized areas can contribute silt, sediment and fines to the trench.	• Repair eroded areas • Stabilize bare patches with turf, mulch, groundcover, etc. • Install temporary erosion and sedimentation controls
Surface Degradation/ Subsidence (e.g. missing gravel, uneven settlement, sinkholes)	No significant sign of degradation/ subsidence	Slight degradation in isolated areas less than 10% of the surface	Major degradation in greater than 10% of surface	Surface degradation or subsidence can cause an unsafe condition and impact the functionality of the system.	• Monitor for source of degradation/ subsidence and eliminate/repair • Patch/fill area of degradation/ subsidence
Flow Dissipation Structures (Splash Block, Cobbles) Clogged, Damaged or Missing (if applicable)	Items in place and in good condition	Items showing minor wear but not affecting the functioning of the facility	Items missing or broken	Missing or damaged flow dissipaters may cause erosion and lead to sedimentation.	• Repair/replace flow dissipation structures

Table 3-2. Infiltration Trench Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Dead/Dying Trees, Turf or Other Vegetation	No sign of vegetation decline	Vegetation dead/ dying in isolated areas less than 10% of the surface	Vegetation dead/ dying in greater than 10% of surface	Vegetation protects soil from erosion and prevents sedimentation and clogging of infiltration trench.	• Monitor for source of degradation and eliminate/ repair • Replace trees/vegetation and restore turf as needed
Structures					
Pretreatment Storage Sump Contains Excessive Sediment (If applicable)	Sump is less than 1/3 full of sediment	Sump is approximately 1/3 full of sediment	Sump is more than 1/3 full of sediment	Excessive sediment in the pretreatment storage sump can cause system clogging.	• Remove and dispose of accumulated sediment • Assess O&M frequency/ timing and adjust if necessary
Inlet/Pretreatment Structure Blockage or Excessive Sediment / Debris in Structure	No evidence of blockage	Minor blockage of structure area, does not appear to affect system functionality	Significant blockage, affecting function of system	Blockages from any materials in inlets or control structures can cause bypass or runoff and debris to back up in the system.	• Remove blockage, trash and debris from system • Assess O&M frequency/ timing and adjust if necessary
Pretreatment /Inlet Filter Inserts Clogged, Damaged or Missing	Filter insert (or another device) present and undamaged	Filter inserts (or other device) showing minor wear but not affecting the functioning of the facility. Filter insert less than 1/3 full.	Filter insert (or other device) full greater than 1/3 the capacity, missing, or damaged	Missing or damaged filter inserts or other devices can allow sediment buildup or clogging within the system.	• Clean, repair or replace filter insert (or another device) and reinstall in inlet • Assess O&M frequency/ timing and adjust if necessary
Underdrain Blockage or Excessive Sediment/ Trash/ Debris in Outlet Control Structure	No evidence of blockage	Minor blockage of structure area (less than 10% of cross-sectional area of pipe), does not appear to affect system functionality	Significant blockage (greater than 10% of cross-sectional area) affecting function of system	Blockages in underdrain or outlet control structure can cause excessive drain down times, flooding and/ or premature overflow events.	• CCTV and jet underdrain • Remove trash and debris

Table 3-2. Infiltration Trench Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/ Objective	Possible Corrective Actions
Inlet /Outlet Structural Damage	Concrete free of cracks, chips and other damage	Some isolated blemishes (cracks or chips) are present	Major damage to inlet or outlet affecting functionality	Damaged inlets or outlets may promote flow backup, blockages, flooding and bypassing of the system.	• Stabilize structure including repair of structural damage • Assess inlet/outlet design and provide protective measures as necessary
Piping, Cleanouts, Vents, Valves or Baffles Damaged	Features free of damage	Minor damage that does not affect system functionality	Major damage affecting system functionality	Damaged features can limit access to underdrain systems for monitoring and O&M and reduce flow control capabilities within system.	• Repair or replace damaged or inoperable components to restore the component's function
Visible Contaminants / Pollution on Interior Surfaces of Cleanout Pipe or Dry Well	No evidence of contaminants	Evidence of inert contaminants, does not appear to affect system functionality	Evidence of hazardous or large volumes of contaminates affecting function of system	Contaminants or pollution on interior surfaces can impair effluent water quality and/or cause clogging within the system.	• Investigate and mitigate at the source of contamination • Remove inert contaminants by scraping, pressure washing or vactor truck • Proper hazardous substance cleanup and disposal requires specially trained and licensed contractors
Lids, Grates, Caps, or Access Hatch Missing, Damaged or Not Operable	Items in place and in good condition	Items showing minor wear but not affecting the functioning of the facility	Items missing, broken or not operable	Missing or damaged system components can impair system function and create unsafe conditions.	• Repair/ replace items • Clean and grease bolts and opening mechanisms to prevent rust and damage
Access Ladders or Steps Damaged or Missing (if meant to be present)	Ladders or steps free of damage	Minor damage to ladder or steps, does not appear to affect feature functionality	Ladders or steps missing or unusable	Missing or damaged access ladders or steps limits system access for inspection and O&M.	• Repair or replace damaged or missing ladders or steps
Monitoring Equipment Damaged or Missing	Monitoring equipment in place and undamaged	Monitoring equipment with minor damage but not affecting the function of the equipment	Monitoring equipment missing or damaged such that function is affected	Monitoring equipment must be present and properly functioning as required by the GROW program.	• Repair/replace equipment

Table 3-3. Permeable Pavement Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/Objective	Potential Corrective Actions
General Site Conditions					
Access to Site or Structures Obstructed	Access is not obstructed	Access feasible but inhibited	Access to site/critical structures is not feasible	System and structures must be accessible to conduct inspections and monitor system functioning.	• Prune or remove vegetation • Remove objects/barriers as needed
Stormwater Runoff Bypassing System	Water easily enters facility	Indication of moderate bypass observed during rainfall or by watermarks, debris buildup, signs of erosion	Indication of significant bypass observed during rainfall or by watermarks, debris buildup, or signs of erosion	Water bypassing the system indicates that the system is not able to manage stormwater at full capacity. Prevent runoff bypass to ensure system provides sewer flow removal benefits.	• Correct flow path to facility • Create new flow path to facility
Vandalism / Damage to Components or Entire System	No evidence of vandalism or damage such as trampling or impacts from nearby construction	Some vandalism or damage present but not impacting the function of the GSI system	Significant vandalism or damage present that affects the function of the GSI system	Vandalism, including graffiti and removal of structures, can compromise the overall performance and/or aesthetics of the system.	• Remove graffiti • Plant individual replacement plants • Repair the GSI structures and inlets • Install protective barriers or implement other strategies to prevent continued vandalism
Unauthorized Modifications to Pavement or Structures	No significant unauthorized modifications made to surface or structures	Minor modification to surface or structures that does not impact function of facility	Major modification that affects functionality of facility	Unauthorized modifications can cause the system to function improperly or reduce performance of the system.	• Return GSI system to original configuration
Illegal Dumping or Hazardous Material on Site	No evidence of hazardous materials or illegal dumping identified on site	N/A	Hazardous materials or illegal dumping identified on site	Illegal dumping or hazardous material can create a dangerous environment at the site and can contribute pollutant loading to surface waters.	• Remove materials • Install signage warning against illegal dumping • Consider lighting, video monitoring, etc.
Storage of Mulch, Soil, Snow or other Materials on Pavement	No storage of mulch, soil, snow, or other materials occurring on site	Storage on less than 10% of the facility	Storage on greater than 10% of facility	Storage of mulch, soil, snow or other materials can contribute debris, sediment, silt and fines to the surface.	• Use alternate storage locations • Vacuum with regenerative air sweeper • Power wash on low pressure

Table 3-3. Permeable Pavement Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/Objective	Potential Corrective Actions
Standing Water					
Surface Ponding or Indication of Ponding (watermarks, etc.) on Permeable Pavement Surface	No significant surface ponding or indication of ponding on pavement surface	Isolated ponding or indications of ponding water on less than 15% of surface	Ponding or indications of ponding water on greater than 15% of surface	Ponding indicates that there is surface clogging preventing rainfall from reaching the storage layer.	• Vacuum with regenerative air sweeper • Power wash on low pressure • Replace paver joint material • CCTV and clean underdrain
Standing Water Present in the Monitoring Well or Structures at a Level Indicating that the System is Not Draining Completely	No excessive standing water observed in monitoring well or structures	N/A	Standing water observed in monitoring well or structures	Standing water in the monitoring well or structures indicate that the system is clogged and is not functioning properly.	• CCTV and jet clean underdrain • Clear structures by hand, hand tools, or vactor truck • Observe drain down after storm events
Mosquitos or Larvae Observed in Inlet Structures or Elsewhere	No mosquitos or larvae observed	Insignificant number of mosquitos observed	Significant number of mosquitos observed, or larvae is present	Mosquitos or larvae observed around the system can indicate that the system is not functioning correctly, and water is pooling.	• Identify and remove any standing water on site and/or appropriately treat water to prevent mosquitos
Surface Conditions					
Sediment or Silt Buildup on Permeable Pavement Surface	Pavement is largely free of sediment or silt	Less than 10% of surface is covered with sediment or silt	Sediment or silt present on over 10% of the surface	Sediment and silt can cause surface clogging and inhibit rainfall from reaching the storage layer.	• Vacuum with regenerative air sweeper to restore permeability and typically at least twice per year (assess O&M frequency/timing) • Assess contributing drainage area for sources • Power wash on low pressure
Paver Joints Clogged	Clean aggregate visible near the lip of paver	Clean aggregate visible but shows signs of fines contamination and minor clogging	No clean aggregate is visible, and the joints appear full of sediment and fines to the lip of paver	Clogged paver joints don't allow rainwater to infiltrate properly into the system.	• Remove sediment, debris, and contaminated aggregate then pressure wash joints clear to the bottom of the pavers. • Add appropriate aggregate and sweep into joints

Table 3-3. Permeable Pavement Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/Objective	Potential Corrective Actions
Accumulated Trash and Debris on Permeable Pavement Surface	No significant trash, debris or leaf litter observed	Moderate amount of trash, debris or leaf litter	Trash, debris or leaf litter appears to be affecting facility functionality	Trash and debris can cause ponded surfaces, clogged outflow structures and poor site aesthetics.	• Remove trash and debris • Assess O&M Frequency/Timing • Maintain/prune nearby vegetation
Excess Oil, Staining, or Other Visible Contaminants on Pavement Surface	No evidence of significant oil or staining	Minor oil or staining on less than 5-10% of surface	Oil or staining on over 5-10% of surface	Contaminants on the surface can degrade the pavement surface, reduce the infiltration capacity, and create contamination issues.	• Power wash on low pressure • Remove and replace surface and aggregate • Remediate using environmentally friendly hydrocarbon remediation product.
Cracked, Settling or Displaced Permeable Pavement or Broken Pavers	No significant signs of degradation	Slight degradation in isolated areas less than 5-10% of the surface	Major degradation in greater than 5-10% of surface	Cracked, settling or broken surfaces can cause buildup of fines, sediment and create a hazard for vehicles and pedestrians.	• Monitor for source of degradation • Patch area of degradation or replace pavement if necessary
Spalling or Raveling of Permeable Asphalt/Concrete	No significant signs of spalling and raveling	Minor signs of spalling and raveling (less than 5-10% of surface)	Major signs of spalling and raveling (greater than 5-10% of surface)	Spalling or raveling of the surface reduces structural integrity of pavement, creates hazards for vehicles and pedestrians, and can contribute fines, silt and sediment.	• Patch area of pavement • Full surface replacement • Protect permeable pavement in good condition during operations
Damage or Surface Clogging Caused by Improper Snow Removal or Deicing	No signs of improper deicing, such as clogging due to application of sand or cinders. No damage from snow plows such as cracks, spalling, damaged curbs or edge treatments.	Minor signs of damage due to improper snow removal (plowing) and deicing but does not inhibit system performance/function (less than 10% of surface)	Major signs of improper snow removal and deicing clogging due to application of sand or cinders. No damage from snow plows such as cracks, spalling, damaged curbs or edge treatments (greater than 10% of surface).	Improper snow removal or deicing procedures reduce the performance of the system by causing pavement surface degradation and clogging of the surface.	• Use only the recommended deicing products such as $MgCl_2$ on pavement and NaCl on pavers • Snow blowers, rotating brooms or snowplows equipped with plastic blades should be used on permeable block pavers • Damage caused by snow removal or deicing should be appropriately repaired in a timely manner

Table 3-3. Permeable Pavement Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/Objective	Potential Corrective Actions
Damage to Edge Treatments, Curbs, etc.	No structural damage observed	Minor structural damage not affecting the functioning of the system	Major structural damage that could affect functionality, such as damage by auto accidents, construction work or natural disasters	Damage to the edges of the system can cause improper functioning of the system and weaken the existing structures.	• Repair damage /replace components as needed
Utility Cuts or Surface Repairs Evident and Improper	Utility cuts and other repairs not present or are appropriately patched	N/A	Patches are uneven with existing surface or showing signs of degradation	Improper repairs during utility trenching can negatively impact the function of the subsurface storage bed and/or surrounding permeable pavement surfaces.	• Replace in-kind per instructions for the surface type • Potentially replace with conventional pavement when restoration is less than 10% of permeable pavement area.
Potholes Forming or Pavers Missing	No sign of pavement degradation or missing pavers	Minor potholes or missing pavers in isolated areas that do not affect the functioning of the facility	Major areas of potholes or missing pavers presenting a hazard	Minor potholes or missing pavers can contribute fines, silt and sediment, and must be repaired immediately to restore the surface.	• Replace surface in-kind per instructions for the surface type • Potentially replace with conventional pavement when restoration is less than 10% of permeable pavement area.
Paver Jointing Material Missing	Paver joint material is filled to near lip of paver	Joint aggregate within 1” of paver surface is missing or settled in isolated areas (less than 10% of paver area)	Joint aggregate is missing at a depth greater than 1” from surface or settled in areas over 10% of paver area.	Missing jointing material causes the system to have less stability and filtering ability.	• Add appropriate aggregate and sweep into joints
Vegetation					
Vegetation Damage, Bare Spots, or Weed Growth in Grass Paver Systems	No significant damaged vegetation, bare spots or weed growth identified in paver system	Minor damaged vegetation, bare spots or weed growth identified in less than 10% of paver system	Over 10% of paver system contains damaged vegetation, bare spots or weed growth	Vegetation loss or damage will reduce evapotranspiration, soil aeration and pollution mitigation that contribute to the system functioning.	• Weed, reseed, maintain grass • Evaluate causes of damage, bare spots, weed growth

Table 3-3. Permeable Pavement Maintenance Conditions

Site Condition	Expected Condition (Satisfactory)	Condition when Maintenance is Needed (Marginal)	Defect or Problem that requires Corrective Action (Unsatisfactory)	Reason for Maintenance/Objective	Potential Corrective Actions
Destabilized Contributing Landscape Areas	Contributing landscape area free of bare patches and signs of erosion	Minor bare patches and some evidence of erosion present	Significant bare patches and erosion in contributing landscaped areas	Destabilized areas can contribute silt, sediment and fines to the pavement surface leading to clogging and/or excessive O&M demands.	• Repair eroded areas • Stabilize bare patches with turf, mulch, groundcover, etc. • Install temporary erosion and sedimentation controls
Weed Growth in Paver or Expansion Joints	No significant weeds evident	Some weeds noticeable in less than 10% of paver joints	Over 10% of paver joints contain weeds	Weeds can impact aesthetics, impair the stability of the pavement, reduce infiltration, and contribute debris to the surface.	• Remove weeds on monthly basis • Replace paver joint material • Evaluate surrounding area for source of weeds
Structures					
Lids, Grates or Caps Missing or Damaged	Items in place and in good condition	Items showing minor wear but not affecting the functioning of the facility	Items missing or broken	Missing or damaged system components will reduce or impair system functioning and create unsafe conditions.	• Repair/replace items
Inlet Blockage or Excessive Sediment/ Debris in Control Structure or Inlet Filter Insert	No evidence of blockage	Minor blockage of structure area, does not appear to affect system functionality	Significant blockage, affecting function of system	Blockages from any materials in the control structure or inlet filter insert can cause rainwater to back up in the system.	• Remove blockage from system • Remove trash and debris • Assess maintenance frequency/timing
Underdrain Blockage or Excessive Sediment/Debris in Control Structure	No evidence of blockage	Minor blockage of structure area, does not appear to affect system functionality	Significant blockage, affecting function of system	Create flooding and/ or premature overflow events, especially during excessive run-off events	• CCTV and jet underdrain • Remove trash and debris • Assess source of sediment/debris
Inlet Filter Inserts Damaged or Missing	Filter inserts present and undamaged	Filter inserts showing minor wear but not affecting the functioning of the facility	Filter insert missing or damaged	Missing or damaged filter inserts can allow sediment buildup or clogging within the system.	• Replace filter insert
Monitoring Equipment Damaged or Missing	Monitoring equipment in place and undamaged	Monitoring equipment with minor damage but not affecting the function of the equipment	Monitoring equipment missing or damaged such that function is affected	Monitoring equipment must be present and properly functioning as require by the GROW program.	• Repair/replace equipment

SECTION 4

Estimating Operations and Maintenance Costs

Properly estimating operations and maintenance costs for GSI systems is important to ensure that adequate maintenance budgets are established and funded to preserve long-term GSI system functionality and performance. The following guidelines are provided to support project planners, designers, site managers and maintenance staff to develop O&M budgets for GROW funded GSI projects.

4.1 General Guidelines

While experience is being gained nationally on GSI maintenance needs and costs, in general most GSI programs are relatively new and maintenance cost tracking data is limited. Literature values for O&M costs vary widely, with factors such as site-specific conditions, economies of scale and who is performing the maintenance all influencing costs.

4.1.1 Budgeting for Maintenance

Individuals planning and budgeting for maintenance should consider GSI system performance requirements, desired aesthetics, level of service and best professional judgment. Planners must also consider available resources and the level of resources to be spent on system inspection versus actual maintenance. To optimize maintenance budgets, inspections and routine maintenance should be performed at an appropriate frequency that reduces the need for significant corrective actions which tend to be expensive. Specific questions that should be considered during maintenance planning include:

- Is maintenance primarily geared toward system performance or is maintaining system aesthetics also a primary goal?
- What level of service is expected?
- What level of inspection and performance assessment is required?
- How does the GSI O&M relate to other ongoing municipal activities? (Street sweeping, landscape maintenance, snow removal, etc.)

GSI system maintenance budgets should be developed based on anticipated maintenance tasks and frequencies to estimate the total number of labor hours required, equipment needs and material removal and disposal costs. If maintenance will be contracted to outside maintenance professionals, annual budgeting should be based on contractor bid costs for routine maintenance as described in the project's GSI maintenance plan. Contingencies should be built into the annual budget to cover any non-routine maintenance that may be required. For higher maintenance systems, such as vegetated GSI, it is recommended that one to two years of vegetation maintenance be included in the construction bid package to ensure adequate vegetation maintenance and watering during the establishment period.

4.2 Factors Influencing Maintenance Costs

Maintenance costs vary based on many factors related to GSI type and location as well as surrounding land cover and site uses. While each GSI system and site is different, for most GSI systems the primary factors that will influence costs include the following:

- physical characteristics of the GSI system
- location and surrounding land uses
- contributing drainage area size (loading ratio)
- desired service level and maintenance history
- site visibility
- design characteristics
- climate and weather
- economies of scale

Maintenance costs are often closely related to the drainage area size and conditions (high urban use or low use) and the GSI system's maintenance history. Large and high use drainage area conditions and surrounding land uses will typically contribute to higher maintenance costs, especially for surface vegetated systems, which require more frequent cleaning and sediment removal in high use areas or when the loading ratio is high. Subsurface GSI systems will require more frequent inlet cleaning and pipe jetting when drainage areas are large and when land uses are more intense (e.g., dense urban areas, busy roads, commercial areas, etc.). The maintenance history of the system can result in significantly higher maintenance costs when GSI has been inadequately maintained since non-routine restoration and repair costs are typically significantly higher than annual routine maintenance costs. The desired service level and site visibility are especially important in vegetated systems, where system aesthetics are important. Visibility and community perception of surface systems often influence, and in some cases trigger, the need for maintenance, leading to more frequent maintenance activities and a higher annual cost.

The design of GSI can have a major influence on maintenance costs by reducing the need for O&M (e.g., through site and material selection), preventing system damage and/or facilitating easier maintenance. For example, a well-designed forebay or pretreatment device can help to reduce maintenance costs by isolating sedimentation and debris accumulation to the forebay or inlet filter where they can be easily removed and preventing damage to the GSI system surface or infiltration zones. Well-designed splash pads and energy dissipaters in vegetated systems are important for preventing erosion or other system damage and their use can help reduce repair costs.

Economies of scale may be realized as a cost savings for larger GSI systems or groups of GSI systems that can be maintained together. For example, maintenance contracts for multiple GSI systems within a municipality or group of municipalities can result in lower individual system costs (e.g., permeable pavement vacuuming, landscape maintenance). Alternatively, smaller GSI systems may be costlier on a unit area basis since minimum maintenance costs associated with mobilization and equipment are not dependent on system size.

4.3 Performing Maintenance

Public stormwater assets such as storm sewers, inlets and catch basins, drainage pipes, outfalls, swales, ponds and detention basins have historically been maintained at the municipal level. Municipal stormwater maintenance budgets are typically spent on activities such as inlet cleaning, pipe televising and jetting, pipe repair and street sweeping. While GSI maintenance is becoming more integrated with existing municipal stormwater maintenance responsibilities, it can raise concerns with maintenance staff due to unfamiliarity with required tasks and new demands on budgets.

GSI operations and maintenance typically involves multiple resources such as municipal staff (potentially from different departments), private contractors, property owners and volunteers. Additionally, equipment and supplies specific to GSI O&M are required to adequately maintain GSI facilities.

4.3.1 In-House Staff

Municipal maintenance staff should include dedicated personnel that ideally are involved with the GSI project from design through construction and implementation. Maintenance staff input early on allows concerns to be addressed and existing maintenance procedure needs to be incorporated into the GSI facility design. Depending on the municipality size, multiple departments may be involved in maintenance activities depending on the project location and staff work function. For example, stormwater structure cleaning and pipe jetting may be performed by stormwater/sewer department staff while landscape maintenance may be performed by parks or other landscape maintenance staff. It is critical to coordinate among departments early on and define maintenance staff responsibilities to manage tasks and effectively implement the maintenance plan.

On-going staff training is critical to the implementation of GSI maintenance plans. Staff responsible for GSI maintenance need training to understand how to inspect and maintain GSI facilities. They should be familiar with the project's GSI maintenance plan and the requirements of the maintenance agreement with ALCOSAN. There are various local and national training programs available in the Pittsburgh region, such as the National Green Infrastructure Certification Program (NGICP), and workshops/training programs have been hosted by 3 Rivers Wet Weather and the National Stormwater Center.

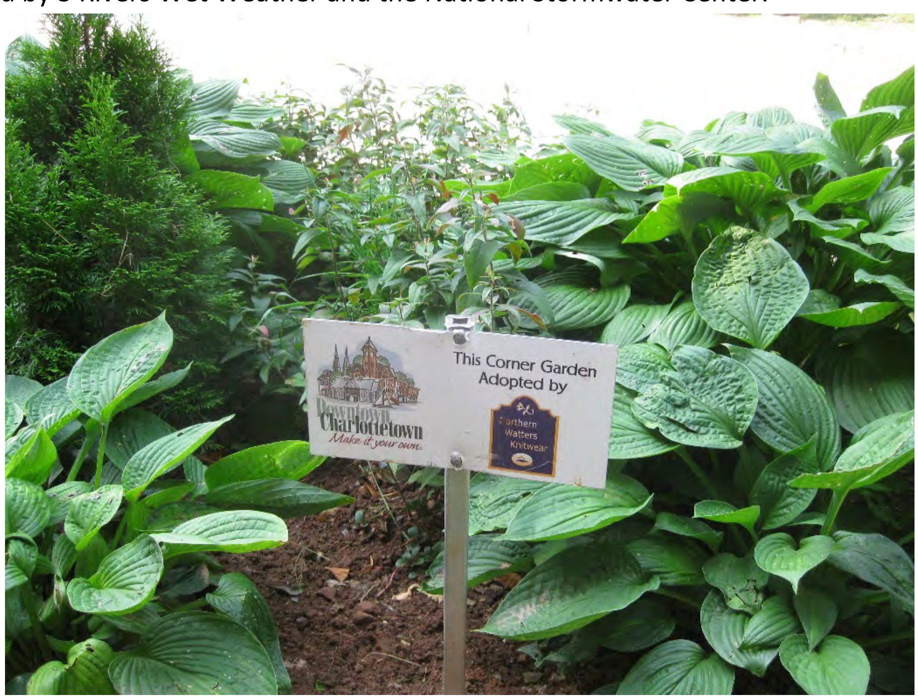


Figure 4-1. Sponsorship Sign in GSI
Partnerships with community volunteers and sponsorship programs can help ease maintenance burdens

For larger and well-staffed municipalities with more robust maintenance budgets and resources, utilizing existing maintenance staff or hiring new staff to maintain GSI facilities may be preferred. Cost benefits may be realized when GSI maintenance tasks can be incorporated into existing maintenance regimes (e.g., inlet and structure cleaning, pipe jetting, street cleaning, etc.), or when existing staff resources have the ability and expertise to manage new tasks (e.g., municipal arborist, landscape staff). For smaller or understaffed municipalities, the additional maintenance requirements associated with GSI facilities may be difficult to implement and it may be preferred to hire outside maintenance contractors, especially when specialized equipment is required or when expertise is needed to make good maintenance decisions. In some cases, partnerships with local community organizations, such as park and garden clubs, can be effective in helping to reduce municipal staff labor requirements and overall maintenance costs, by utilizing volunteers to complete some maintenance activities (e.g., weeding and collecting trash from rain gardens located in public spaces).

4.3.2 Contractors & Maintenance Contracts

Municipalities may decide that outsourcing some of the inspection and maintenance tasks is more cost effective than or otherwise preferable to completing the work in-house. Requirements such as the need for specialized equipment, special training or lack of staff resources may influence this decision. Seasonal demands or frequency of required maintenance may also create a need to outsource maintenance to contracted professionals. For example, vegetated GSI facilities typically require more intense maintenance during the first several years as plants are becoming established, including frequent watering. It is often beneficial to include this initial maintenance period in the construction bid so that the maintenance is performed as needed by a contractor and plant warranties can be effectively imposed. When specialized equipment is required for maintenance, outsourcing is often more cost effective than purchasing or renting the equipment and performing the work in-house. Economies of scale can also be realized when multiple GSI facilities are grouped onto one maintenance contract.

When establishing maintenance contracts, it is important to ensure that contractors are thoroughly trained to maintain GSI facilities as specialized maintenance is often required to protect long term system performance and prevent system degradation. For example, landscape contractors should recognize desired native species, be able to identify invasive plants, assess plant health, and understand how to manage pests and diseases. Contracted inspectors should be trained and certified to inspect GSI facilities and should be familiar with the GROW maintenance reporting requirements and be able to recommend maintenance and corrective actions when needed.

Appendix 5-A
GSI Maintenance Annual Self-Certification Checklists

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW) Green Stormwater Infrastructure (GSI) Practices
MAINTENANCE SELF-CERTIFICATION FORM

Annual Self-Certification Maintenance Checklist
For BIORETENTION FACILITIES

Inspected By: ______________________________ **Phone:** ______________________________ ☐ **Property Owner** ☐ **Site Manager** ☐ **Other**
Inspection Date: ____________________________

Address: ______________________________ **GROW ID:** ______________________________ **Installation Date:** ______________________________

Instructions: Mark the status column of each site condition with S (Satisfactory), M (Marginal), U (Unsatisfactory), or NA (Not Applicable). Please refer to Table 3-1 in Chapter 5 for supplemental information.
Send completed checklist to: GROW@alcosan.org

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
1. General Site Conditions			
Obstructed Access to Site or Structures for O&M			
Stormwater Runoff Bypassing System Inlets (curb cuts, inlet pipe, etc.)			
Unpleasant Odors			
Vandalism / Damage to Components or Entire System			
Unauthorized Modifications			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Rodent Damage / Burrowing			
Evidence of Illegal Dumping or Hazardous Material on Site			
2. Standing Water			
Indication of Prolonged Ponding on Surface			
Mosquitos or Mosquito Larvae Observed			
3. Surface Conditions			
Excessive Trash/ Debris/ Leaf Accumulation			
Sediment Accumulation at Curb Cut, Forebay, or System Low Points			
Erosion and/or Subsequent Sediment Deposits at Inlet, Outlet, Overflow, Check Dams, Facility Bottom, or Side Slopes			
Lack of Mulch Cover			
Visible Surface Contaminants/ Pollution			
Poor Condition of Rip Rap/ Cobbles/ Energy Dissipaters			
Evidence of Poor Flow Distribution Through System			
Surface Degradation/ Subsidence (e.g. missing gravel, uneven settlement, sinkholes)			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Destabilized Contributing Conveyance Swale/Drainage Area			
4. Vegetation			
Excessive Weed Growth			
Dead, Diseased, Dying or Missing Plants			
Vegetation Obstructing Sidewalk or Line of Sight at Roadway or Intersection			
Vegetation Blocking Inflow at Curb Cut/Inlet Structure			
Vegetation Blocking Operation & Maintenance (O&M) Access to GSI System Components			
5. Structures			
Irrigation System Damaged, Leaking or Out of Adjustment (If Applicable)			
Structural Damage (Bioretention/Planter/Bioswale Edge Treatment, Check Dams or Outlet Structure)			
Underdrain Blockage or Excessive Sediment/ Debris in Control Structure			
Monitoring Equipment Damaged or Missing			

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW) Green Stormwater Infrastructure (GSI) Practices
MAINTENANCE SELF-CERTIFICATION FORM

Annual Self-Certification Maintenance Checklist
For INFILTRATION TRENCH

Inspected By: ______________________________ **Phone:** ______________________________ ☐ **Property Owner** ☐ **Site Manager** ☐ **Other**

Inspection Date: ____________________________

Address: ______________________________ **GROW ID:** ______________________________ **Installation Date:** ______________________________

Instructions: Mark the status column of each site condition with S (Satisfactory), M (Marginal), U (Unsatisfactory), or NA (Not Applicable). Please refer to Table 3-2 in Chapter 5 for supplemental information.

Send completed checklist to: GROW@alcosan.org

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
1. General Site Conditions			
Obstructed Access to Site or Structures for O&M			
Stormwater Runoff Bypassing System Inlets			
Unpleasant Odors			
Vandalism / Damage to Components or Entire System			
Unauthorized Modifications			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Evidence of Illegal Dumping or Hazardous Material on Site			
2. Standing Water			
Standing Water on Surface or in Structures Indicating that the System is Not Draining Completely			
Mosquitos or Mosquito Larvae Observed			
3. Surface Conditions			
Excessive Trash/ Debris/ Leaf Accumulation			
Sediment Accumulation on Trench Surface (if applicable)			
Structural Damage to Surface and/ or Edge Pretreatments (if present)			
Destabilized Contributing Landscape Areas			
Surface Degradation/ Subsidence (e.g. missing gravel, uneven settlement, sinkholes)			
Flow Dissipation Structures (Splash Block, Cobbles) Clogged, Damaged or Missing (if applicable)			
Dead/Dying Trees, Turf, or Other Vegetation			
4. Structures			
Pretreatment Storage Sump Contains Excessive Sediment (If applicable)			
Inlet/Pretreatment Structure Blockage or Excessive Sediment / Debris in Structure			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Pretreatment /Inlet Filter Inserts Clogged, Damaged or Missing			
Underdrain Blockage or Excessive Sediment/ Trash/ Debris in Outlet Control Structure			
Inlet /Outlet Structural Damage			
Piping, Cleanouts, Vents, Valves or Baffles Damaged			
Visible Contaminants / Pollution on Interior Surfaces of Cleanout Pipe or Dry Well			
Lids, Grates, Caps, or Access Hatch Missing, Damaged, or Not Operable			
Access Ladders or Steps Damaged or Missing (if meant to be present)			
Monitoring Equipment Damaged or Missing			

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW) Green Stormwater Infrastructure (GSI) Practices
MAINTENANCE SELF-CERTIFICATION FORM

Annual Self-Certification Maintenance Checklist
For PERMEABLE PAVEMENT

Inspected By: ____________________________ **Phone:** ____________________________ ☐ **Property Owner** ☐ **Site Manager** ☐ **Other**

Inspection Date: __________________________

Address: ____________________________ **GROW ID:** ____________________________ **Installation Date:** ____________________________

Instructions: Mark the status column of each site condition with S (Satisfactory), M (Marginal), U (Unsatisfactory), or NA (Not Applicable). Please refer to Table 3-3 in Chapter 5 for supplemental information.

Send completed checklist to: GROW@alcosan.org

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
1. General Site Conditions			
Access to Site or Structures Obstructed			
Stormwater Runoff Bypassing System			
Vandalism / Damage to Components or Entire System			
Unauthorized Modifications to Pavement or Structures			
Illegal Dumping or Hazardous Material on Site			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Storage of Mulch, Soil, Snow, or other Materials on Pavement			
2. Standing Water			
Surface Ponding or Indication of Ponding (watermarks, etc.) on Permeable Pavement Surface			
Standing Water Present in the Monitoring Well or Structures at a Level Indicating that the System is Not Draining Completely			
Mosquitos or Larvae Observed in Inlet Structures or Elsewhere			
3. Surface Conditions			
Sediment or Silt Buildup on Permeable Pavement Surface			
Paver Joints Clogged			
Accumulated Trash and Debris on Permeable Pavement Surface			
Excess Oil, Staining, or Other Visible Contaminants on Pavement Surface			
Cracked, Settling or Displaced Permeable Pavement or Broken Pavers			
Spalling or Raveling of Permeable Asphalt/Concrete			
Damage or Surface Clogging Caused by Improper Snow Removal or Deicing			
Damage to Edge Treatments, Curbs, etc.			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Utility Cuts or Surface Repairs Evident and Improper			
Potholes Forming or Pavers Missing			
Paver Jointing Material Missing			
4. Vegetation			
Vegetation Damage, Bare Spots, or Weed Growth in Grass Paver Systems			
Destabilized Contributing Landscape Areas			
Weed Growth in Paver or Expansion Joints			
5. Structures			
Lids, Grates, or Caps Missing or Damaged			
Inlet Blockage or Excessive Sediment/Debris in Control Structure or Inlet Filter Insert			
Underdrain Blockage or Excessive Sediment/Debris in Control Structure			
Inlet Filter Inserts Damaged or Missing			
Monitoring Equipment Damaged or Missing			

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW) Green Stormwater Infrastructure (GSI) Practices
MAINTENANCE SELF-CERTIFICATION FORM

Annual Self-Certification Maintenance Checklist
For BIORETENTION FACILITIES

Inspected By: ____________________________ **Phone:** ____________________________ ☐ **Property Owner** ☐ **Site Manager** ☐ **Other**

Inspection Date: __________________________

Address: ____________________________ **GROW ID:** ____________________________ **Installation Date:** ____________________________

Instructions: Mark the status column of each site condition with S (Satisfactory), M (Marginal), U (Unsatisfactory), or NA (Not Applicable). Please refer to Table 3-1 in Chapter 5 for supplemental information.

Send completed checklist to: GROW@alcosan.org

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
1. General Site Conditions			
Obstructed Access to Site or Structures for O&M			
Stormwater Runoff Bypassing System Inlets (curb cuts, inlet pipe, etc.)			
Unpleasant Odors			
Vandalism / Damage to Components or Entire System			
Unauthorized Modifications			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Rodent Damage / Burrowing			
Evidence of Illegal Dumping or Hazardous Material on Site			
2. Standing Water			
Indication of Prolonged Ponding on Surface			
Mosquitos or Mosquito Larvae Observed			
3. Surface Conditions			
Excessive Trash/ Debris/ Leaf Accumulation			
Sediment Accumulation at Curb Cut, Forebay, or System Low Points			
Erosion and/or Subsequent Sediment Deposits at Inlet, Outlet, Overflow, Check Dams, Facility Bottom, or Side Slopes			
Lack of Mulch Cover			
Visible Surface Contaminants/ Pollution			
Poor Condition of Rip Rap/ Cobbles/ Energy Dissipaters			
Evidence of Poor Flow Distribution Through System			
Surface Degradation/ Subsidence (e.g. missing gravel, uneven settlement, sinkholes)			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Destabilized Contributing Conveyance Swale/Drainage Area			
4. Vegetation			
Excessive Weed Growth			
Dead, Diseased, Dying or Missing Plants			
Vegetation Obstructing Sidewalk or Line of Sight at Roadway or Intersection			
Vegetation Blocking Inflow at Curb Cut/Inlet Structure			
Vegetation Blocking Operation & Maintenance (O&M) Access to GSI System Components			
5. Structures			
Irrigation System Damaged, Leaking or Out of Adjustment (If Applicable)			
Structural Damage (Bioretention/Planter/Bioswale Edge Treatment, Check Dams or Outlet Structure)			
Underdrain Blockage or Excessive Sediment/ Debris in Control Structure			
Monitoring Equipment Damaged or Missing			

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW) Green Stormwater Infrastructure (GSI) Practices
MAINTENANCE SELF-CERTIFICATION FORM

Annual Self-Certification Maintenance Checklist
For INFILTRATION TRENCH

Inspected By: ______________________________ **Phone:** ______________________________ ☐ **Property Owner** ☐ **Site Manager** ☐ **Other**
Inspection Date: ____________________________

Address: ______________________________ **GROW ID:** ______________________________ **Installation Date:** ______________________________

Instructions: Mark the status column of each site condition with S (Satisfactory), M (Marginal), U (Unsatisfactory), or NA (Not Applicable). Please refer to Table 3-2 in Chapter 5 for supplemental information.
Send completed checklist to: GROW@alcosan.org

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
1. General Site Conditions			
Obstructed Access to Site or Structures for O&M			
Stormwater Runoff Bypassing System Inlets			
Unpleasant Odors			
Vandalism / Damage to Components or Entire System			
Unauthorized Modifications			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Evidence of Illegal Dumping or Hazardous Material on Site			
2. Standing Water			
Standing Water on Surface or in Structures Indicating that the System is Not Draining Completely			
Mosquitos or Mosquito Larvae Observed			
3. Surface Conditions			
Excessive Trash/ Debris/ Leaf Accumulation			
Sediment Accumulation on Trench Surface (if applicable)			
Structural Damage to Surface and/ or Edge Pretreatments (if present)			
Destabilized Contributing Landscape Areas			
Surface Degradation/ Subsidence (e.g. missing gravel, uneven settlement, sinkholes)			
Flow Dissipation Structures (Splash Block, Cobbles) Clogged, Damaged or Missing (if applicable)			
Dead/Dying Trees, Turf, or Other Vegetation			
4. Structures			
Pretreatment Storage Sump Contains Excessive Sediment (If applicable)			
Inlet/Pretreatment Structure Blockage or Excessive Sediment / Debris in Structure			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Pretreatment /Inlet Filter Inserts Clogged, Damaged or Missing			
Underdrain Blockage or Excessive Sediment/ Trash/ Debris in Outlet Control Structure			
Inlet /Outlet Structural Damage			
Piping, Cleanouts, Vents, Valves or Baffles Damaged			
Visible Contaminants / Pollution on Interior Surfaces of Cleanout Pipe or Dry Well			
Lids, Grates, Caps, or Access Hatch Missing, Damaged, or Not Operable			
Access Ladders or Steps Damaged or Missing (if meant to be present)			
Monitoring Equipment Damaged or Missing			

ALLEGHENY COUNTY SANITARY AUTHORITY
Green Revitalization of Our Waterways (GROW) Green Stormwater Infrastructure (GSI) Practices
MAINTENANCE SELF-CERTIFICATION FORM

Annual Self-Certification Maintenance Checklist For PERMEABLE PAVEMENT

Inspected By: ______________________________ **Phone:** ______________________________ ☐ Property Owner ☐ Site Manager ☐ Other
Inspection Date: ____________________________

Address: ______________________________ **GROW ID:** ______________________________ **Installation Date:** ______________________________

Instructions: Mark the status column of each site condition with S (Satisfactory), M (Marginal), U (Unsatisfactory), or NA (Not Applicable). Please refer to Table 3-3 in Chapter 5 for supplemental information.
Send completed checklist to: GROW@alcosan.org

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
1. General Site Conditions			
Access to Site or Structures Obstructed			
Stormwater Runoff Bypassing System			
Vandalism / Damage to Components or Entire System			
Unauthorized Modifications to Pavement or Structures			
Illegal Dumping or Hazardous Material on Site			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Storage of Mulch, Soil, Snow, or other Materials on Pavement			
2. Standing Water			
Surface Ponding or Indication of Ponding (watermarks, etc.) on Permeable Pavement Surface			
Standing Water Present in the Monitoring Well or Structures at a Level Indicating that the System is Not Draining Completely			
Mosquitos or Larvae Observed in Inlet Structures or Elsewhere			
3. Surface Conditions			
Sediment or Silt Buildup on Permeable Pavement Surface			
Paver Joints Clogged			
Accumulated Trash and Debris on Permeable Pavement Surface			
Excess Oil, Staining, or Other Visible Contaminants on Pavement Surface			
Cracked, Settling or Displaced Permeable Pavement or Broken Pavers			
Spalling or Raveling of Permeable Asphalt/Concrete			
Damage or Surface Clogging Caused by Improper Snow Removal or Deicing			
Damage to Edge Treatments, Curbs, etc.			

SITE CONDITION	STATUS	MAINTENANCE ACTION REQUIRED	MAINTENANCE ACTION COMPLETED (INCLUDE DATE)
Utility Cuts or Surface Repairs Evident and Improper			
Potholes Forming or Pavers Missing			
Paver Jointing Material Missing			
4. Vegetation			
Vegetation Damage, Bare Spots, or Weed Growth in Grass Paver Systems			
Destabilized Contributing Landscape Areas			
Weed Growth in Paver or Expansion Joints			
5. Structures			
Lids, Grates, or Caps Missing or Damaged			
Inlet Blockage or Excessive Sediment/Debris in Control Structure or Inlet Filter Insert			
Underdrain Blockage or Excessive Sediment/Debris in Control Structure			
Inlet Filter Inserts Damaged or Missing			
Monitoring Equipment Damaged or Missing			

Appendix 5-B
GSI Maintenance Guidance Resources

GSI Maintenance Guidance Resources

American Rivers and Green for All (2013). *Staying Green and Growing Jobs: Green Infrastructure Operations and Maintenance as Career Pathway Stepping Stones.* https://www.greenforall.org/staying_green_and_growing_jobs_green (accessed August 2018).

American Society of Civil Engineers (2017). *Cost of Maintaining Green Infrastructure.* Edited by Jane Clary and Holly Piza. American Society of Civil Engineers: Reston, Virginia. http://www.asce.org/templates/publications-book-detail.aspx?id=25533

City of Edmonton (2016). *Low Impact Development Construction, Inspection & Maintenance Guide, Edition 1.* City of Edmonton: City of Edmonton, Alberta, Canada. https://www.edmonton.ca/city_government/environmental_stewardship/low-impact-development.aspx

Detwiler, Stacey (2013). *Staying Green: Strategies to Improve Operations and Maintenance of Green Infrastructure in the Chesapeake Bay Watershed;* American Rivers and Green for All: Washington, DC. https://www.americanrivers.org/conservation-resource/operations-maintenance-green-infrastructure/

Onondaga County (2013). *Save the Rain Program Green Infrastructure Maintenance Manual & Training Materials.* Onondaga County, New York. http://savetherain.us/wp-content/uploads/2012/03/MaintenanceBinder_Rev-april2013.pdf

Philadelphia Water Department (2016). *Green City, Clean Waters: Pilot Program Final Report;* Philadelphia Water Department: Philadelphia, Pennsylvania. http://phillywatersheds.org/doc/Year5_EAPBody_website.pdf

Philadelphia Water Department (2016). *Green Stormwater Infrastructure Maintenance Manual, Version 2.0.* Philadelphia Water Department: Philadelphia, Pennsylvania. http://documents.philadelphiawater.org/gsi/GSI_Maintenance_Manual.pdf

Seattle Public Utilities (2009). *Green Stormwater Operations and Maintenance Manual.* Seattle Public Utilities: Seattle, Washington. http://www.seattle.gov/util/cs/groups/public/@spu/@usm/documents/webcontent/spu02_020023.pdf

United States Environmental Protection Agency Office of Water (2013). *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.* United States Environmental Protection Agency: Washington, DC. https://www.epa.gov/sites/production/files/2015-04/documents/green_infrastructure-om_report.pdf

Water Environment Federation (2014). *Green Infrastructure Implementation;* Water Environment Federation: Alexandria, Virginia. https://www.e-wef.org/Default.aspx?TabID=251&productId=38340815

Water Environment Federation (2016). *National Green Infrastructure Certification Program (NGCIP) Body of Knowledge;* Water Environment Federation: Alexandria, Virginia. http://ngicp.org/project/body-of-knowledge/